"Irrigation in Local Adaptation and Resilience"

Proceedings of the Seventh International Seminar
Held on 11-12 April 2017, Kathmandu, Nepal

Farmer Managed Irrigation Systems Promotion Trust

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Edited by

Naveen Mangal Joshi
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Editors' Note

The context, meaning and impact of adaptation and resilience of irrigation in the local situation have substantial sustainability dimension. The adaptation process and resilience, policy, institutions, technology and interaction with the environment and resources at the local level do affect livelihood of a larger number of agriculture based population. Urbanization, migration pattern, food-water security nexus and political agricultural economy as a whole have influence on irrigation adaptation and resilient response. Irrigation is found in all eco-geographic terrains where human civilization has flourished in general. Without irrigation, enrichment of civilization from agriculture is not possible. Without adaptation and resilience of the irrigation in the local context more so in the scenario of changing climate, a social and economic order cannot be ensured.

With the theme mentioned in the proceeding section, the Farmer Managed Irrigation Systems Promotion Trust (FMIST) organized the Seventh International Seminar on "Irrigation in Local Adaptation and Resilience" in Kathmandu on 11-12 April 2017. Since 1997, FMIS Promotion Trust is continuing its efforts to promote and share knowledge and experiences on FMIS through conferences, seminars and public discourse on contemporary issues both at national and international level. In the understanding of the editors, the impressive array of key note speakers, paper presenters and participants was enough in itself to mirror the high relevancy with the context and issues discussed in the announcements of the seminar.

The water resources sector is one of the hardest hit sectors due to climate changes. The remarkable changes observed are variation in temperature, delays in monsoon rain or amplified intensity of rain etc. resulting in flash-floods. They are becoming a regular phenomenon and are considered as a result of climate change. Irrigation systems are severely affected by climatic factors such as (a) reduced runoff in rivers, due to changing rainfall patterns, (b) increased flood flows due to more intense rainfall, (c) increased demand for water due to higher temperatures and more erratic rainfall, and (d) changes in crop suitability. From this lense, FMIS are facing colossal task of maintaining and sustaining their systems. Therefore, a need to make irrigation systems more resilient to climate uncertainty becomes major concern of water professionals.

Over the period of time, FMIS have developed and internalized coping and adaptation mechanisms as many of them have visibly survived over decades or even for century. However, the adaptive capacity of FMIS to cope with multifaceted impacts of climate change is in decreasing trend. Hence, in order to develop climate-resilient irrigation sector, “the existing arrangements for irrigation design and management may need to be reconsidered”. In this context, we are of the view that the seminar has been successful in providing knowledge platform to learn, share and disseminate experience and information on local adaptation of the irrigation systems. The seminar proved successful to inspire policy makers, practitioners and researchers of irrigation sector for being adequately informed about the process of adaptation and associated resilience of irrigation community and pursue for a learned framework that better serves farmers' irrigation interest.

The two-day seminar format consisted of: (a) initiation and honoring ceremony followed by book launching, (b) parallel sessions, and (c) plenary sessions. The interlocutors included a mix of academics, policy analysts, and high-ranking government officials and farmers with diverse background and experiences. This contributed in making the seminar as a "FMIS Hub" with full of dynamic and diversified activities in a mutually learning and sharing environment. The seminar was participated by 140 professional and farmers from 12 different Farmer Managed Irrigation Systems. Participants from Nepal, India, Bangladesh, Thailand, Ireland, France, USA, Finland, Afghanistan, Netherland.

Keeping up with the tradition of honoring remarkable contribution of individual professionals, FMIS Trust, acknowledged the contribution of two individual professionals Dr. Upendra Gautam from Nepal and Dr. Md. Abdul Ghani form Bangladesh. Dr. Gautam was recognized for his outstanding and considerable contribution in promoting knowledge and good practices of farmer managed irrigation systems in Nepal and elsewhere. Dr. Md. Abdul Ghani on the other hand was recognized for his, consistent and extensive contribution in promoting better water management in improving the livelihood of millions of marginal farmers. In the same ceremony, two better performed FMIS of Nepal were also honored. Together with the individual professionals, two irrigation schemes, Singhe Ghat Irrigation System of Kapilbastu and Newar Kulo Irrigation System of Panchthar were also honored for their remarkable operational existence adopting local strategies to cope with climate extremes.

As a part of research and development, FMIST was engaged in research on "Application of Modern Technologies to Facilitate Commercial Irrigated Agriculture for Improving Rural Livelihood in Nepal". The research findings were documented as publication. The book "Application of Modern Technologies to Facilitate Commercial Irrigated Agriculture for Improving Rural Livelihood in Nepal" was lunched by Mr. Ramananda Prasad Yadav Secretary of the Ministry of Irrigation of Government of Nepal.

In order to organize the deliberations, 33 papers were grouped into 8 thematic sub-sessions: (a) Mapping climate, gender and social ecological challenges; (b) Climate change and irrigation management; (c) Perception of farmer ; (d) MUS challenges and applications; (e) Climate change and methods of adaptation and approaches for increasing resilience; (f) Water energy and benefit sharing; (g) Past and future of irrigation system in the context of climate change and; (h) National Policy, institutions and intervention strategy.

Two thematic sub-sessions were allocated to two organizations. The first sub-session on "Mapping climate, gender and socio-ecological challenges" was exclusively presented by ICIMOD, Nepal. The papers under sub-session were largely focused on mapping the socio-economic, gender, environmental, institutional and governance challenges faced by FMIS. Towards the end of the same session, a panel discussion was organized where panelists expressed their views on the challenges faced by FMIS due to Climate change, out-migration and feminization of agriculture.

The second sub-session on farmer's perceptions was delivered by farmer representatives from the five-irrigation system. These presentations broadly focused on (a) sharing up-to-date information relating to small-scale farmers' involvement in production of traditional and alternative agricultural products; (b) creating awareness on often changing climatic pattern and mitigating measures being followed by different irrigation systems; (c) linkages and networking between the irrigation systems to address problems of irrigator farmers. It was impressive to note the resilience and indigenous knowledge of the farming community which were shared during individual deliberations.

At the concluding plenary session of the seminar, expert panel discussion was organized on " Meeting the Challenges of Climate Change: What Next?" with the objective of exploring the way ahead based on the rich experiences of the panelists. The panelists broadly agreed on changes and variation in climate that have become a global issue as well as key challenges for irrigation that are found in all eco-geographic terrains. The panelists suggested for the formulation of strategic adaptation plan against climate change, with high priority given to the development of climate resilient irrigation infrastructure belonging to the farming communities. The panelists agreed on the need to review the approach on irrigation development in the country and move towards the attainment of round the year irrigation supply utilizing all available technologies.

The takeaway from this seminar is two-fold: a better understanding of the climate change and its multifaceted impacts on current irrigation regime; and need for the development of adaptation frameworks for water sector acknowledging the traditional and indigenous knowledge available at local level.

We would like to thank especially Dr. Prachanda Pradhan for his generous contribution for making the printing of this publication possible. Mr. Samudra Sigdel, Associate, FMIS Promotion Trust, is likewise appreciated for his hard work in preparing the proceedings of the seminar. Many institutions including Department of Irrigation, IWMI, ICIMOD, GEOMAX, Hexagon, Community Irrigation Project (CIP), Jalshrot Vikas Sanstha (JVS), INPIM Nepal, Community-Managed Irrigated Agriculture Sector Project – AF/DOI and IIT Roorkee Alumni Association Nepal had contributed the organization of this seminar.

Naveen Mangal Joshi
Sushil Subedee
Deepak Raj Pandey

PART 1:

INITIATION
AND HONOR CEREMONY

WELCOME ADDRESS AND INTRODUCTION OF SEMINAR THEME

SUSHIL SUBEDEE[1]

LADIES AND GENTLEMEN

GOOD MORNING

We, the people at FMIS Promotion Trust (known as FMIST) extend our warmest welcome to you all on this occasion. I fervently stand here at the moment to greet you all in our Seventh International Seminar on "Irrigation in Local Adaptation and Resilience." Together with me, equally spirited are our Co-organizer the Department of Irrigation, GON and our co-partner ICMOD Nepal in welcoming you in the seminar. Likewise, I also accord you a heartfelt welcome on behalf of our esteemed associated partner institutions like IWMI, GEOMAX, Hexagon, Community Irrigation Project (CIP), Jalsrot Vikas Sanstha with Global Water Partnership (JVS), INPIM Nepal, and IIT Roorkee Alumni Association Nepal. With all the support and reassurances from the said organizations, FMIST has been able to hold this seminar.

FMIST for the past 19 years has doggedly pursued its basic goal; promotion of and advocacy for self-regulating, self-governing and self-supporting irrigation institutions, the FMIS. In addition, knowledge and experience sharing and knowledge management through conferences, seminars and public discourse on contemporary issues have remained at the core of Trust's activities. In this regard, FMIS Trust has so far conducted 6 international seminars with focus on contemporary issues. These seminars have proved to be a platform for evocative

1 Member-secretary, FMIS Promotion Trust

discourse between the scholars and practitioners including farmers. The present Seventh International seminar has paper contributors from Nepal and outside of Nepal. Within Nepal, we have paper contributions from DOI, ICIMOD, IDE, JVS, IWMI, CRT, Tribhuban University faculty, NEC, CDKN, Ministry of Population and Environment and individual paper writers. Over period of time, concerns on FMIS have expanded and efforts are now made to look at FMIST from different dimensions of farmers' livelihood.

Contributions of outstanding authors of the world have made the FMIST organized seminar even more pertinent and useful. In recognition of their outstanding contributions, FMIST recognized them as the "ICON" of FMIST. Some of such dignitaries included Prof. Lucas Horst, Prof. Linden Vincent, Nobel Laureate Elinor Ostrom, Prof. Norman Uphoff, Prof. Walter Coward, Dr. Robert Yoder, Mr. Charlse Lindsay Abernethy, Dr. Emmanuel Reynard, Prof. Nyoman Sutawan, Prof. Nirmal Sen Gupta, Dr. Ujjwal Pradhan, Dr. Ganesh Shivakoti, Mr. Kenichi Yokoyama, Prof Wai Fung Lam, Prof, Narpat S Jodha and Dr. Prachanda Pradhan. Keeping up with this tradition, FMIS Trust has decided this year as well to acknowledge the contribution of individual professionals and farmers organizations. Accordingly 2 distinguished professionals and 2 sustainably performing FMIS have been selected for the honor.

Moving ahead, now I would like to submit a brief account of present seminar and its operational modality. As scheduled, the 2 days seminar shall be deliberated at 9.00 AM – 5.00 PM each day with 2 parallel sessions in different Halls. Please feel free to join sessions of your personal interest.

While changes and variation in climate have become a global issue, the discussion on this issue in our context is still in its infancy. Nevertheless in recent years, it is increasingly acknowledged that visible change in thermosphere is occurring. Temperature and precipitation are largely taken as key indicators of climate change. Changes in temperature (elongated hot or cold days) delays in monsoon rain or amplified intensity of rain etc resulting in flash-floods, are becoming a regular phenomenon. From this perspective, FMIS face colossal task to maintain and sustain their systems. Irrigation systems are severely affected by climatic factors. The impact of climate change include[2] (a) reduced runoff in rivers, due to changing rainfall patterns, (b) increased flood flows due to more intense rainfall, (c) increased demand for water due to higher temperatures and more erratic rainfall, and (d) changes in crop suitability. There is, therefore, a need to make irrigation systems more resilient to climate uncertainty

Seemingly FMIS have developed coping and adaptation mechanisms, as numerous FMISs have visibly survived over decades. However the adaptive capacity of FMIS to cope with

2 Framework for Effectiveness and Resilience of Small and Medium Scale Irrigation Systems in Nepal: Prachanda Pradhan, Umesh Nath Parajuli, Ram Chandra Khanal

ever increasing and frequent changes is in decline or weak. Hence in order to develop climate- resilient irrigation sector, “the existing arrangements for irrigation design and management may need to be reconsidered”. It is for this reason that the present seminar aims to provide a knowledge platform to learn, share and disseminate experience and information on local adaptation and resilience of the irrigation systems. In the like manner the seminar further aspires to make policy makers, practitioners and researchers of irrigation systems to be adequately informed about the process of adaptation and associated resilience of irrigation community and pursue for a learned framework that better serves farmers' irrigation interest.

In view of above the seminar deliberations shall mainly focus on the following themes;

Stock taking of the challenges related to Climate, Gender, Socio-ecological changes

- Climate Change and Irrigation Management
- Multiple Use Water Systems
- Climate Change and Modality of Adaptation, approaches for increasing resilience
- Water – Energy Benefit sharing Arrangement
- National policy, institutions and intervention strategy on climate resilient local adaptation of irrigation
- Way Forward for Irrigation System in the context of Climate Change

We believe that the seminar will offer an ingenious rostrum wherein the primary and secondary stakeholders can have rewarding discourse to attend to the core issues and the academia will augment the learning with the output of their grueling research.

Finally, I would like to take opportunity to recognize the presence of our three of FMIST “ICONs” in this seminar, namely Dr. Robert Yoder from USA, Dr. Barbara van Koppen, IWMI- South Africa and Dr. Prachanda Pradhan, Nepal. Dr. Robert Yoder coined Farmer Managed Irrigation Systems in his Ph.D. thesis while describing the local irrigation systems otherwise known as community irrigation or village irrigation or indigenous irrigation systems. We are honored to have him with us in this seminar. Other two icons of FMIST have considerably contributed in promoting knowledge on FMIS in Nepal and elsewhere.

I hope that you will have two days of fruitful deliberations.

Thank you, and a warm welcome again

Honor Awards

Introduction of the "ICON of HONOR"

DR. PRACHANDA PRADHAN[1]

Dr. Md. Abdul Ghani……………

Dr. Upendra Gautam…………….

BESTOWING THE HONOR AWARDS

After the introduction, Mr. Naveen Mangal Joshi, Chairman, FMIS Promotion Trust, honored the "Icons of Honor" by presenting Dosallah (shawl), which is a traditional Nepali way of bestowing honors to the distinguished persons. Mr. Suman Sijapati, Vice-chairman, FMIS Promotion Trust, honored them by presenting commendation plaques, and Mr. Sushil Subedee, Member Secretary, FMIS Promotion Trust by offering bouquets. Dr. Prachanda Pradhan read out the citations inscribed in the commendation plaques.

Commendation plaque to Dr. Md. Abdul Ghani reads: This Plaque of honor is presented to **Dr. Md. Abdul Ghani** in recognition to his outstanding, consistent and extensive contribution in promoting better water management in improving the livelihood of millions of marginal farmers.

Commendation plaque to Dr. Upendra Gautam reads: This Plaque of honor is presented to **Dr. Upendra Gautam** in recognition to his outstanding and considerable contribution in promoting knowledge and good practices of farmer managed irrigation systems in Nepal and elsewhere.

The glorious moments of honor award ceremony capatured in photographs, are shown in the following pages.

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1 Patron, FMIS Promotion Trust

Key Note Speeches

1.1 FOR A WEALTHY FMIS AND AMIS

UPENDRA GAUTAM[1]

In terms of managing and organizing the irrigation resources, FMIS in Nepal give us the best learning. Dr. Prachanda Pradhan, my university college teacher, the patron of FMIS promotion Trust, pioneered research work in this field. The Trust has recognized FMIS as a national heritage. They have been so because of their culture of social capital, autonomy, self-governance and their contribution to national food security. In particular, the conceptualization and formation of Trust in 1997-1998 at the CMS had symbolized our professional as well as personal tribute to FMIS of Nepal. This solemn ceremony organized by the friends of the FMIS Promotion Trust, to say the least, only reminds me of my further duties towards farmers. I am thankful to you all.

In contemporary times, FMIS are also facing several challenges of Climate Change, outmigration and urbanization. We will not be doing justice to FMIS if we merely glorify them. They need concomitant supportive measures to develop their enough adaptive capability to handle these challenges. On the other hand, an AMIS lives in two cultures- a) the central political-bureaucratic and b) the local farming community. It is not self-managing and autonomous and depends elsewhere for important decisions. An AMIS is mostly perceived as less productive, taking issues with each other because of the two work cultures where stakeholders are put in a situation of getting spoiled.

Let us take the traditional discourse on so-called FMIS versus AMIS to another plane. Whether FMIS or AMIS, the ultimate

1 Founding chair, Advisor FMIS Promotion Trust.

person we need to benefit is the farmer in a way that he/she becomes increasingly capable and competitive in his or her times. But why a farmer in our scheme of things should generally be projected less capable and less competitive?

In mid 1990s, I had to organize and conduct a training program for senior engineers and social science staff in Water and Land Management Institute in Anand, Gujarat. I was required to use the outcome of the training in developing a farmer-friendly staff training course. Staff engineers and other participants came from all over India. They were also taken to field visit of Mohini Cooperative in Valsad district of Kakrapar Irrigation scheme in Tapi river basin and had direct interaction with the farmers.

I did note participant engineers coming from Bihar and UP refused to accept that they actually interacted with farmers. For them farmers could not be rich and articulate. They felt the interaction with farmers was stage managed and fake. They just could not recognize the fact that the farmers there were rich because they were collectively supplying sugarcane to the mills and they were also associated with the mills as shareholders. The wastages from the sugar mills which worked as good fertilizer were channeled to the agricultural farms had also established another mutually beneficial linkage between industry and agriculture.

We all are aware that farming community supports the national economy significantly and is important for the agri-economic diversity and local wellbeing. It critically contributes to the nation's food security. Society's law and order is much assured when agricultural activities in the farms intensify and proceed normally. Irrigation adds value to farmers' efforts in the field and supports the farming to be more productive. Yet irrigated agricultural activities are not perceived as enterprising. Is a farmer not an entrepreneur so he/she cannot be rich?

A typical individual farmer in our context is not rich. Yet at a field channel level, he or she has some land or some land operation right, possesses some water, has some labor at his/her disposal. He or she may also have some livestock. At the field channel level the existing water user association or farmer organization could be a catalyst in mobilizing and pooling individual farmer's resources under sound principle and mechanism of a cooperative enterprise. Farmer holds a direct and critical stake in the crop productivity and the price he or she fetches for his or her produce. His or her stake is much increased in the context of climate change and its impact on irrigated agricultural land, outmigration that brings labor crisis to agriculture and rapid pace of urbanization which so far has been viewed as an encroacher of farmer's land so therefore was anti-agriculture. We need to legalize a cooperative entrepreneurial set up in irrigated agriculture which a) is resilient in its responses to the local ecological and economic needs, b) enforces accountability transparently according to the recognized procedure, and c) is able to adjust and allocate cost and benefits after its every key performance.

Now let us turn to Xinjiang region of China. It was middle of 2002. We were conducting interaction with the farmers in the Aksu prefecture in the Tarim river basin in preparation of forming WUA. This is the river that feeds surface irrigation schemes in the desert region. In 2001, China had officially become member of the World Trade Organization. This was big news in China as it was institutionally opening up and several matching reforms had to follow.

A farmer had a question for us: "Tell me as China has become a member of WTO, how we are going to make our product competitive?" I had never come across this type of question from a farmer before and that too from a farmer in Xinjiang. I tried to answer him as I had organizational tool of WUA with me, which, as I explained, would give a bottom-up scale and efficiency to the agricultural and irrigation performance.

I could see that it was not the asking farmer but an official listening to my response from the side line was visibly annoyed after hearing what I said. Later this official wanted to inform me that in the name of agricultural scale and efficiency now China could not go back to the commune model of agricultural organization. Clearly he was trying to be careful as any implications of commune would not have gone well with China's image of recent accession to WTO.

I explained to him that it was not Commune I was talking about. What I was talking about was distinctively different from a commune. Whereas a commune was imposed upon the farmers with an ideological objective of control on farmer and production resources, a WUA/farmer organization was based on principles of i) delineated hydrologic boundary, ii) direct representation of the farmers, iii) empowerment of farming community, iv) self-governing interface with local government and related line agencies, and v) cost and benefit sharing. The WUA/farmer organization model could be reformed according to the business principles of a multi-function cooperative enterprise. As scale and efficiency matter, and indigenous innovations triggered by right institutional set up go a long way in harnessing farmers' capability and his or her product's competitiveness, cooperative commercialization of WUA/farmer organization offered a way out.

Innovation is going to be the element at the heart of capability and competitiveness building. In the context of climate change, a Chinese experience informs us a lot. What was done there sounds simple common sense: Seeds from the historically warm ecological region were used in cultivation in a region with increasing temperature. The local government and farmers' WUAs became the partners in this seed transfer and adaptation process. This experience showed that even in the context of climate change, strong and relevant local institutions become the effective vehicle for inter-regional transfer and use of seeds, the most important component for improved agricultural productivity. On top of this, this solution did not entail as much time and cost that breeding of new seed variety might have taken.

The Gujarat and Xinjiang cases have lessons for Nepal. An enterprising model of FMIS will take them beyond autonomy, and make them as capable and competitive enough as required. Such model will make AMIS on the one hand a dynamic partnership between public irrigation agency, the water and irrigation technology provider, and WUA, the water user, commercially viable. In this way an AMIS will effectively get transferred into an AFMIS ((agency-farmer managed irrigations system). In a specified timeframe, each AMIS will have a significant area under FMIS WUA that not only cherish autonomy within their jurisdiction but also increases effectiveness of shared cost and impact of improved benefits. This is a way we can jointly address the needs of both FMIS and AMIS utilizing their comparative advantage.

To take irrigated agriculture towards steady commercialization, some overdue policy actions are to be taken. In view of the huge investment made in public irrigation sector, donor and government recommendations so far have been centered on (i) expansion of irrigated area, (ii) irrigation management transfer and (iii) agriculture extension. During the life of the projects, all these measures contributed temporarily. In FMIS, formation of WUA was targeted more for meeting the financing covenant than graduating them to a higher wealth status.

A sustainable development approach asks for institutional solutions, whereby public irrigation systems are: first, localized to establish system's operational autonomy with ownership and governance; second, treated as a rich resource-base with water, land and labor; and third, recognized as multi-function cooperative enterprise of local stakeholders by law with authorities to enter into joint actions with relevant public and private organizations for promoting irrigation technology, commercialization and environmental quality of irrigated agriculture. For FMIS, above mentioned second and third institutional development solutions will be equally relevant.

Existing Irrigation Policy and Cooperative Act could be suitably used also to recognize multipurpose land and water cooperative and Department of Irrigation could establish an appropriately staffed division first to pilot establishment and demonstration of multipurpose land and water cooperative.

While teaching history of ancient administrative thoughts to students of master's of public administration in Tribhuvan University, Confucius (551 BC – 479 BC) had always struck me by his prerequisites to run a government. The most important prerequisite identified was the people’s confidence in their rulers followed by sufficiency of food.

Kautilya (321 BC to 290 BC), the sage statesman of Magadh Desh, seems to have learned from Confucius (551 BC – 479 BC), when he said: "There is enemy equal to hunger. Poverty is death while living. There is nothing uneatable for a hungry one. The poor one is despised (hated) by his wife. Learning is wealth for the poor."

The ultimate question is: Can we still afford to refuse learning and reform FMIS and AMIS for viable generation and fair distribution of wealth?

I thank you for your kind attention.

1.2 IRRIGATION SYSTEMS: SUSTAINABILITY AND RESILIENCE IN CLIMATE CHANGE SCENARIO*

DR. MD. ABDUL GHANI[1]

ABSTRACT

Annual rainfall distribution patterns in countries like Bangladesh can not plan for year-round crop production without irrigation. Due to climate change, potential yield of most crops can not be achieved without irrigation. The country has irrigated area of 66% against its potential of 76%. About 78% of the irrigated area is using groundwater and the remaining 22% are covered with surface water. Major public irrigation systems are covering about 10% of total irrigation area. It has been observed that Bangladesh Water Development Board (BWDB) and Local Government Engineering Department (LGED) initiate organizing beneficiaries after completion of irrigation and flood control drainage and irrigation (FCDI) projects. This approach takes few more years in local adaptation of the projects to accrue benefits from the investments as well as contributes to lack of beneficiary participation in management, operation and maintenance (MOM) of irrigation and FCDI systems.

Irrigation systems developed in Bangladesh under public and private sectors are operating below 50% of efficiency levels. Management, operation and maintenance levels

* Keynote paper to be presented in the 7th International Seminar of Farmer Managed Irrigation Systems Promotion Trust on "Irrigations in Local Adaptation and Resilience" jointly organized with Department of Irrigation (DOI) and International Center for Integrated Mountain Development (ICIMOD) in Kathmandu, Nepal during April 11-12, 2017

1 Irrigation and Water Management Specialist and Independent Consultant.House # 8/A/3, Road # 13, Dhanmondi, Dhaka 1209, Bangladesh. Email: ghani.abdul.m@gmail.com

especially for the public irrigation systems are poor. About 78% of irrigated area is covered with groundwater based shallow and deep tubewells, which are under private or farmers management. Resilience of groundwater based irrigation systems are mostly related to annual recharge, which is satisfactory. However, resilience of public irrigation systems depends on annual o&m and availability of surface water status of both are below satisfactory level needing improvement.

Surface water based low lift pump irrigation systems and larger public irrigations systems are planned to involve water users and ensure beneficiary participation, which has hardly happened. In most irrigation systems, water availability is problematic due to erratic availability of water in the rivers. However, water availability situation in the sub-continent can be resolved to meet dry season needs for irrigation and other purposes with effective cooperation among the nations.

Climate change will result to sea-level rise, increase in crop water requirement, increase in green house gas emission and increase salinity in coastal area. These in turn will make water environment more complex in Bangladesh and affect irrigation systems by making them more costly, unsustainable and problematic to resilience.

There are discussions and talks about participatory irrigation system or water management in Bangladesh since early 1970s. In real sense there have not been any significant improvements in water management and efficient use of water resources. It is believed that there have been changes of terminology but not much in utilization level of water resources and its management to date.

KEYWORDS: Climate, Irrigation, Management, Resilience, System, Sustainability, Water.

INTRODUCTION

Year-round water availability situation in most countries of the world demands creating irrigation facilities for increasing crop production. In most part of South-East Asia and especially in the sub-continent annual rainfall pattern is skewed and about 90% of the annual rainfall occurs in the rainy season or monsoon, which is during June to September. Onrush of river flows are also very high during these months and cause flooding in the countries of the region. Therefore, in most part of the sub-continent, flood control, drainage and irrigation (FCDI) is more important than irrigation or flood control alone for annual crop production and safe harvest. Global climate change has made water environment more complex by influencing water availability and water use parameters. The changes are affecting water availability both in terms of quality and quantity for crop production and even human consumption. Therefore, water management has become more important and challenging to mitigate consequences of climate change, sustainability of irrigation and FCDI infrastructures and resilience of irrigation systems.

Government organizations cannot meet the challenges of operation and management (O&M) of irrigation (I), flood control and drainage (FCD) and FCDI projects without active participation of water users and water management organizations (WMOs). However, effective participation of WMOs can not be ensured unless project beneficiaries are convinced about importance of these projects in improving their livelihood. The WMOs may not like to contribute to O&M of irrigation and FCDI projects unless they are involved in management of the systems. In real sense, public-private, government-user and stakeholders participation in O&M of FCD and FCDI systems in most countries are either limited on writings or at very early stage of implementation. I understand this arrangement is at satisfactory level due to contribution of FMIS in Nepal but in Bangladesh it is limited in popular talks.

In this keynote paper, I will address importance of water and infrastructure management issues in FCDI projects with examples of Bangladesh and leave it to distinguished participants of the seminar to compare with conditions they are encountering in respective home countries. Bangladesh deals with too much and too little water environment over the year. Excess water causes flooding every year between June to September, however, significant changes of the situation are observed in recent years. Extent of water availability status in Bangladesh may be felt from the following facts;

Bangladesh receives annually about 7.5 meters of water, 5.5 meters from surface flow and 2 meters from rainfall. About 90% of the huge water volume is available during June to September each year and remaining 10% is received during October to May. Therefore, water environment forces Bangladesh for irrigated agriculture supported by flood control measures and provision of drainage facilities. With water potential of the country, about 76% of the cultivable area can be irrigated of which about 66% are presently under irrigation. Due to fluctuation in availability and lack of control over surface water, about 78% of the irrigated area use groundwater.

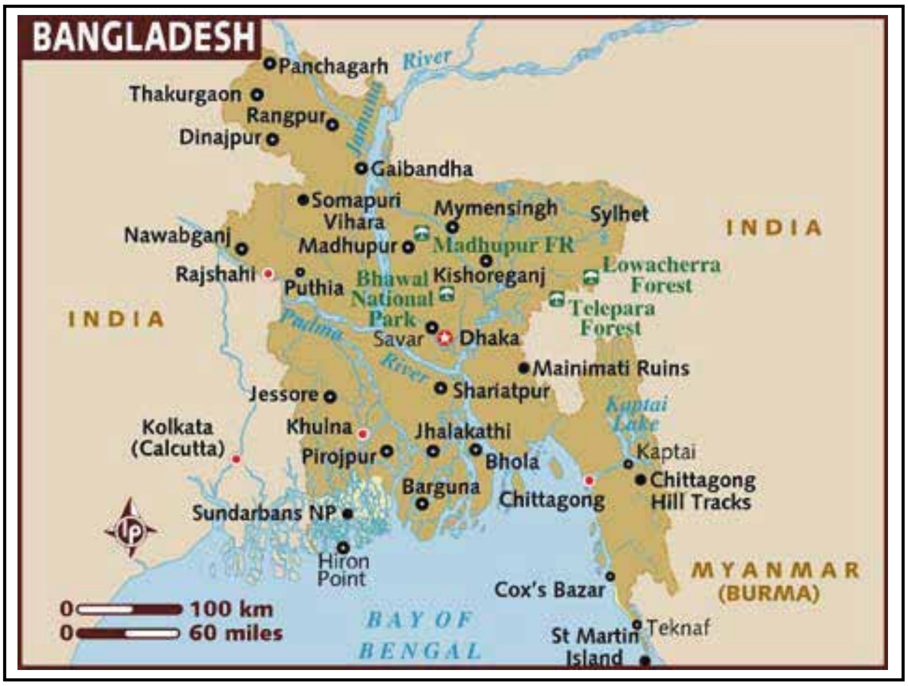

Figure 1: Bangladesh Map with Neighboring Countries, Bay of Bengal, Major Rivers and Forests.

Due to water shortage, crop production during October to May is not possible without irrigation. The National Water Policy acknowledges that surface water availability is unreliable and Bangladesh as the lower riparian has limited control over the rivers entering into its borders (Figure 1). Therefore, the country will have to depend mostly on groundwater for its agricultural production and household water supply. In most part of the country, whatever volume of water is withdrawn during dry season is almost fully recharged during the following wet season.

The unfortunate scenario is that during dry season, (i) groundwater level goes down in many places beyond suction limit (>8m), (ii) arsenic contamination causes quality deterioration and crosses safe limit (>0.05 ppm), (iii) coastal salinity affects about 25% people of the country living in coastal areas, and (iv) surface water sources especially smaller rivers, and low lying areas become dry.

Bangladesh is facing adverse consequences of global climate change, which is further aggravating the above factors, though Bangladesh is a very insignificant contributor to the causes for global climate change. The probable impacts of climate change based on some common indicators are: (a) increased temperature, (b) increased evaporation, (c) lower dry season rainfall, (d) increased soil salinity, (e) higher monsoon rainfall, (f) increased intensity of storms including cyclones, and (g) increased sea level rise.

The country is irrigating about 5.5 million ha (Mha), that is 66% of its cultivable land against irrigation potential of 76% with ground and surface water irrigation systems, of which about 78% is irrigated with groundwater (MOA, 2015) . Moreover, the country will have to provide adequate water for household uses during dry season mostly using groundwater. Arsenic contamination of groundwater, salinity increase in coastal water due to reduced river flow in dry season, emission of green house gases (GHG) from irrigated land have added new dimensions due to climate change. Emissions of GHG from agriculture is comparatively small but it directly releases into the atmosphere a significant amount of carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O) and requires actions to minimize their affects..

Water conservation, especially in smaller rivers, canals, and low-lying areas (beels) can improve water availability in dry season and ensure water security for year-round use for agriculture, household and other purposes. It will also contribute to resilience of irrigation systems especially groundwater based systems through continued groundwater recharge. Therefore, conjunctive use of available water resources needs to be extended to face challenges of improved irrigation management and to mitigate challenges of climate change in Bangladesh.

IMPORTANCE OF WATER MANAGEMENT IN BANGLADESH

Bangladesh is required to increase crop production per unit of land, unit of water and unit of time to feed increasing population and to match with very low land-population ratio. It is known that population density of the country is very high (1077/square kilometer) and cultivable land is decreasing annually by about one percent (1%) and population is increasing by 1.4%. To face the challenges of increasing food requirement, the country will have to produce about 35 million metric tons (MT) per year for consumption including seeds (about 10% of produce) and 2 MT to meet emergency , which is about 6.5 tons/ha. This is not possible without achieving potential yields of most crops under farmers' management with irrigation. Sustainable and economic return of crop production is not possible without improved water management of irrigation systems. We, irrigation professionals understand that cropping intensity of 250 to 300% (against present national average of 192%) and irrigation efficiency of about 70% will be required for years to come to support increasing population. Higher level of cropping intensity and irrigation efficiency will not be possible unless resilience of irrigation systems and continued quality improvement and management of land and water resources are ensured.

ANNUAL CROP PRODUCTION WITH IRRIGATION

Bangladesh has created facilities for 5.5 Mha of irrigated and 5.89 Mha of flood control, drainage and irrigation (FCDI) area. Water potential permits irrigation development up to 6.55 Mha by 2025 and 7.45 Mha to the maximum (WARPO, 2000). Therefore, about 6 Mha may easily be planned for year-round crop production through effective use of FCDI facilities. About 10 tons/ha of grain can be harvested in the FCDI area per year adopting available technology. Therefore, the country can produce 60 million tons food grain (paddy + other grains + pulses) from the FCDI area, which may be about 45 million tons of net grain production (rice + other grains). This production target can be achieved adopting available research and management technology through integrated land and water management and adopting agricultural mechanization. Remaining about 2 million hectare even under traditional cultivation (which is not practical in the present context and improved cultivation may be practiced) will make the country surplus in food production. However, it will require coordinated efforts for improved water management, use of mechanical power in agriculture, post harvest technology, processing and improved storage for favourable returns to the farmers.

Rice and wheat are the major irrigated crops in Bangladesh. To most people in Bangladesh, irrigated crops mean irrigated rice. It makes sense as, rice covers about 77% of the total cropped area and constitutes about 92% of total food grains. Furthermore, rice provides about 75% of the calorie and 55% of protein in the average daily diet of people of Bangladesh. To most Bangladeshis, 'Rice is Life' (Bhuiyan, 2004). Rice production needs adequate supply and management of water for optimum production. Therefore, increased production per unit of land and water is essential. For sustainable food and nutrition supply for the country, integrated land and water use and diversified agricultural production is essential.

WATER AVAILABILITY AND MANAGEMENT

It has been observed over several years that both tubewells using groundwater and large-scale canal irrigation systems in Bangladesh are operating at less than 50% of their efficiency level. All the systems, shallow and deep tubewells, low lift pumps and canal irrigations, irrigated about 5.5 million ha during 2014-15 irrigation season Over the last 10 years, there was annual increase in irrigated area in nine out of ten years except only in 2005-06. The statistics of year 2015 shows that shallow tubewells were operated at about 42% of their rated capacity and irrigated about 2.08 ha against potential of 5 ha. Deep tubewells were operated at 66% of rated capacity and covered on an average 24.03 ha against potential capacity of 40 ha. Low lift pumps were operated at 24% of rated capacity and irrigated 6.62 ha against their potential area coverage of 28 ha.

Experiences indicate that over all irrigation efficiency levels of tubewells and canal irrigation systems can easily be increased to 75% and 70% respectively (it was proved it in Ganges - Kobadak and North Bangladesh Tubewell projects in 1980s). That means another 25% area can be brought under irrigation by increasing efficiency of the existing systems. Therefore, irrigated area of Bangladesh could be about 7 million ha with irrigation facilities operated during 2014-15. Thereby performance improvement of existing irrigation systems can be one of the ways of making the systems cost effective and sustainable.

Soil Moisture Management: Selected cereals, peas, pulses, oil seeds and vegetables can be grown with soil moisture management after harvesting Aman (Kharif – II) rice. Farmers used to practice it as irrigation was seldom provided to these crops. However, with improved price structure and demand, these crops are also irrigated for obtaining higher yield (research findings of NARS confirmed it). Experimental results show that significant quantity (70%) of water requirement for land preparation for rice cultivation can be saved by adopting dry land preparation with optimum soil moisture (closer to field capacity) and flooding rice plots before final pass for land preparation and transplant seedlings. This will save water for land preparation compared to traditional way.

FCDI Facilities: It has been highlighted that FCDI facilities are not performing efficiently. Impact analysis study in 10 FCDI sub-projects indicates that even underperforming projects contributed significantly in increased income, poverty reduction, and better production and living environment. During pre-project period, people of the study area were not able to have three meals daily, whereas after the project, people of the area take adequate food of better quality. Completed projects assisted in reducing poverty through irrigation development, protecting project area from flood and improving communication and contributing to economic development. It also assisted to achieve improved quality of life and life style, increased attendance to schools, increased attendance to health clinics and increased job opportunities (READ, 2008).

Change Water Use Pattern Especially for Rice Cultivation: In Bangladesh, irrigated agriculture means rice cultivation. Diversification of crops under irrigated conditions may make agriculture more profitable and may also reduce pressure on irrigation facilities. Wheat and other non-rice crops require much less irrigation water compared to rice irrigation and are becoming popular. But market variability of price for other crops still discourages cultivation of non-rice crops. Marketing system development for non-rice crops will require administrative supports from the government for facilitating market chain development for domestic and export markets. Irrigation management for rice cultivation should be revisited as alternate wetting and drying can save about 25% of irrigation requirement, which may bring about 25% additional areas under cultivation without significant yield reduction with same amount of water delivery against traditional irrigation (continuous standing water). This will make irrigation systems cost effective.

Conjunctive Use of Water: Bangladesh has 30 Agro-Ecological Regions (UNDP & FAO, 1988) of which 76% has adequate groundwater and 33% has adequate surface water for irrigation development. Therefore, irrigation or water resources development of the country should be different for different agro-ecological regions. The national development plan should be to maximize utilization of rain, surface and ground water through conjunctive use of these resources. Comprehensive studies should be undertaken at upazila level involving stakeholders, government and non-government organizations (NGOs) working in agriculture. Local level production plan for each upazila, considering information on land and water resources should be developed and implemented. An exploratory survey revealed that there was wide variation in irrigated area coverage even within agro-ecological area. If appropriate professionals are provided opportunities, with stakeholder participation can narrow the gaps in irrigation achievement and make agriculture cost effective. It is assumed that this is similar to one of the priority issues considered by farmer managed irrigation systems (FMIS) approach in Nepal.

Surface Water Augmentation:Rain water and part of surface flow during later part of monsoon can be stored in low-lying area, canals and ponds for supplemental irrigation of rice crops. There are opportunities to use pond water for supplemental irrigation to stabilize yield of Aman crop and for dry season irrigation. Observations have also been made that with one ha of pond about 10 hectare lands can be brought under supplemental irrigation for rice. The same pond can also be used for irrigating about 10 hectare of dry season non-rice crops. Excavation of ponds and re-excavation of existing canals will increase storage capacity for subsequent use of water for irrigating the second crop. New ponds and re-excavated canals can also be used for fish cultivation (personal communication with fisheries experts). Fish cultivation alone in the ponds and re-excavated canals will be cost effective.

Bangladesh has river area of 12,790 square km of which about 1,890 square km (15%) have width between 25 to 100 meters. They can be converted to temporary water reservoirs during November to May with suitable water conservation structures for dry season irrigation. Water conservation in irrigation and drainage canals during the lean period will also provide opportunities for storing water over an additional area of about 192,000 ha(Ghani, 2010).

Community based fisheries management system can be introduced in the seasonal water reservoirs following “Common Property Resource Management Procedure” of the country.

Fisheries experts confirmed that these seasonal ponds could be brought under profitable fish cultivation program through stakeholder participation and on an average, 2.0 ton fish can be harvested per hectare of water body. Moreover, water stored in the dry season will be a continuous source for groundwater recharge, which subsequently can be used for irrigation using deep and shallow tubewells without severe lowering of groundwater table. Water conservation in rivers and canals will also contribute to afforestation program along the banks and irrigation development using low lift pumps for the lands adjacent to water bodies. This will also facilitate availability of drinking water and bathing place for cattle. Success of this approach in one river may be replicated in other area of the country, which will contribute to its overall development. This approach will also contribute to better natural and production environments.

Ganges Barrage:Government of Bangladesh has completed feasibility study and design of Ganges barrage project and intents to construct barrage as soon as possible. Completion of the barrage will benefit about 4.6 Mha, which is known as Ganges Dependent Area (GDA). Twenty six districts (partial or full) will be benefited from the barrage. The distribution network channels would carry fresh water from the Ganges to cater needs of irrigation, pushback salinity front, internal navigation, open water fisheries and maintenance of ecological balance in the service area. GOB may advise agriculture extension service providers to plan development initiatives to achieve benefits from the costly investment. Experiences showed that BWDB and LGED engineers initiate organizing beneficiaries after completion of development projects, which takes few more years to accrue benefits from the investments. Agricultural engineers, if entrusted can play effective role in delivering potential benefits of the project as soon as it starts providing irrigation water.

Trans-boundary Issues: It is an established fact thatwater availability situation in the sub-continent can be resolved to meet dry season needs for irrigation and other purposes with effective cooperation among the nations. Flood problem during wet season can also be minimized to great extent through water conservation especially in the Himalaya mountain area. This will also create ample opportunity for production of hydro-electricity. This is very important for Bangladesh as the country is the worst sufferer of existing unfavouravle water environment. Let us hope for better understanding among our political leaders for their contribution to best use of water resources of the region.

Climate change: Climate change may result to sea-level rise of 4.5 to 23 cm in 2025 and 6.5 to 44 cm by 2050(Bangladesh Climate Change Strategy and Action Plan 2008). It may also influence to increase in crop water requirement by 25% by 2025. Rainfall in peak monsoon may be about 28.6% higher by 2050. This may increase flood problem and drainage requirements. Extent of drought will also be higher. These are water management related issues to be affected more by climate change. The community should be equipped to face all the adverse situations and save the nation through appropriate adaptation to the changes and mitigation of anticipated problems.

PROSPECTS AND PROBLEMS

Recently, much concern is being expressed about need for improving performance of irrigation systems and their sustainability. However, it is not new as irrigation systems are operated with low efficiency since beginning of irrigation in Bangladesh. Over the years, terminologies changed from Thana irrigation program (TIP) in early 1960s to water management during early 1970s, to on-farm water management (during late 1970s and 1980s), to improved water management (during early 1990s), to participatory water management (since late 1990s) and to the recent integrated water resources management (IWRM). In real sense there have not been any significant improvements in water management and efficient use of water resources. It is believed that there have been changes of terminology but not much in utilization level of water resources and its management since early sixties of last century to date.

Water Management: Irrigation system management and more specifically water management has different meanings to different people. Water is often considered to be free commodity; therefore, its management also varies. To me water management defined by Alvin Bishop is very relevant to our subject of discussion and he defined it as "Water management is a combination of science and art that requires application of knowledge of water, soil, climate, crops, and their interactions together with inputs and management for agricultural production". Let us ask ourselves, can a single discipline oriented professional handle all the knowledge required for water management.

As professionals of this field let us ask ourselves, are we using our water resources and doing water management in our countries that meets the criteria set in the above definition? Probably not! We could achieve a lot through improved water management by achieving the development potentials. Some of the improvement potentials could be achieved without additional investment at least for infrastructure development.

Infrastructure Development: For protecting lives and properties of the people, FCDI facilities are essential. During infrastructure development for providing FCDI facilities, construction of embankments and irrigation and drainage canals are required. These infrastructures are mostly used for saving lives and properties and creating favorable environment for increasing agricultural production. Multiple uses of these facilities for afforestation and fish cultivation in addition to their primary uses will make irrigation systems more cost effective.

HOW THE SITUATION CAN BE IMPROVED?

Irrigation personnel should be trained to use FCDI facilities and associated infrastructures for their best use with active participation of the stakeholders/beneficiaries. Participatory management and more specifically participatory water management in water sector projects are widely discussed now -a - days. Under present condition, government agencies are still the main player and beneficiaries are consulted for their opinion and expected assigned roles by the implementing agency or agencies. To be more specific, so far one of the agencies, which has been assigned responsibility of project implementation and operating funding arrangement for the development works become “captain” in the implementation team. Beneficiaries are expected to be good listeners and to follow directions of the captain. In real sense, beneficiaries should be the decision makers while agency personnel, researchers and NGOs engaged in development activities in the project area would work as advisors.

Other important deviation from common thinking is that, in most FCDI projects, activities related to management, operation and maintenance (MOM) of flood control, drainage and irrigation infrastructures although not addressed properly, get all the importance by the project management. Other components like, efficient use of water, crop production, fish, forest and livestock production are not getting due importance. Improvements of these aspects are left with the concerned line agencies and beneficiaries of the project area. However, multiple and integrated use of the FCDI projects and integrated water resources management (IWRM) should be the priority areas for water sector projects.

Few examples are cited in this respect to emphasize and elaborate difference of the concept from the existing operational procedures. Guidelines for Participatory Water Management (GPWM) in Bangladesh states that “Participation is an important voluntary process in which local stakeholders influence policy formulation, alternative plans/designs, investment choices and management decisions affecting their communities and establish the sense of ownership”. The GPWM indicate that “Give the local stakeholders a decisive voice at all stages of water management”. The co-management concept validated through a case study supports decision - making power than the decisive voice.

The GPWM also supports participation of local stakeholders to “prepare production plans on agriculture, fishery, forestry and livestock development and environmental management plan based on the feasibility study” by the implementing agencies. In real life, the implementing agencies, BWDB and LGED are not doing these as existing government mandates entitles Department of Agricultural Extension (DAE), Forest Department (FD), Department of Fisheries (DOF) and Livestock Department (LOD) to prepare their plan of action for the country including water sector project areas.

Co-management and participatory management support that mere participation in decision - making and consultation by agency personnel in water sector projects will not bring much benefit to the stakeholders. For increasing agricultural production, which is required for improved livelihood of stakeholders and for effective use of land and water resources in irrigation projects, stakeholders should have authority of decision – making for management of all infrastructures. Proposals agreed by the stakeholders should be implemented to achieve maximum benefit from the investment made in implementation of irrigation projects and in building infrastructures.

Improvement Potentials: The Ganges-Kobadak Irrigation Project (GKIP) is the oldest and largest irrigation project in Bangladesh.The project is highly criticized for low irrigation and water use efficiency, poor operation and management and cost recovery. Several rehabilitation programs have been undertaken with donor supports since its beginning of operation in 1962. Focus group discussions with project beneficiaries during 2015 revealed that management, operation and maintenance (MOM) of the system can be improved if the following actions are implemented through water management organizations (WMOs):

SUSTAINABILITY OF WATER MANAGEMENT ORGANIZATIONS AND IRRIGATION PROJECT

The following activities and income generating approaches are suggested to make WMOs and O&M sustainable in GKIP. However, before handing over responsibilities to the WMOs for O&M of tertiary and secondary canals, the entire GKIP infrastructures should be rehabilitated (including replacement if required) by BWDB.

Water rate collection: A reasonable rate of water charge per crop season should be carefully reviewed and agreed with WMOs. Water rate collection may be handled on secondary canal basis and collection may be responsibility of water management association (WMA) for the secondary with support of water management groups (WMGs) formed at tertiary level. A fixed percentage of collection charge may be paid to the water management groups (WMGs) as incentive for water rate collection and submitting to BWDB or deposited in a bank account as agreed by BWDB and WMOs. There will be water management federation (WMF) for the entire project for sharing management responsibility with project management.

Crop production potential: Project area can easily be converted to triple crop area through year-round use of the irrigation facilities. Research data reveal that with annually two rice crops and a non-rice cultivation practices, production of at least 12 tons/ha of rice equivalent yield per year can be achieved adopting available technology. Therefore, about 11, 47392 tons (12 ton/ha x irrigated area of 95616) can be produced in the GKIP area against present annual production of 5, 92375 ton in 2013 (Agriculture Report). This will make the project economically viable (to be supported by benefit-cost analysis). Production of rice, wheat, maize, pulses, oilseeds, potato, winter vegetables and green manure crops will assist in increasing cropping intensity to about 300% and in soil health improvement. However, it will require comprehensive plan for integrated use of water and land resources.

Fish cultivation: Opportunities for multiple uses of irrigation and drainage can be explored for additional income generating activities like fish cultivation in the secondary and main canals. Discussion with GKIP professionals, farmers and WMO personnel revealed that fish cultivation in the secondary and main canals is possible. The WMAs are ready to take responsibility of fish cultivation on profit sharing arrangement with GKIP management. Initial computation supports that 467 km secondary canals with average width of 10 meter and about of 2 meter water depth, water body suitable for fish cultivation will be about 147 ha. Personal communication with fishery experts confirmed that about 2 tons/ha fish can easily be produced in 6 to 9 months of irrigation season. Fish produced in the canal can be sold at the rate of Taka 150/kg at site. This will provide annual return worth Taka 44,100000 equivalent to US$572727 (considering 1US$ = 77 Taka) per year from the secondary canals. From 193 Km of main canal with average water width of 25 meter and depth of 3 meter, fish cultivable water body will be 482.5 ha. With similar assumed production and sales price, it will provide annual return worth Taka 144,750000 equivalent to US$1, 879870 (considering 1US$ = 77 Taka).

Therefore, total annual income from water bodies in secondary and main canals will be Taka 188,850000 equivalent to US$2, 452597. Cost of fish production per ha per year is about Taka 150000 (personal communication with fishery experts). Therefore, total cost of fish production for secondary and main canal area (949.5 ha) will be Taka 141825000 equivalent to US$ 1,841,883 taking similar Taka and US$ exchange rate. Therefore, net annual profit from fish cultivation will be worth Taka 97,025000 or US$ 610714. That means profit from water bodies will be Taka 198012 per secondary if the profit is divided among 49 WMAs, and with less than this amount WMAs can take care of annual O&M of all tertiary canals if they are given responsibility.

Plantation Program along Country Sides of Canal Banks: Secondary canals with average height of 1.5 meter and average side slope of 1:3 will have 420 ha land for 467 km of secondary canals. Main canals with average height of 3 meter and average country side slopes will have 347 ha of land area for 193 km of main canal. The total land area of 767 ha (420 + 347) can accommodate about 1,150500 trees along canal banks. This will also provide return worth Taka 23 billion equivalent to US$298 million after 20 years (taking wood value of Taka 20000 per tree after 20 years). That is on an average annual return form plantation will be Taka 1.15 billion equivalent to US$14.9 million.

The project management of similar projects in Bangladesh and elsewhere can have a look to take advantages of using infrastructures for fish cultivation and afforestation involving WMOs to make investments worthy and make FCDI projects self sustainable. Active participation of beneficiaries will ensure O&M of projects sustainable, cost effective and resilience which is one of the thrusts of this seminar. Plantation on embankment slopes and year-round crop production will also contribute to minimize affects of climate change assimilation of carbon dioxide gas.

SUMMARY AND CONCLUSION

In most irrigation and FCDI projects, management, operation and maintenance (MOM) are not addressed properly but it gets importance by the project management. Other components like, efficient use of water, crop production, fish, forest and livestock production are not getting due importance in the project area. Improvements of these aspects are left with the concerned line agencies and beneficiaries of the project area. Integrated use of FCDI infrastructures and integrated water resources management (IWRM) should be the priority areas for water sector projects to make them cost effective, sustainable, local adaptation and resilience.

The GPWM supports participation of local stakeholders to "prepare production plans on agriculture, fishery, forestry and livestock development and environmental management plan based on the feasibility study" by the implementing agencies. Co-management and participatory management suggest that mere participation in decision - making and consultation by agency personnel in water sector projects will not bring much benefit to the stakeholders. For increasing agricultural production, improved livelihood of stakeholders, effective use of land and water resources in irrigation projects, stakeholders should have authority of decision – making for management of all infrastructures.

The project management of similar projects in Bangladesh and else where can have a look to take advantages of using infrastructures for fish cultivation and plantation involving WMOs to make investments worthy and make FCDI projects self sustainable. Active participation of beneficiaries will ensure O&M of projects sustainable, cost effective and resilience which is one of the thrusts of this seminar.

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The author is grateful to FMIST members and management for selecting me as Keynote Speaker and "ICON of FMIST of 2017". It is a great honour to me and my family. I would like to extend my special gratitude to Dr. Prachanda Pradhan, Patron of FMIS communicating this decision to me. As Irrigation Engineer and Water Management professional, I am concerned about participatory water management for increasing irrigation and water use efficiencies at farm and irrigation system levels. My association with IRRI as Research Scholar and Research Fellow and as Ph. D student with Professors of Agriculture and Water Management Department of Utah State University provided me opportunities to sharpen the ideas in this field. I was aware of FMIS as professional and my acquaintance with Dr. Pradhan helped me to know in-depth about contributions of FMIST for its beneficiaries.

I am also grateful to my family members, our two sons and my wife who ensured enabling environment to be more active in my professional life. They are very generous to support my participation in national and international seminars and workshops even with family resources. I am glad to inform you that I participated in six out of seven international seminars of FMIST.

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REMARKS BY CHIEF GUEST

RAMANAND PRASAD YADAV[1]

Respected Chairman, Distinguished Keynote Speakers Dr. U Gautam, Dr. Md. Ghani, Paper Presentaters, Dear Guests, invitee friends, ladies and Gentleman;

First of all I would like to congratulate chairman of FMIS promotion trust and the entire team for arranging this 7th international seminar on a very important topic, "Irrigation in local adaptation and resilience." I would also like to thank the trust for giving me this opportunity to be here. I would like to thank you all for being here and taking part in a lively and fruitful discussionon the relevant issues.

Now starting from my own country, as we know Nepal has a long history of irrigation water management by farmers where they take the sole responsibility of operating and maintaining the irrigation systems. These FMIS are characterized by the use of low cost technology appropriate for local condition, autonomous decision making suited to them, with suitable and collective action for O & M of the system.

But due to changes in hydro climatic, socio- institutional and policy dimensions their performances are in decline. They are facing problem of water availability at the intake as well as flood and erosion damages at the same point. So challenges are from both the demand and supply sides. The demands are increasing and supply is decreasing in an inconsistent way. In such situation Nepalese farmers, engineers, researches, designer and water leaders all are facing problem in taking appropriate decisions.

1 Secretary, Ministry of Irrigation

In such situation water management has become more important and challenging to mitigate consequences of climate changes on the sustainability of irrigation systems. Government organization cannot meet the challenges of O&M of irrigation system without active participation of WUA. We are facing financial crisis in operating and managing AMIS because of low cost recovery. Therefore, Ministry of Irrigation has given priority to PIM especially in all types of irrigation projects, from selection to commissioning of the project. Also, great attention has been given to research and study in order to increase the efficiency of the system as well as to support for local adaptation and resilience of the irrigation system.

The irrigation policy 2013 of Govt. of Nepal has very clear mandate to support FMIS for the sustainability. Climate risk management and disaster Risk Management program have been given high priority for adaptation and mitigations. Govt. of Nepal has given high priority for the sustainable development of irrigation systems and these will be even more strengthened in the days to come as Nepal has headed towards economic growth, catch-up, and modernization to put the country in the league of developing nations by 2022 and transform Nepal in to a middle-income country by 2030.

Now with these words I would like to conclude my remarks wishing grand success of this seminar. I also congratulate Dr. Gautam and Dr. Ghani Sir for receiving FMIS Promotion trust's Icon of honor 2017 and also Durga Sen and Mr. Pradhan for receiving Medini-Kamala Trust Award. I also like to wish our international guests for their nice and healthy stay here in Kathmandu.

Thank you all.

CONCLUDING REMARKS AND VOTE OF THANKS

NAVEEN MANGAL JOSHI[1]

Honorable Chief Guest, Secretary, Ministry of Water Resources, Mr. Ramanand Prasad Yadav, Director General, Department of Irrigation, Mr. Rajendra Adhikari, Icons of FMIS 2017, Dr. Md. Abdul Ghani, Dr. Upendra Gautam and the Patron of FMIS promotion Trust, Dr. Prachand Pradhan, other members on the dais, media and friends of FMIST.

First of all, I like to thank honorable Secretary, Mr. Ramanand Prasad Yadav for joining this event as Chief Guest and launching the book "Application of Modern Technologies to Facilitate Commercial Irrigated Agriculture for Improving Rural Livelihood in Nepal"

The conclusion of present event marks the crossing of half a dozen of International Seminar on Farmer Managed Irrigation System, its dynamics, pertinent issues and the way forward. We, at the FMIST feel proud to be closely associated with all the events over the years. In the meantime, the present discourse is expected to prove more meaningful as it tried to address the issue of national food security through the development of Farmers Managed Irrigation Systems and impact in the systems due to the present trend of climatic variations in the Nepal including other developing countries. And for the successful conduct of the event, credit definitely will go to the co-organizer and all the co-partners as well as the friends of FMIST. We sincerely acknowledge all and highly appreciate for entire support offered to us. Similar thanks goes to the Director General of Department of Irrigation, Mr. Rajendra Prasad Adhikari for kindly accepting our request to partake in the seminar as Co-organizer. In

1 Chairperson FMIS Promotion Trust

addition, ICIMOD has come forward this time for co-partnering this seminar. Likewise, we cannot forget the participation with big heart from Jalsrot Vikas Sasntha, Community Irrigation Project, IIT Roorkee Alumni Association (Nepal Chapter), and INPIM Nepal.

For your kind information, FMIST has taken some steps in the rehabilitation of few earthquake damaged FMISs. I like to thank all the friends, who joined with us for rehabilitation works in Sindhupalchowk, Dhading and Dolkha. Such participation definitely shows the increasing importance given to the Farmer Managed Irrigation Systems in present context. We heartily extend our gratitude to all those contributors.

FMIST has further stepped in some research works for irrigation systems for affect climate change with the collaboration with CDKN and commercially viable small irrigation system, which could be a means of enhancement of livelihood in rural area of Nepal in collaboration with FAO. Special thanks goes to Dr. Pushpa Khanal of FAO for his continued support during the study period.

Furthermore, we express our sincere thanks to Dr. Upendra Gautam and Dr. Md. Abdul Ghani for accepting our request and contributing the Key Note speeches. We once again congratulate our honorable new icons of 2017. I request all the friends of FMIS to give big hands to these honorable icons. In addition, similar congratulation goes to User's Group of Singhe Ghat Irrigation System of Kapilvastu and Newar Kulo Irrigation System of Panchthar for remarkable performance of systems.

Papers on FMIS from different sectors and countries have been another milestone of this seminar in terms of its value and role. We highly appreciate the efforts of all the paper presenter and researchers.

Finally, we offer our thanks to Media, Hotel Management and Team of FMIST. Support from CMS (Nepal) and Nepal Engineering College has always been encouraging for FMIST. Ms. Monica Maharjan and all the team members involved in the Seminar have labored hard and I cannot leave space without thanking them. Lastly thanks to all the Friends of FMIST and different national as well as International organization for increasing confidence and the continued support as well as participation in the activities on FMIST. Thank you and thank you all.

2. CLIMATE CHANGE AND IRRIGATION MANAGEMENT

2.1 IMPACT OF CLIMATE CHANGE ON SMALL AND MEDIUM IRRIGATION SYSTEMS IN NEPAL

UMESH NATH PARAJULI[1]

INTRODUCTION

Although Nepal is endowed with enormous water resources, climate change poses a significant risk in the coming decades. Because of its rugged mountainous terrain and wide altitudinal variations within short horizontal distances, Nepal is unique in having perhaps the greatest variety of climates for a country of its size. This characteristic of Nepal makes it particularly vulnerable to the adverse effects of climate change. Further, being located in the region of the Hindu Kush-Himalayas, where the warming rate has been greater than the global average, threats due to climate change further increases in Nepal.

Temperature and precipitation are two key climatic variables most influenced by climate change. This phenomenon is predicted to affect seasonal water availability, which could have serious impacts on irrigated agriculture, and consequently on Nepal's overall economy.

In general, although irrigation is taken as a way to reduce climatic variability, all irrigation systems in Nepal are not resilient to climate change. This is explained below

Most of the small and medium irrigation systems[2]in Nepal that are commonly found in hills and river valleys are of run-off-the river type, where there is no storage possible and where there is

1 Engineer, Water Resources Development Consultant.

2 The Irrigation Policy splits irrigation into four size categories: major, large, medium and small. Irrigation systems with less than 10 ha in the hills and less than 100 ha in the tarai are defined as small irrigation, while systems with 10-500 ha in the hills and 100-2,000 ha in the tarai are said to be medium irrigation. It is estimated that about 75% of the irrigated areas covering about 900,000 ha is under small and medium schemes, which is the focus of this study.

already a shortage of water. Many of these systems are developed by farmers since long. They draw water from adjoining small tributaries (often seasonal) of the major rivers whose discharge depends mainly on the rainfall. In the past, these tributaries used to supply a fair amount of water to their respective command areas, but they are now reported to be drying up. Traditionally, they were used for paddy cultivation, particularly to enable timely planting and to protect against dry periods during the monsoon. They still provide some protection but probably less so than in the past. Operation of these small systems is equally vulnerable to the range of other changes in livelihoods, population growth and local governance system.

As a result, despite a long history of government support in rehabilitation, improvement and modernization of small and medium irrigation systems in Nepal, their performance is still not satisfactory and constraint due to water shortage still remain. This phenomenon has led to a thinking that the conventional surface irrigation do not perform well[3].

Recognizing above constraints, many technological interventions[4]were made in recent years in developing and improving performance of small irrigation in Nepal. Plastic-lined pond is one of such well-accepted technologies, which is recognized as a milestone in the development of small irrigation in hills. These ponds receive water from local springs, and the storage increases climate resilience. However, they are also vulnerable to springs drying up over the medium to long term.

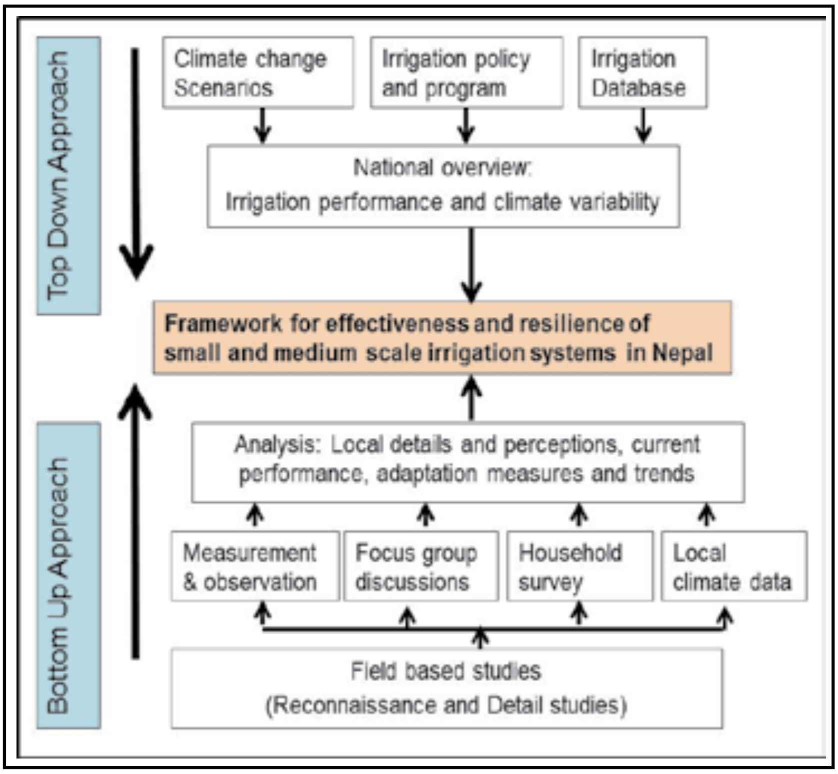
This paper examines impact of climate change and local level adaptations in small and medium irrigation systems in Nepal. The paper is based on the studies conducted during 2015 and 16 with an objective of developing a framework for improving the resilience and effectiveness of small and medium scale irrigation systems in Nepal (Mott MacDonald, 2017). The paper suggests that climate change does have influences on irrigation system and its management, but it is not the only agents for changes. There are other agents as well that bring changes on irrigation management.

METHODOLOGY

The said study conducted during 2015 / 16 followed two pronged approach – top down and bottom up. The top down approach focussed on understanding Nepal's climate vulnerability and overall performance of irrigation sector including its challenges and opportunities. This was done through analysis of existing climate data and literature, and projections of climate change for alternative emission scenarios and timescales from CMIP5 (Fifth Coupled Model Inter-comparison Project). The foundation for the study was a review of existing evidence, climate models and literature to assess current and projected

3 One of the reasons of their dismal performance is that the Government intervention on these systems focused only on replacing temporary nature of infrastructure by a more permanent infrastructure without examining their management from the broader perspective of governance, socio-economic and climate change

4 Some of the well noted technological interventions are: diversification of water source of small run of the river surface canal, provision of plastic ponds, micro irrigation (drip and sprinkler), low-lift treadle pump, rower pumps, multiple-water use systems (MUS), shallow tube wells, solar-powered lift systems, and rainwater harvesting.



impacts of climate change on small- and medium-scale irrigation systems, analysis of irrigation database, and review of relevant policies and program. The top down approach helped in developing knowledge on irrigation performance from the perspective of climate change.

Nepal experiences greatest variety of climate due to its wide altitudinal variations across short horizontal distances. As a result, impact of climate change on irrigation system varies from place to place, which in turn is shaped by the local context of natural resource endowments, livelihood activities, vulnerability patterns and adaptive capacity. This suggests that impact of climate change on irrigation system should also be examined also at system level.

Recognizing this, the bottom up approach focussed on understanding climate vulnerability and performance of irrigation system at field level. This was done by following case study method that encompassed both the reconnaissance and detail studies.

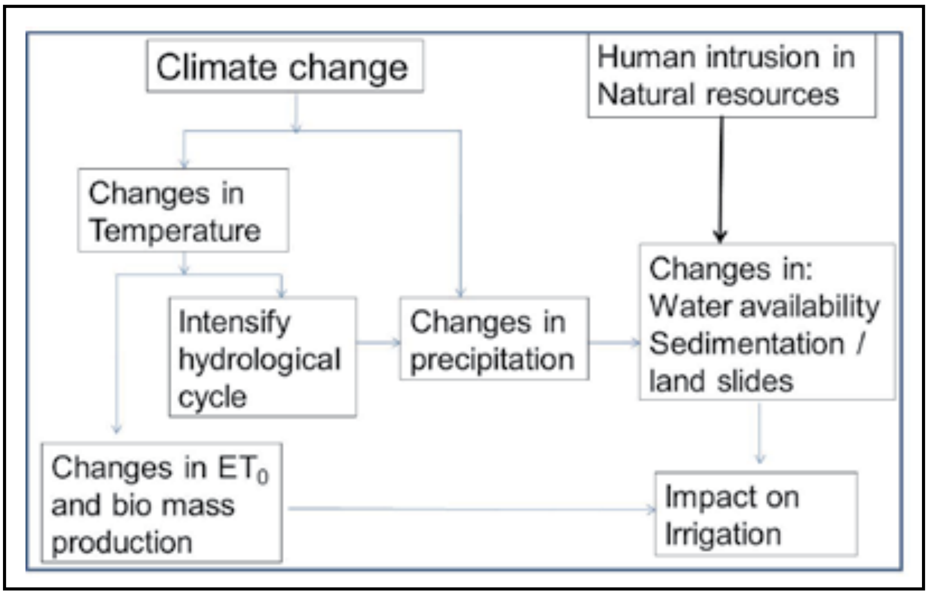
The reconnaissance study covered 17 irrigation systems across various geographical and agro-ecological zones, while detail studies were conducted in the Singhegaht Irrigation Systems of the Bangana Basin and Julphe Irrigation System of the Girwari basin. Besides examining particular irrigation system, the study also examined the basin as a whole and other irrigation system therein.

IMPACT OF CLIMATE CHANGE ON IRRIGATION

As noted above, temperature and precipitation are two key climatic variables most influenced by climate change. With regard to temperature, DHM data suggests that the temperature across most of Nepal has shown an increasing trend of up to 0.55°C per decade. Other studies have indicated trends of 0.27°C per decade (1975-2006) and 0.4°C to 0.6°C per decade (1976-2005). Despite these differences, all studies suggest that temperature in Nepal is increasing at a faster rate than the global warming rate.

Unlike in the case of temperature,studies on precipitation do not reveal clear or consistent trends. Some studies indicate a decrease and others suggest an increasing trend in mean annual precipitation. However, none of these projections are statistically significant. Further, precipitation data exhibits high seasonal and inter-annual variability.

Impact of climate change on irrigation will be of two types: direct and indirect. Likely changes in crop water demand and biomass production is the direct impact, while likely changes in water availability present indirect impact. Other than climate change, human intrusions in Natural resources also influence water availability, which in turn influences irrigation performance. Figure 2 presents a conceptual framework on consequence of climate change on irrigation.



CASE STUDIES OF THE SYSTEMS

GIRWARI RIVER: JULPHE IRRIGATION

The Girwari River is a tributary of the Narayani River. It originates in the Mahabharat mountains. At the foothill of this mountain range, the river discharges into a wide river valley of the Deurali Village Development Committee (VDC) where people maintain their livelihood through irrigated agriculture.

Irrigation in this area dates back about 100 years and was initiated by zamindars who could mobilize their tenants to maintain the system. Water rights were linked to land, and paddy was the only crop grown. The cultivated area remained low until rapid migration from the Hills started in the 1960s when much was cleared and cropped. There are now five separate but adjacent systems irrigating about 1,000 ha on the left bank of the Girwari River after it emerges from the Hills and as far as the East west highway (plus one small one on the right bank). A further 10 systems irrigate the southern part of the sub-basin as far as the confluence with the Narayani River (Figure 3).

The upper six systems abstract all surface water from the river at critical times, but water re-emerges 5-10km further downstream and can be abstracted to irrigate the southern area. The catchment upstream of the irrigation systems is about 50 km2, with only small areas of cultivation. The total cultivable area downstream of the upstream intakes is about 2,000 ha (20 km2) and thus a shortage of surface water is inevitable in the dry season.


Figure 3: Location map of irrigation systems in the Girwari River (basin)

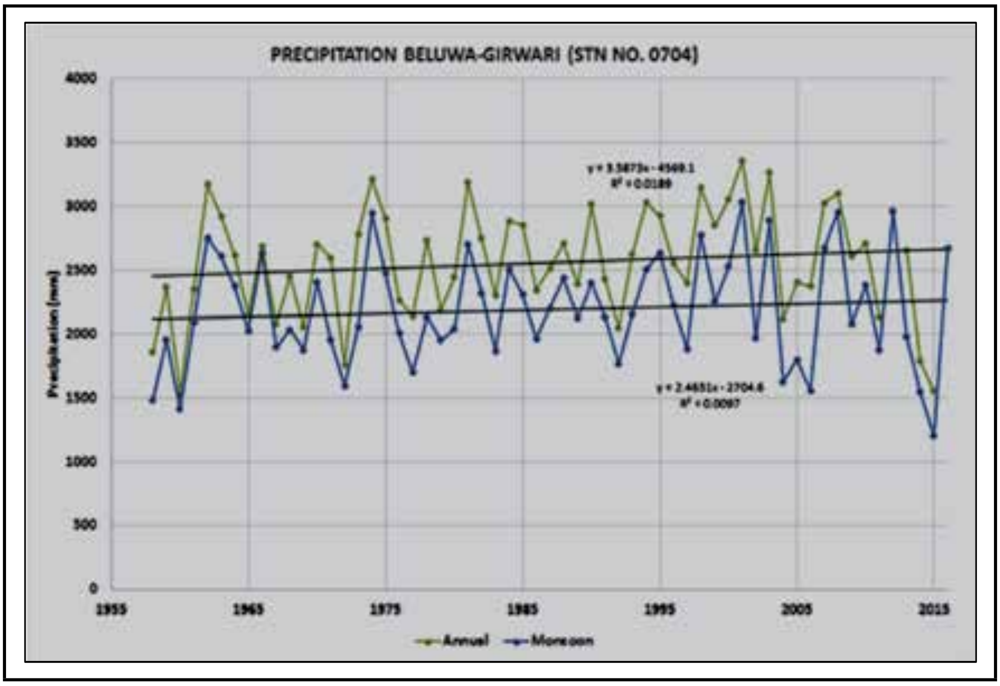
These six systems are separate but still interdependent and require a degree of cooperation in management. The southern most intake (for Akase kulo) has gradually been moved northwards because of problems with diverting water from the wide river bed, until it is almost at the same location as the Julphe kulo; there is now ongoing discussion about formally combining the two systems which already share water during the dry season.

The Julphe kulo is the largest system and is the focus of this study, but relations between systems and overall management of the sub-basin are increasingly important because of the growing demands for, and declining supply of, water. Since the 1970s, cultivation has become increasingly intense, reaching up to 300% in places with water being a major constraint. A lack of surface water can be offset by using groundwater although the depth to the water table is quite great in this northern area, making pumping difficult and expensive.

The system was rehabilitated in the 1970s extending the Julphe systems so there are now three command areas (Julphe, Koliya and Basantapur) which receive proportionate shares of the main canal flow. These function as independent sub-systems with their own organizational and institutional arrangements, and water rights are no longer linked to land area. These water rights are now unequal in comparison to land area and this makes it difficult to formalise the water-sharing arrangements with the Akase kulo.

Climatic data

The Beluwa meteorological station is located close to Julphe and has data extending back to 1958. Although a straight line regression shows a slight (but significant) increasing trend (Figure 4) this is very small compared to the annual variation. Extreme daily rainfall is also highly variable and has also not changed significantly over this period;nor the number of days with more than 10mm rainfall.



Source: DHM Data

Figure 4. Rainfall trends in Beluwa, Girwari

By contrast local perceptions are that rainfall is decreasing significantly. Reason may be of two folds:

First, this may be a consequence of a marked decline since 2001 and four increasingly dry years from 2012 to 2015, with the rainfall in 2015 being barely half of the long-term average.

Second, farmer's perception on declining rainfall may have been derived largely from their assessment of how well it meets agricultural needs for water (especially crop water requirements). This is supported by following facts:

The effectiveness of rainfall in meeting agricultural need is decreasing because days with smaller rains (up to 50 mm) are decreasing, and A week long dry spell in the month of September is increasing. It is to be noted that the September rainfall is critical because the flowering and grain formation stages of paddy cultivation fall in this month, however, the 2016 has been a much wetter year that has included several unusually intense events causing flood damage to irrigation infrastructure rather than alleviating water shortages for crops.

System management

The six systems are operated independently but various coordination arrangements have been set up, especially for the spring season resulting each system receiving water in turn with about a 10-day cycle, and then with a further rotation within the system. During the monsoon, systems can be operated continuously with ad hoc arrangements at times of intermittent rainfall. As irrigation is supplementary to rainfall, such dry periods both create additional demands and reduce the availability in the river.

Water supply appears to be decreasing, although this is based on very limited data. The minimum flow recorded in April/May 1982 was 310 l/sec (Parajuli, 1999), whereas a flow of 90 l/sec was observed in April 2016 against the estimated natural minimum river flow of about 400 l/sec. This reduction in flows is not only related to climate change, there has been substantial increase (up to 80% of the potential runoff) in the uses of water in the upper catchment. The corresponding for upstream water use in 1980 would have been just 20%.

Floods also appear to be increasing, with intense rainfall recorded in 22 July, 26 August and 1st September, 2016. These cause high sediment inflows to the canals and also washed out the weir which supplied water to the Akase kulo (Figure 5).

Eroded river bed at the intake of the Aakase kulo after July flood | *Left river bank with pipe intake after July flood (but before Sept flood)* | *Aakase kulo after its intake & flood bank washed away by Sept flood*

Source: Mott MacDonald (2017

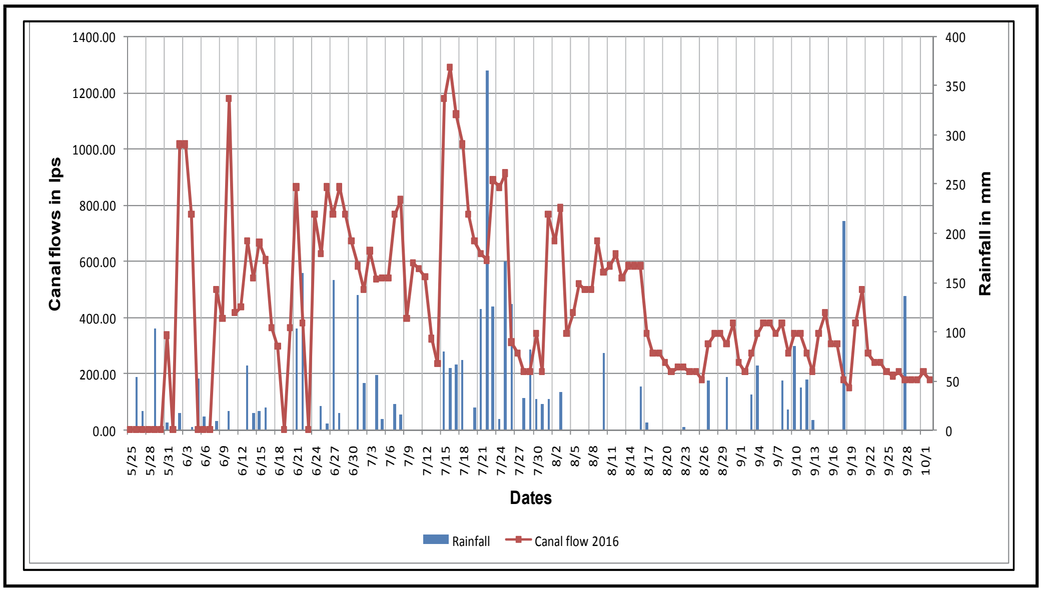
Figure 5: Intake of the Aakasekulo and Girwari River before and after floods

However, such damage is not only related to flood flows. There is extensive quarrying of construction materials in the river bed which has significantly lowered the bed making it difficult to raise the water level and divert water. Such quarrying is locally recognised to cause significant problems, but is an important source of revenue for the DDC. Much of the quarrying is believed to be illicit and there is no data on the quantities removed.

Irrigation management

The three sub-systems of Julphe operate continuously during the monsoon and winter seasons, but only the head (Julphe sub-system) operates during the spring season, as seepage losses from the smaller dry season flows would be too great to deliver sufficient water to the tail. Within these constraints distribution to the tertiary canals appears to be equitable, and the management arrangements have not changed in the last decade.

At lower levels of the system, management has been improved recently to formalise a rotational schedule for transplanting since the previous *ad hoc* arrangements had led to increasing conflict. During the crop growth stages much of the water to most fields in some areas comes from runoff and seepage from upper areas. Such reuse is reported to have declined because of construction of roads which divert drainage water and due to improvement of the canal networks which reduces seepage losses. Other areas are unable to tap drainage water and rely entirely on the canals system; in these places canals are operated to deliver water on a uniform basis according to area. Flows in canals depend mainly on availability of river water, which in turn is shaped by rainfall in the area (Figure 6). It can be seen that there is a close relationship between rainfall and canal flows[5] - with canal flows rising as it rains, rather than being curtailed due to less demand.

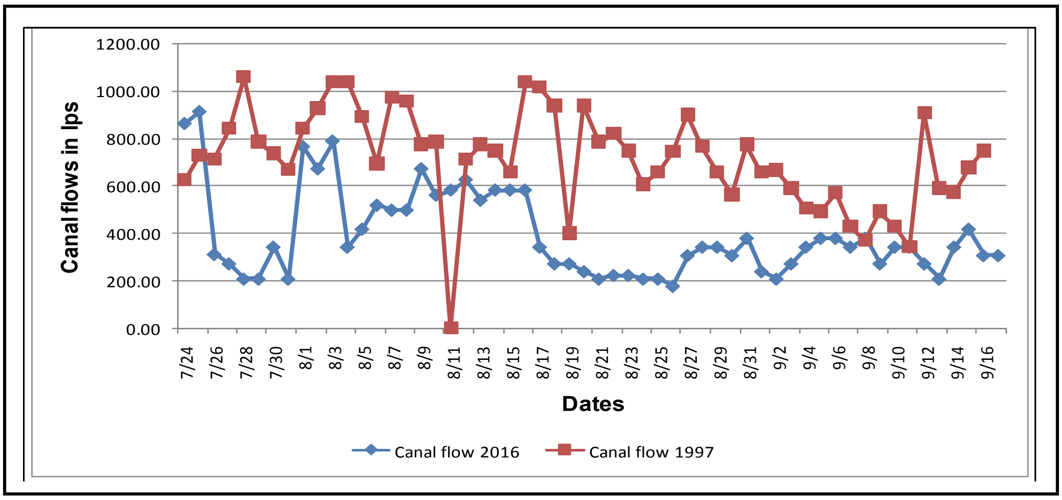


Source: Mott MacDonald (2017)

Figure 6: Rainfall and canal flow at head of Julphe

Further, there is a strong local perception that the available flows in canals are decreasing significantly. To verify this perception, the main canal flows were measured upstream of the main (or first) proportioning weir at the end of feeder canal and at several locations further downstream, which were compared with flows measured in 1997 at the same locations. Figure 7 present comparison of these flows at one such location.

5 Rapid decreases in the main canal flows from 9th to 15th July, 17-26th August, and 19-29th September are as a result of dry spells in those periods. Further, almost continuous rainfalls between 15th July and 2nd August resulted in larger canal flows in that period, but these also decreased rapidly due to flood damage at the intake



Source: Mott MacDonald (2017) and Parajuli (1999)

Figure 7: Canal flow at Julphe upstream of main proportioning weir

This figure suggests that over the season the flow is about half that recorded in 1997 – but this is consistent down the main canal suggesting that management remains strong, and that farmers have been able to cope with the deteriorating situation.

Local adaptation

The Girwari systems have been adapting to change over the past 50 years, largely because of the strong institutional arrangements supported by limited investment in infrastructure. However, they are increasingly water-stressed and riverbed quarries are making it more difficult to abstract the limited water from the river.

The cost of permanent solutions would make them uneconomic, but some improvements to infrastructure may be possible and necessary. Water rights are not uniform, and must be carefully considered when planning any changes to the system. Some of the local level adaptations are: (a) institutional strengthening both at the level of water shed and system, (b) infrastructural adjustments, (c) augmentation of water sources - partly due to trading of water rights, and partly due to installation of six tube wells (4 operating) each irrigating about 10-12 ha (d) accept higher level of risks by adapting deficit irrigation (e) adjusting cropping patterns and crop scheduling

BANGANGA RIVER: SINGHEGHAT IRRIGATION

The Banganga River originates in the Mahabharat mountains. At the foothill of this mountain range, about 6-7 km north of highway, the river discharges into a wide river valley in the Kapilvastu District where people maintain their livelihood through irrigated agriculture. The Singeghat Irrigation System (SIS) draws water from this river as it emerges from the hills, and irrigates both the right and left banks of the Banganga River.

Irrigation dates back centuries, with the areas under the present irrigation system divided into 11 *mauja*, each with an independent canal and water diversion weir at the

BangangaRiver. Irrigation in each *mauja* used to be managed by a water manager (*Badghar) who* was elected or selected each year and was in charge of local public work activities including irrigation and water management.

Each canal used to divert water from the Banganga River independently, but there were rules on how much water each could abstract. During times of water scarcity, the length of weir permitted in the river was proportional to the water right.All the diversion weirs were temporary, made of boulders and brushwood, and were frequently washed away by floods. Each *mauja* had to mobilize huge labour resources[6] for their repeated maintenance. Changing river morphology and declining availability of labour and brushwood made it increasingly difficult for farmers to build and maintain the weirs.

A joint committee of all 11 canals was formed in 1972 to manage the river water more systematically. This was later registered with the District Water Resource Committee (DWRC)[7]and lobbied the government to build a common permanent weir for all 11 canals. This was built in 1999-2006, and included a concrete weir and a new main canal 4.5 km long to feed the old branch canals via proportional dividers in accordance with their traditional water shares. Table-1 presents the distribution of water shares among the 11 canals, while Figure 8 presents location of common permanent intake (weir)

Table.1: Details of the Singeghat Irrigation System

Right bank canals						**Left bank canals.**				
Total water shares 4 Aana (16 paisa) that corresponds to 25% of the incoming water						Total water shares 12 Aana (48 paisa) that corresponds to 75% of the incoming water				
SN	Existing canals / mauja	Water shares (Paisa)	Irrigated areas (Bigha)	HH		SN	Existing canals / maujas	Water shares (paisa)	Irrigated areas (Bigha)	HH
1	Motipur	10	995	1565		1	Baijalpur	2	158	273
2	Madhuban	6	405	795		2	Tinaiya	2	290	490
						3	Pipara	6	418	1072
						4	Rajpur	3	136	275
						5	Bathanpur	3	320	415
						6	Gaieda	14	536	1050
						7	Jeetpur	2	202	547
						8	Jhanda	8	507	940
						9	Dugaha[8]	8	635	1085
	Total (Paisa)	16					Total (Paisa)	48		

Source: Mott MacDonald (2017)

6 Farmers report that on average about 120,000 person day of labour per annum was required for construction and repair of temporary diversion weirs for all 11 canals.

7 The SanghaSansthaDarta Ain came into existence in 2035 BS. WUAs could then be registered in the CDO office. After Water Resources Act 1992, District Water Resources Committee (DWRC) started registration of WUA to establish water rights. After approval of Irrigation Regulation under Water Resources Act of 1992, DOI also started to register WUAs

8 Including Siddhipur&Bungchi

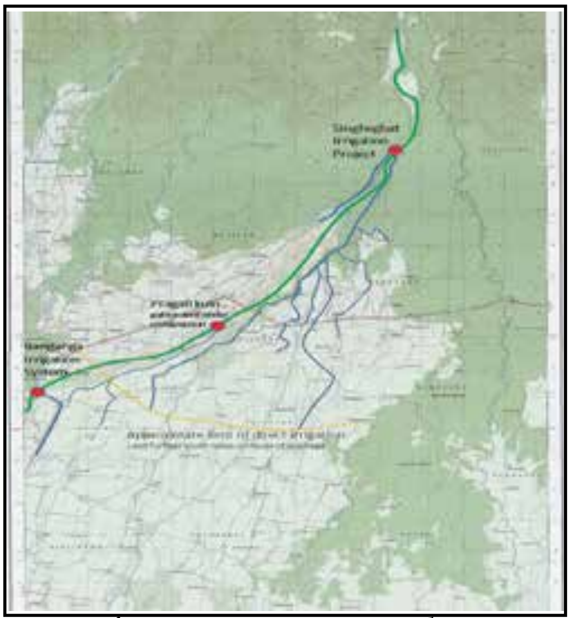
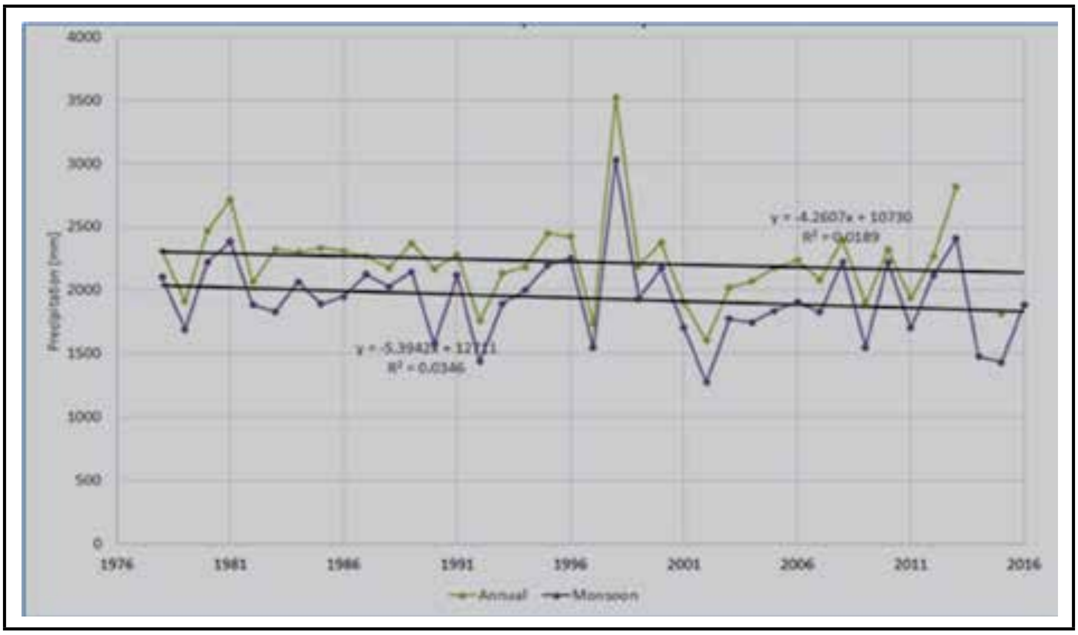


Figure 8: Location map of irrigation systems in the Banganga River (basin)

Climate Data

Rainfall is recorded at the nearby Patharkot station (Figure 9), which suggests little change compared to annual variation. Unlike Girwari, rainfall appears to be increasing since 2001, apart from very dry years in 2014 and 2015. However, the general trend suggests that the average annual rainfall is decreasing though these trends are not significant and likely to represent short term fluctuations rather than climate change.

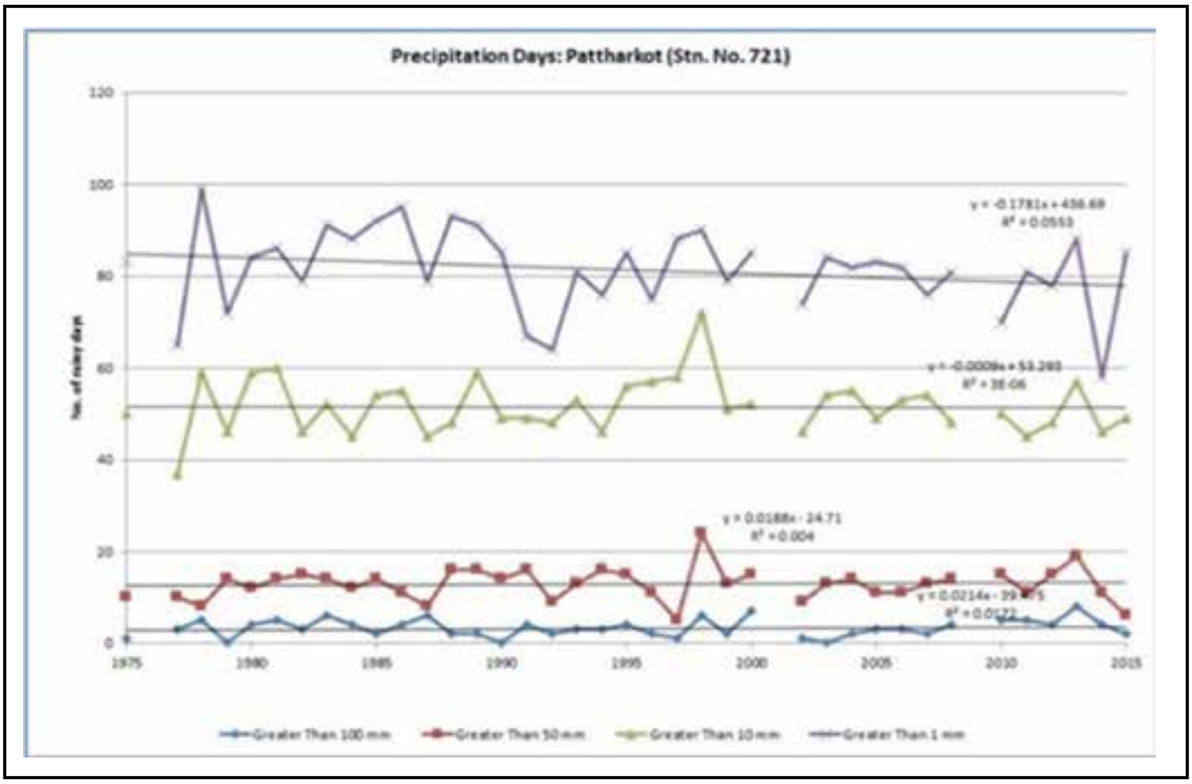


Source: DHM data

Figure 9: Rainfall at Patharkot

Farmers perceive a more severe decline than this data suggests, but this may reflect an overall shortage of water as the irrigation system only provides part of their needs. Further, farmer's perception on rainfall may also have been derived largely from their assessment of how well it meets agricultural needs for water (especially crop water requirements).

Although rainfall intensity can be expected to increase, and thus the proportion of total rainfall that is effective, there is little sign that this has happened so far (Figure 10). But, days with smaller rains (up to 50 mm) are certainly in a decreasing trend – though these may not be significant. This trend of decreasing small rains, which are more effective for crops, supports farmers' perceptions on rainfall change compared to decade ago.



Source: DHM Data

Figure 10: Rainfall Characteristics at Patharkot

System management

There is a general consensus that the availability of water in the river, especially during the dry season, has decreased significantly in recent past. The flow in the Banganga River was measured in May 2016 as 240 l/sec given in Table 2. However the natural flow, calculated according to the WECS/DHM method is 1.47 m^3/sec meaning that 1.23 m^3/sec is used in the upper catchment. Small changes in the upstream will thus have a profound impact.

Table 2: River Flows for Singheghat

Date	Location	Flow area (M2)	Adjusted velocity (m/sec)	Flow (lps)	Remarks
04 May 2016	Singeghat left main canal (head)	0.6	0.3	180	
04 May 2016	Singeghat right main canal (head)	0.35	0.18	60	
	Total water in the river (at Singeghat weir)			240	All incoming waters were diverted to the Singeghat canals
04 May 2016	Banganga River at highway bridge			0.00	River bed was dry
04 May 2016	Kaila Nadi (at highway)	0.416	0.402	165	
03 May 2016	Banganga River upstream of the Banganga barrage of the Jagdishpur reservoir	0.744		310	

Source: Mott MacDonald (2017)

Most of the flow for the Banganga project is contributed by the Kaila Nadi (165 l/sec) as there is much less agriculture in the catchment. The remainder of the discharge is from subsurface flow which re-emerges between the highway and the barrage, since all of the surface flow in the Banganga River is diverted by SIS. This is about 50% of the flow measured in the dry season in 1980 (Pradhan TMS, 1996).

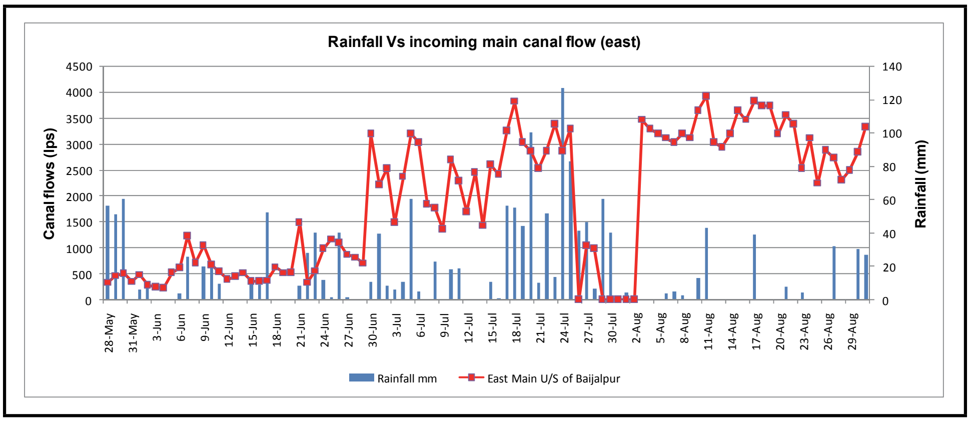
There is a consensus among the farmers that the availability of water is not adequate because:

There is less water in the source river. Less water is diverted as a result of the integration – water is now abstracted from one point at the head of the system, whereas previously there were multiple diversion points which meant that return flows downstream of the first weir were re-diverted by downstream weirs

Although there is less water available, the improved infrastructural control has improved both the reliability of water delivery and efficiency of system operation. It is also possible to manage very low flows in ways which would not have been possible before. This is a valuable lesson for coping with water shortage more widely.

There is, however, a negative impact on users further downstream, outside the formal (water rights) boundaries of the Singeghat canals who used to benefit from the uncontrolled flows which passed into and through the system.

There has not been any major change on irrigation management since construction of the weir. The new main committee is able to manage the main canal, and the long-established branch canal committees continue with their traditional arrangements. The flow in the canals is usually well below the demand for water, even allowing for rainfall. As a result, the flow in the canal increases with rainfall until the demand is met in mid-July (Figure 11).



Source: Mott MacDonald (2017)

Figure 11: Rainfall and canal flow at head of East main canal Julphe

However, the canals are not then actively managed and continue to respond more to rainfall than the need for irrigation. If the canals were closed when water is no longer needed for irrigation, this would enable water to be made available for others and it would also mean that flood flows could be excluded from the canal. In the event, a major flood in late July caused considerable damage and sediment entry into the canals.

Floods

There is a general perception that the instantaneous peak floods in these rivers are increasing. The 2016 July flood overtopped the abutment of the Singeghat weir although without causing significant damage. On the basis of peak water level, the flood flow is estimated to be about 675m^3/sec, as compared to a 1:50 year design flood of 564m^3/sec based on the 1990 irrigation design manual. It was a short duration flood, with the peak subsiding after about one hour but a considerable volume of gravel was deposited in the canal head reach.

Source: Mott MacDonald (2017)

Figure 12: Flood damage of Signheghat weir by floods

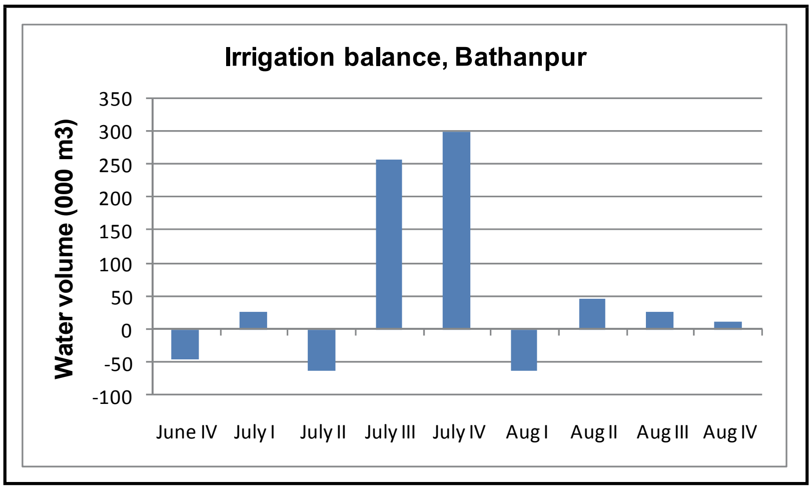
The weir and canal system thus withstood a flood of 20% more than the design flood, and it should also be noted that the abutments and canal head regulator appear to have been built significantly lower than the required level. A flood of over 470m^3/sec (85% of the actual design flood) would exceed the safe design level for the head regulator with 50cm freeboard.

As the flood overtopped the structure it was not possible to operate the gates at the peak of the flood, but considerable damage would have been avoided if the canal gates had been closed as the flood was rising.This incident highlights the need to ensure that designs are carefully detailed with adequate safety factors / freeboard, and to ensure that there are appropriate operating rules and that the structure is operable under peak design conditions. Automation or electrification of such small structures is unlikely to be feasible in the short to medium term, but operators need to have a good understanding of the operating rules and be able to apply them.

Local adaptation

The Singeghat systems have also been adapting to change over the past 50 years, with water availability dropping to much less than 50% of the natural flow due to upstream water use. This response has been achieved through a combination of strong institutional arrangements supported by external investments in infrastructure. The provision of a weir has improved acquisition of water from the river even during low flows, minimised imergency maintenance need, and protected it from the impact of riverbed quarries. However, downstream systems are still vulnerable and this is being addressed by construction of a new gabion weir

Some of the local level adaptations are: (a) merging of intakes and improvement in infrastructure, (b) institutional strengthening both at all levels (c) augmentation of water sources through installation of tube wells (c) accept higher level of risks by adapting deficit irrigation (Figure 13) (e) adjusting cropping patterns and crop scheduling



Source: Mott MacDonald (2017)

Figure 13: Irrigation balance, Bathanpur Branch, Singeghat Irrigation System

SUMMARY AND CONCLUSIONS

This paper suggests that climate change does have some influences on irrigation system and its management. Some of the influences are: dry season flows appear to have reduced; sediment transport has changed; and there is evidence of increasing peak flood flows in rivers. This study further suggests that irrigation system with strong institutions and adequate infrastructural control are relatively more resilient to climate change.

But, climate change is not the only aspect for changes. Other important aspects that are likely to be responsible for such changes are: increasing water uses upstream, degradation of watershed, mining of riverbed materials, and declining interests on agriculture due to changing socio-economic situations.

Existing knowledge on climate change and its impact on the small and medium irrigation systems is still inadequate. What is already known is that by 2070 the total economic loss associated with climate change will be equivalent to around 0.8% of current annual GDP (IDS-Nepal, PAC and GCAP, 2014), if no action is taken for developing climate resilient irrigated agriculture. For this reason, climate change and its impact on irrigation now needs due considerations. Following are some of the recommendations for developing climate resilient irrigation systems resilient

1. Provide more focus to enhance irrigation supply in the area through infrastructural intervention. Some of the likely intervention are:
   - Development of tube wells in surface irrigation command
   - Development of buffer stock for augmenting the supply
   - Rainwater harvesting where appropriate
   - Inter-basin transfer of water
2. Minimize irrigation demands through:
   - Improvement on “On farm water management”
   - Mechanization of irrigated agriculture
   - Land levelling
3. Focus should be directed towards management improvement through:
   - Establishment of River Basin Organization (RBO) for water accounting, water regulation, monitoring, and providing techno-economic clearance of water sector interventions
   - River basin based management of water resources through federated WUA under RBO
   - Promote Integrated Water Resources Management (IWRM)
4. Revisit hydrological design parameters in designing irrigation systems through:
   - Assessment of return periods
   - Assessment of flood flows, low flows, and available flows

- Estimation of effective rainfall and crop water requirements
- Assessment of water ways

5. Initiate innovative design for building climate resilient major hydraulic structures. These may include infrastructural components like design of safety embankment as fuse plug, and so on.
6. Initiate design of irrigation system with appropriate technologies. These may include (a) focus to dry season irrigation (b) lift irrigation through several means (c) piped distribution system (d) multiple uses irrigation system etc
7. Deliver services through following three channels for development of climate resilient irrigation system

Farmer level	For enhancing on farm water management and uses of water saving technologies
Community level	For community level management improvement, water augmentation, demand management, initiating basin approach in water management through federated WUA
National level	Policy and program support for (a) institutional capacity building on hydro-met data management, (b) monitoring of water uses at community level, (c) rehabilitation of water systems in a cluster within a basin / sub-basin (d) establishment of RBO (e) promotion of IWRM (f) promotion of water saving technologies (g) research & capacity building

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2.2 CLIMATIC TRENDS WITH REFERENCE TO SMALL IRRIGATION MANAGEMENT IN NEPAL

KESHAV P. SHARMA[1]

INTRODUCTION

Most areas of the southward flowing rivers originating from the Mahabharat range lie in the Siwaliks,the most fragile hills in Nepal. These rivers and their tributaries are responsible to transport and deposit huge amount of sediment along the river channels. The river channels are meandering with shifts following most of the extreme flood events. The Siwaliks are also the regions of high rainfall intensity causing flash floods. Most of the rivers, passing through Siwaliks, are the major source of small and medium irrigation in the Terai.

Irrigation water sources were investigated at five locations in four Terai/inner Terai districts (Kapilbastu, Nawalparasi, Sindhuli and Jhapa) and one in a middle mountain district (Nuwakot). Eight basins, which serve as water sources for the small and medium-scale irrigation systems, were selected in five locations in five districts. As shown in Figure 1, considered river basins were the Banganga, Girwari, Likhu, Kamala and Biring. Among the selected watersheds, the Gadyauli is a sub-catchment of the Kamala basin. Similarly, the Tanting, Biring and Kali combine to form the Biring river. Except the Likhu, all river basins considered in this study originate in the Mahabharat range passing through the Siwalik region of Nepal.

None of the basins has hydrometric facilities. Figure 1 presents the meteorological stations in and around the study area. As illustrated in the figure, only one meteorological station (Sindhulimadi), which lies in the Kamala basin, falls within the

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study basins. Stations with relatively long-term data, close to the catchments under the study, were considered for climatic assessments. As illustrated in Figure 2, the stations included Ilam, Soktim and Gaida around the Tanting/Biring/Kali catchment; Kakani and Nuwakot near the Likhu catchment; and Rampur, Dumkauli and Simari near the Girwari catchment. Because of higher data quality, the synoptic stations located at Okhaldhunga, Kathmandu, Simara and Janakur were studied in greater details for climatic trend analysis.

The Girwari and Banganga catchments were considered for detail studies on the irrigation resilience. The aero-synoptic station located at the Bhairahawa Airport was considered as a reference station that could represent the climatic variations in the areas where the Girwari and Banganga irrigated the Terai farms. Studies in these areas were further supplemented by the data recorded at Taulihawa, Butwal, Lumbini and the Agriculture Farm located in Bhairahawa. Precipitation and temperature were also monitored by the project during 2015-16 at Singeghat in the Banganga watershed and Girwari in the Girwari watershed.

In the absence of hydrometric data in the basins under study, regional hydrology was used to estimate the flows (WECS/DHM, 1990; Sharma and Adhikari, 2004). Additionally, the flows at all the studied locations were assessed applying float measurement.

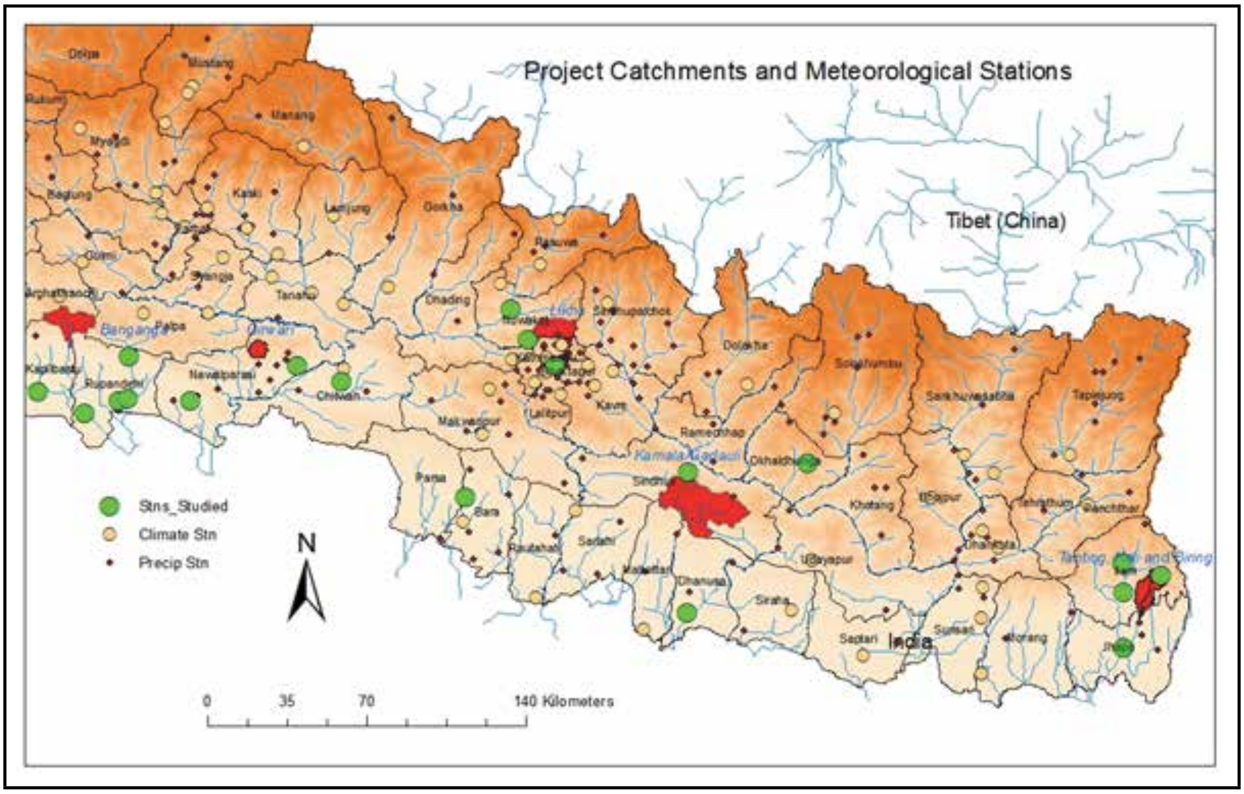

Figure 1. Locations of the study catchments and Meteorological Stations in and around the project area.

THE BASINS

Except the Likhu watershed, all the basins selected for the studies lie mainly in Siwalik Zone with rivers originating from the Mahabharat. The Likhu river, originating from the middle mountain region, provides irrigation in the middle mountain valley, whereas all the other rivers irrigate the Terai or the inner Terai. Figure 1 presents the location of the watersheds and Figure 2 and Table 1illustrate the nature of basin characteristics. These basin characteristics were used for the estimation of stream flows using regional methodologies.

Banganga Watershed: The Bangaga river basin, a lifeline to the farming communities in the Kapilbastu district, has most of its headwater areas in the Arghakhanchi district and some parts in the Palpa district. Land-use patterns are primarily dominated by mixed forest (63%). Rest of the catchment is covered by agriculture land (28%), grazing land (5%) and shrub (4%).

Girwari Watershed: The Girwari watershed with circular shape in its headwater area and elongated shape downstream contributes to the Narayani River. The basin is dominated by mixed forest (54%). Rest of the basin is covered by shrub (35%) agriculture land (10%) and grazing land (3%).

Gadyauli: The Gadyauli watershed is drained by two similar sized watersheds: Thakle (13 km^2) and Gadyauli (12 km^2). The Thakle river provides most of its water to irrigate Bardeutar. The Gadyauli provides water to Khulitar, a relatively flat land on the other side of the river. Most part of the watershed is covered by mixed forest. River sides are extensively cultivated in the lower side of the valley. Intake site is located at Hatti Daha, downstream of the Gadyauli-Thakle confluence.

Kamala River Basin: Major tributary (the Gwang Khola) of the Kamala originates from the Mahabharat range along Sindhuligarhi-Mahadev danda in the Sindhuli District at an elevation of 1,898 m. The Kamala originates in the Siwaliks merging into the Gwang Khola at Maithan, from where it is called Kamala until it merges into the Bagmati River in India. The headwater of the river, including the project area, lies in the Sindhuli district. The irrigation intake is located close to a bridge under construction joining Sindhuli to the eastern part of Nepal.

LikhuKhola Basin: The Likhu originates from the Nuwakot-Sindhupalchwk border at Borlang and Mamache Danda. The river receives flows from the Chhahare Khola, Mahadev Khola, Chinnaya Khola, Dhee Khola, Ghyampe Khola and Khahare Khola. The river flows almost parallel to the Tadi before it merges with the Tadi at Dhikure Bazar.

Biring Khola: The Biring Khola gets integrated with the Tanting river system both originating from the Mahabharat range at an elevation of about 1,800 m. The Kali Khola that supplements the Biring Khola originates from the Siwaliks. Since the river system lies mainly in the Siwaliks, flood flows are usually accompanied with huge sediment transport.

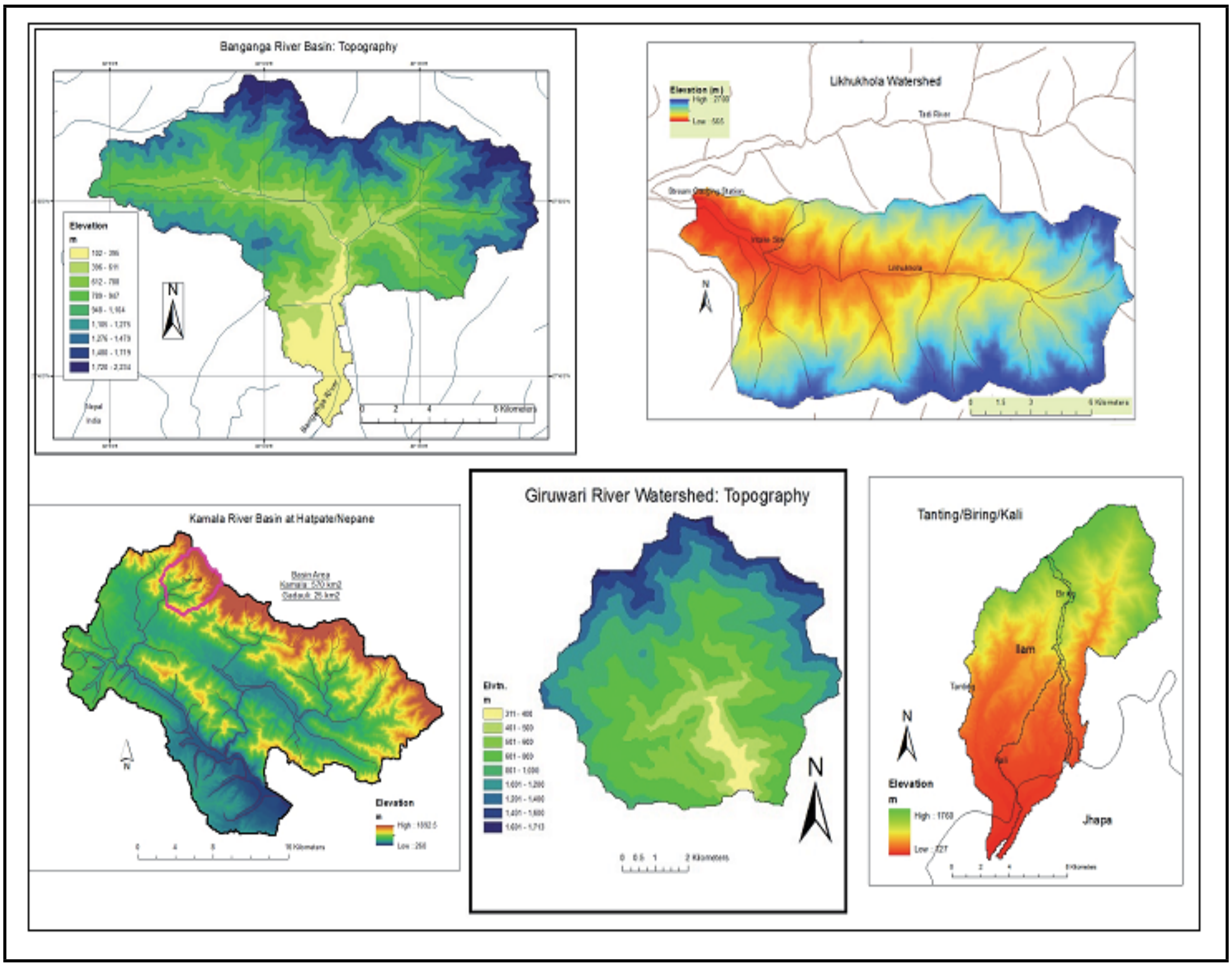

Figure 2. Watersheds of the small and medium irrigation schemes.

Table 1. Basic basin data

River Basin	Banganga	Girwari	Kamala	Likhu	Gadyauli	Biring
Basin Area (km^2)	187 at Singheghat	52 at Jhyalbas	570 at Nepane	146 at Thansing	25 at Bardeutar	61 at Arjundhara
Average Elevation (m)	977	862	698	1469	988	1070
Maximum Elevation (m)	2230	1720	1900	2710	1710	1760
Minimum Elevation (m)	162	266	260	616	526	214
Annual Precipitation (mm)	2200	2200	2200	2200	2200	2200
Monsoon Precipitation (mm)	1760	1760	1760	1760	1760	1760
Measured flow (L/s)	1000* on 4 May'16	100 on 30 Apr'16	12,000 on 23 Sept'15	7,00 on 27 Sept'15	28,000 on 24 Sept,15	600 on 29 Jan'16
Estimated natural flow (L/s)	2000	500	15,000	8,000	30,000	800

**The Banganga flow, presented here, was measured about 3 km u/s of Singheghat.*

CLIMATIC CHANGES IN AND AROUND PROJECT AREAS

Besides monsoon effectiveness, arrival, advancement and withdrawal of monsoon are the vital components of agriculture in relation to irrigation management. Isochrones of the normal onset date of monsoons, as reviewed by Tyagi et al (2011) indicate that the monsoon delay has been realized by five days in Nepal compared to the period until 1950s. Onset and withdrawal of mosoons have also been monitored in Nepal from 1940s. The records maintained by the Department of Hydrology and Meteorology (DHM) supports the finding of Tyagi et al (2011). Besides, the records indicate that the monsoon duration in Nepal has been marginally increasing with time (Sharma, 2010).

Recent patterns of climatic changes in Nepal indicate the rate of average warming ofabout 0.3°C/decade with higher increasing rate of maximum temperature (Sharma, 2010; DHM, 2015). The patterns of temperature change, however, differ from one physiographic region to another; the rates being lower in the Terai.There is a limited database in Nepal for detail study of long-term precipitation pattern. The available studies indicate diverse results depending on the considered areas and time period (McSweeney et al., n.d; Baidya et al., 2008). All the studies, however, indicate insignificant long-term trends of annual as well as monsoon precipitation (Sharma, 2010).

Management of irrigation systems should consider recurrent droughts. Winter and spring precipitation, although small in amount, is important for winter and spring crops. Precipitation data over Nepal indicate that any or all eight months of a year from December to April can be totally precipitation free. Typical examples of long-period dry spells were observed in 1998-1999, 2005-2006 and 2008-2009. Dry pre-monsoon period and delayed monsoon in 2009 resulted in the rice production below eleven percent of normal and orange production in the Sindhuli district fell by more than fifty percent (Sharma, 2010).

Climatic Scenarios

IPCC (2013) has reviewed the results of future scenarios and climate models, which consistently show warming trends. The projected increase in annual temperature, however, varies between scenarios and models, ranging from 2 to 5 ^{0}C of annual mean temperature increase by the end of the Century.

Impact of climatic changes on the monsoons, the most prominent large-scale process, is one of the most studied topic in atmospheric sciences. One of the studies indicate that Nepal may face reduced convective precipitation in Terai during summer (PU, 2009). Since the project areas considered in this study lie in a transitional zone, changing from reduced convective activities and enhanced conductivity activities, significant changes are less likely. Notwithstanding, delayed monsoon arrivals may cause significant impacts. The IPCC (2014) observation of weakened monsoon but intensified precipitation events needs careful considerations (Rupa Kumar, 2002; CDKN, 2014; GEB, 2014).

Climatic Trends in Project Areas

Figure 3 presents a typical example of temperature trends in the south-west Terai of Nepal. Table 2 presents the summary of temperature trends in the vicinity of study areas.

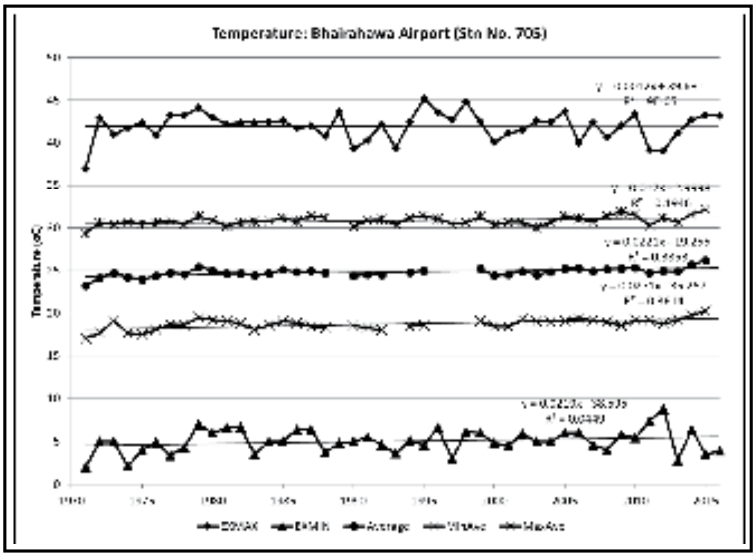

Figure 3. Temperature trends in Bhairahawa

.Table 2. Temperature trends at selected DHM stations

			Maximum		Minimum		Average
		Period	Average	Extreme	Average	Extreme	Average
1030	Kathmandu Airport	1968-2014	**0.069**	0.057	**0.04**	0.051	0.055
1206	Okhaldhunga	1962-2014	**0.094**	**0.076**	-0.01	-0.014	**0.042**
0909	Simara	1975-2014	0.009	0.015	**0.027**	-0.013	0.018
1111	Janakpur	1971-2014	0.003	-0.011	0.03	-0.018	0.015
0705	Bhairahawa	1975-2015	0.017	0.0012	**0.027**	0.022	**0.022**
	Average		0.038	0.028	0.023	0.006	0.030

Bold letters indicate statistically significant trends.

Table 2 shows that the temperature trends indicate higher rate of increase in maximum temperature in the mountainous areas and higher rate of increase in minimum temperature in the Terai. Since the project areas lie in the transition zone the average warming rate of 0.03°C per year can be considered applicable in the study areas.

Figure 4 and Figure 5 present typical examples of precipitation trends in the south-west Terai of Nepal. Table 3 presents the summary of precipitation trends in the vicinity of study areas.

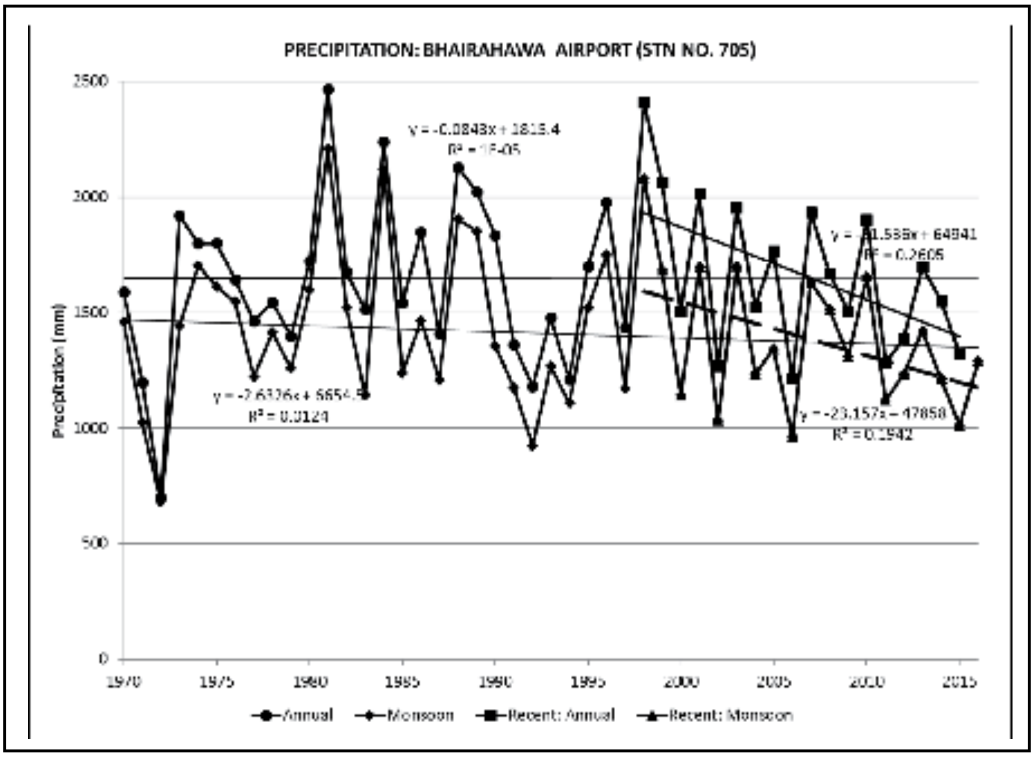

Figure 4. Precipitation trends in Bhairahawa.

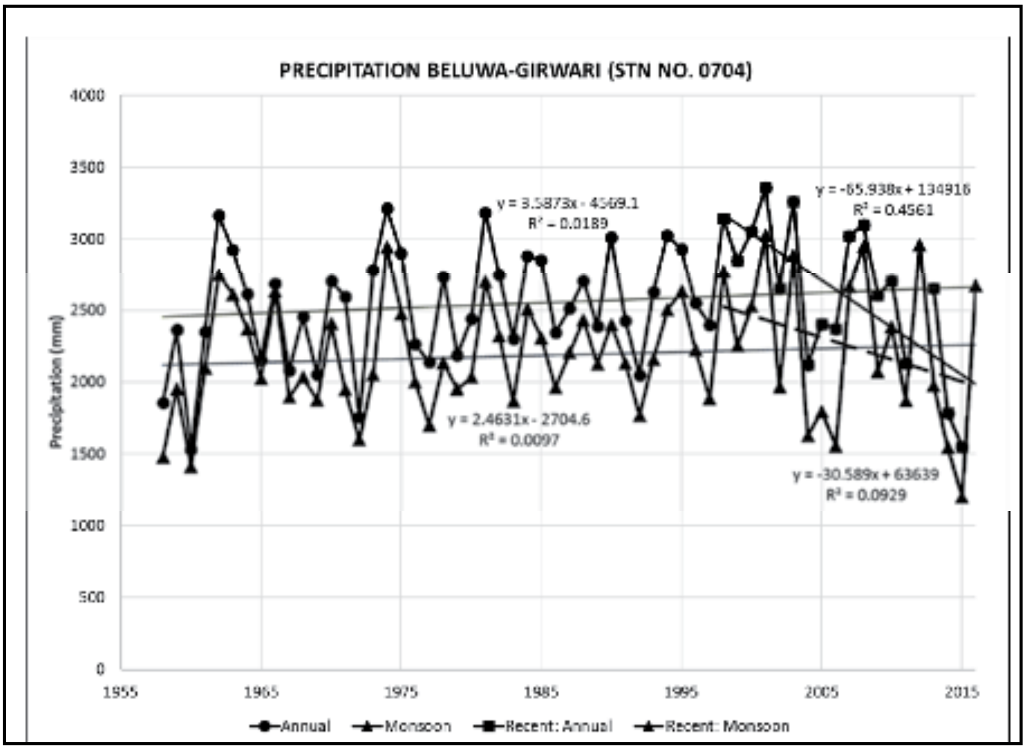

Figure 5: Precipitation trends in Beluwa-Girwari

Table 3. Precipitation trends at selected DHM stations.

Stn. No.	Location	Period	Annual	Monsoon	Daily Extreme	Dry Season
			mm/year	mm/year	mm/year	mm/year
0704	Beluwa-Girwari	1958-2016	3.587	2.463	-0.076	0.654
0705	Bhairahawa	1970-2016	-0.084	-2.632	0.017	1.125
0909	Simara	1966-2014	-2.370	-1.390	-1.110	-1.130
1005	Dhading	1956-2014	-16.700	-12.900	-1.000	-0.280
1007	Kakani	1962-2014	2.300	1.900	0.029	0.890
1030	Kathmandu Airport	1968-2015	4.420	3.730	0.230	0.590
1057	Pansayakhola	1973-2014	-4.640	-7.410	-0.170	1.350
1108	Bahuntilpung	1958-2014	0.370	-0.930	-1.730	0.590
1110	Tulsi	1956-2014	-1.480	-1.260	-0.630	0.126
1111	Janakpur	1969-2014	5.550	4.250	1.740	0.220
1117	Hariharpur	1978-2014	2.400	1.000	-1.190	0.160
1115	Nepalthok	1948-2014	-0.160	-2.070	-0.830	-0.340
1206	Okhaldhunga	1962-2014	2.850	0.040	0.330	-0.150
	Average		**-0.304**	**-1.170**	**-0.338**	**0.293**

Figure 4 and Figure 5 indicate a similar pattern of precipitation trends in Girwari and Bhairahawa. There were no significant trends in long-term precipitation. Records from 1998 onwards, however, showed marked decrease in annual as well as monsoon precipitation.

The assessment of daily precipitation recorded at Bhairahawa indicated significant decrease in the days of light rain (>1 mm and >10 mm), whereas there were no significant trends in extreme daily precipitation exceeding 100 mm. Seven-day and fifteen-day precipitation during monsoon in Bhairahawa was found to be decreasing in all the cases of maximum, minimum and average values; but the rate of decreases were not statistically significant.

Climatic Extremes

Floods and droughts are frequent phenomenon in the project areas. Inundation, sedimentation (deposition, scouring) and riverbank cutting are the major hazards related to floods, whereas extensive damages in food production is a major hazard during drought conditions. Estimates of production loss during a drought-like situation in Banganga area was estimated as high as 70% in 2001 (Gautam, Gautam&Poudel, 2007). The authors also report the cold wave-related hazards to winter crops.

Impacts of a severe flood that occurred on 31 August 2015 were visible during the field survey on 23 September 2015 in the Kamala. The flood marks were about half a metre on trees along the banks. The event causing severe damage in the Kamala basin is one of the worst disasters in the area. The rainstorm was widespread with records ranging from 91.8 mm to 211 mm (329 mm in two days in Sindhulimadi).

Besides the 1993 flood, the locals reported the severe flood events of 1982 and 1984. Meteorological records maintained by DHM show that Bahuntilpung, about 35 km east of Sindhuligadhi, received 355 mm precipitation on 17 September 1984.

The Biring Khola in Jhapa recorded historical flood in 2015, which was the severest flood on the Biring as reported by the local inhabitants. We assessed precipitation records available in the headwater areas of the watershed. Precipitation frequency analysis indicated that the rainstorm was close to 100-year precipitation. Short-duration precipitation intensity exceeded 60 mm/hour (Figure 6).

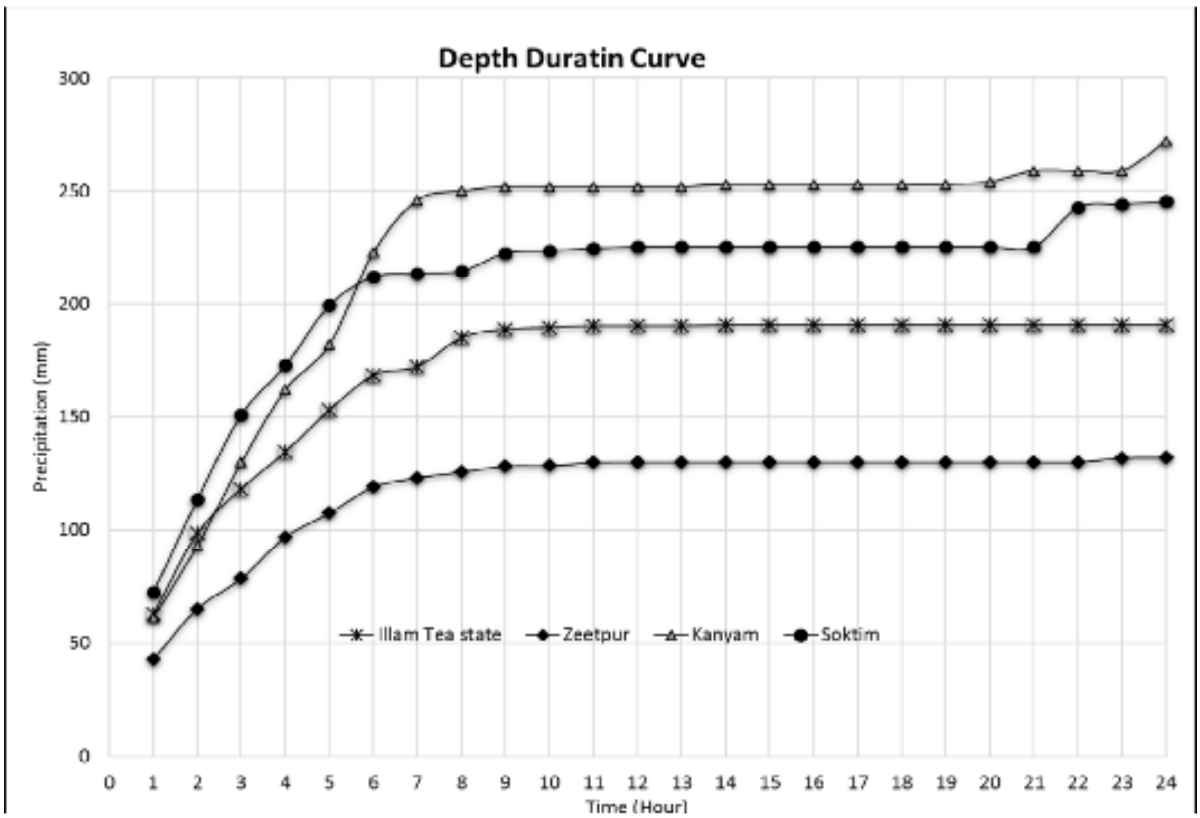

Figure 6: Comparison of precipitation depth-duration curves among four DHM stations in the headwater areas of the Biring catchment (Source: DHM online data).

The year 2016 was a drought as well as flood year. Winter and spring were dry with acute water shortage in irrigation schemes. The recorded precipitation at Bhairahawa indicates only one significant event exceeding twenty millimeters in March 2016. There were only two events below 5 mm and three events below 1 mm from October 2015 to April 2016. On the other hand, the year 2016 was also a year of severe rainstorm. Extreme precipitation recorded with rain gauges installed by the project are compared to the DHM stations of the surrounding areas in Table 4. The table indicates widespread heavy precipitation in the area during the 19-28 July 2016 with daily amount as high as 411 mm.

Table 4. Extreme precipitation (mm) in Girwari and Singheghat compared with the closest DHM stations.

Dates	Bhairahawa (DHM Stn 0705)	Girwari	Singheghat	Beluwa (DHM Stn0704)	Patharkot (DHM Stn0721)
19-Jul-16	29.8	71.0	44.0	30.2	36.2
20-Jul-16	33.3	0.0	100.2	42.2	0.0
21-Jul-16	6.0	22.8	9.8	150.2	4.3
22-Jul-16	123.1	122.0	51.6	225.3	72.0
23-Jul-16	102.4	365.0	13.6	67.5	8.2
24-Jul-16	1.9	124.4	127.0	13.5	22.0
25-Jul-16	51.3	11.0	83.0	83.5	25.3
26-Jul-16	72.2	170.2	411.0	82.8	260.0
27-Jul-16	9.0	126.6	46.2	18.7	56.7
28-Jul-16	37.4	0.0	6.4	0.0	7.4

The flood recorded at Shingeghat on the Bangangariver on 26 July 2016 was a historical one with estimate at 619 m^3/s (calculations illustrated in the following box).

Discharge Estimation on the Banganga at Singheghat: Broad Crested Weir [$Q = CLH^{3/2}$]

$C = (2/3)^{3/2}(g)^{1/2}$; $G = 9.806$ m/s; $C = 1.704\ m^{1/2}\ S^{-1}$; $L = 58$ m; $H = 3.4$ m

$Q = 1.704*58*3.4^{3/2} =$ **619 m^3/s.**

CONCLUSIONS AND RECOMMENDATIONS

Climatic changes that are likely to cause impacts on the monsoons in the region are the major concerns in the effectiveness of irrigation systems. Because of the better access of communities but limited potentials, smaller water sources will be experiencing larger impacts as a result of significant changes in temperature and monsoon patterns. Changes in monsoon patterns signified by the increases of extreme events but decreasing tendencies of moderate rainfall days in the last decades are likely to be a major concern in irrigation management. The major findings of the study can be summarized as:

- Expected average annual warming rate in the project area at 0.3°C/decade in the vicinity of project areas confirmed the patterns of global warming with increasing temperature.

- Increase of average maximum temperature was higher than minimum temperature in mountainous areas.

- Impacts of cold waves were observed in the Terai areas controlling the increasing rate of minimum temperature. Although insignificant, decreasing trends of extreme minimum temperature are observed in some of the Terai records, whereas the Terai records indicated higher increasing rate of average minimum temperature compared to maximum temperature.

- Use of water for irrigation is higher in small watersheds with higher impacts on the hydrology and water availability.
- No significant long-term change in precipitation is anticipated; however, significant changes in precipitation patterns were realized in most of the cases. Observed decrease in precipitation was more pronounced in the last two decades.
- Number of days with light precipitation, were found to be decreasing and dry periods increasing leading to the increase in irrigation demands.
- Irrigation systems need to consider the observed as well as projected delayed monsoon onset, which are often associated with ENSO events.
- Increase in irrigation water demand is expected in both the scenarios of rise in temperature and reduction in precipitation. Since temperature rise as well as decrease in number of precipitation days have been found in all the case studies, irrigation facilities need to be enhanced.

Major challenges regarding climatic changes and impact assessments are the wide range of temporal and spatial uncertainties in precipitation patterns. Assessments were primarily based on first hand observations and limited measurements as the studied catchments were neither gauged in terms of stream-flows nor in terms of satisfactory precipitation network. There is a need to establish well-equipped monitoring systems in small watersheds. Proper modeling of such basins can provide means to reduce uncertainties in understanding the nature of climate change impacts on water resources.

The study areas have experienced extreme floods as indicated by recent severe floods and the floods observed in recent past. Detail assessment of such extreme events needs priority for monitoring weather induced hazards that could also be linked with changes in monsoonal pattern. Similarly, drought conditions, which are critical for the management of irrigation, need priority in research programs. Monitoring changes in groundwater levels is another important area of research in the Terai areas as groundwater has high potential in supplementing surface water irrigation.

ACKNOWLEDGEMENTS

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2.3 WATER MEASUREMENT AND IMPLICATIONS ON WATER AVAILABILITY AND WATER DISTRIBUTION AND IMPACT OF CLIMATE CHANGE ON IRRIGATION MANAGEMENT: EXAMPLES OF SRINGEGHAT, KAPILBASTU AND JULFETAR IRRIGATIONN SYSTEMS, NAWALPARASI

RAJENDRA BIR JOSHI[1]

JULPHE IRRIGATION SYSTEM

Introduction

The Julphe Irrigation System (JIS) falls under the Deurali VDC and Madhyabindu Municipality, Nawalparasi District. It is located at the foothills of the Mahabharat mountain range, about 6 to 10 km north of Chormara along the Narayanghat-Butwal Highway and about 40 km west of Narayanghat town. The system serves about 200 ha and is divided into three sub-systems namely Julphe, Kolia and Basantapur located at the head, middle and tail of the command area.

Giruwari River is the main source of water for the system. It is a tributary of the Narayani River and flows from north to south. There are five other irrigation systems in this river namely Jhyalbas Kulo, Tribhuvantar Kulo, Bari Kulo, Goyari Kulo and Aakase Kulo. All the irrigation systems have temporary weirs. The first three irrigation systems on the left bank are located upstream of the Julphe Irrigation System.

Water Availability

Flow measurements undertaken during this study indicated an average low flow of about 90 lps. (Table-1)

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Table 1: Flow measurements

Date	Location	Flow area (m^2)	Adjusted velocity (m/s)	River flow (lps)
30 April2016	Jhyalbas	0.300	0.24	72.00
30 April 2016	Jhyalbas	0.143	0.72	102.00
01 May 2016	JIS, Intake site	0.216	0.45	97.00
			Average	90.30

Farmers reported that water in the river especially during the dry season, had decreased significantly. So it is difficult to allow water flowing in the canal up to March. They are diverting river water in one canal at a time on a water sharing basis. This method of sharing water is locally called Kulo-palo.

Irrigation Management

The river water at the upper Girwari River is shared by 6 canals.

- Jhyalbas ko Kulo
- Tribhuvantar ko Kulo or Adarsha Nahar
- Bari Kulo
- Guheri Kulo
- Juphe Kulo
- Aakase Kulo

Sharing of water of Girwari River by these canals remained the same in the past and present also. Water users have their federated WUA named as "Girwari Irrigation Coordination Committee". This committee manages sharing of river water by canals. For doing so, all the river water is diverted to one canal for a specified duration. Table-2 shows the schedule for sharing river water for a period 2072/11/19 to 2073/2/8.

Table 2: Schedule for river water sharing

Jhyalbas ko Kulo	12 hours
Tribhuvantar ko Kulo or Adarsha Nahar	84 hours
Bari Kulo	44 hours
Guheri Kulo	7 hours
Juphe Kulo	66 hours
Total	213 hours

Each of the above canals gets water after every 213 hours rotation.

Water Distribution

The JIS constitutes of three subsystems, namely Julphe, Kolia and Basantapur in head, middle and tail sections. All the subsystems operate continuously during the monsoon and winter. Only Julphe subsystem operates in spring season, this is because of low flow in river. If the available flow is taken to Kolia and Basantapur subsystems, most of water flow seeps through their canal bed.

With the declining availability of canal water, the Basantapur WUA installed 6 deep tube wells in 2011, of which 4 are operating. These tube wells are about 80m deep; one pump can irrigate about 10 to 12 ha of land. About 40 ha of Basantapur command area receives supplementary irrigation through these tube wells.

SRINGEGHAT IRRIGATION SYSTEM, KAPILBASTU

Introduction

The Sringeghat Irrigation System (SIS) lies in the Kapilvastu District. The system covers Motipur, Banganga, Kopuwa and Gajada villages under Banganga Municipality. The system has a permanent weir with two side intakes (East and West) at Banganga River. The headwork is located at the foot-hills of the Mahabharat maountain range, about 7 km north from East-West Highway. The climate is sub-tropical in this area.

With initiation of DoI, the construction of infrastructural development works of the system was completed in 2006. Since then the system is functioning as an integrated system of 11 existing canals.

Water availability

The dry season flows at different locations in canals and Banganga River were measured during the field study. This is tabulated in Table-3

Table 3: Flow measurements in canal and river, SIS

Date	Location	Flow area (m^2)	Adjusted velocity	Flow (lps)	Remarks
04 May 2016	Sringeghat left main canal (head end)	(3x0.2) = 0.6	0.3	180	
04 May 2016	Sringeghat right main canal (head end)	(1.6x0.22) = 0.35	0.18	63	Rounded
	Total incoming water in the river at Sringeghat			243	All water diverted to the Sringeghat canals
04 May 2016	Banganga River at highway			0	No flow in river
04 May 2016	Kaila Nadi at highway	0.416	.402	167	Rounded
03 May 2016	Banganga River upstream of Banganga Weir	0.744		310	At intake of Banganga I.S.

Table-3 suggests that the present dry season flow (310 lps) of the Banganga River at Banganga I.S. intake is the major contribution of Kaila River (167 lps).

Flood and flooding

25th July night 2016, flood overtopped the abutment of the SIS diversion weir and washed away most of the steel capping placed along the weir portion. The steel capping work was just completed. The rainfall recorded was 411 mm on that day. It seems the 2016 July flood was larger than the design flood. Observation of flow depth of 4 m over 53m crest length estimates about 720 m^3/s flood flow. This was reported to be the largest flood in recent memory.

Irrigation Management

The present irrigation system is an integrated system of 11 existing canals. The system was integrated through the construction of diversion weir and feeder canal in 2006. The development of infrastructure improved both the reliability of water delivery and efficiency of system operation. Also, even the low flows can now be successfully diverted into the system. and used efficiently.

Irrigation starts from the head to tail end of each sub branch canal. The Badgar (operator) diverts the incoming water into one or two sub branch canals, and irrigates therein from head to tail. This process continues until all lands of branch canal get irrigation. Thereafter the flow is diverted to other canals and the process continues. Depending on the canal flows, one or more than one canals are operated at a time. In general condition, each parcel of land gets irrigation in an interval of 10 days for paddy cultivation.

Water Distribution

The river water is divided in 64 paisa-pani (shares), 16 paisa-pani (25%) for west system and 48 paisa-pani (75%) for east system. This share of water is distributed within east and west systems as per their established water shares. For an example, Laugai Kulo in west system owns 1.5 paisa-pani (1.5 units of water share means 9.375% of incoming water in the west main canal) for 47 ha.

Because of declining availability of canal water at the tail end of SIS, the farmers in the Jhanda area installed 5 deep tube wells. Now 4 wells are operating. Each pump can irrigate about 25 ha of land. The farmers are using these pumps for seed bed preparation for paddy, wheat, mustard and maize crops.

Water Dispute: A case of Pragati Kulo and Charmauja Kulo

Pragati Kulo and Charmauja Kulo are located on the left bank of the Banganga River, downstream of the East-West Highway-Bridge. The intake of Pragati Kulo is located about 4.4 km upstream of the Banganga Irrigation System Intake Weir. The intakes of these two systems are just 2 km apart. Unlike Charmauja Kulo, the Pragati Kulo is still functioning but every year farmers have to shift its intake due to riverbed degradation. These two Kulos (canals) are as old as the 11 traditional canals of the Sringeghat Irrigation System. The farmers of these two canals also have been approaching the government for modernizing their system since many years. The DoI has approved the Pragati Charmauja Irrigation Project in 2016. The Kapilvastu Irrigation Development Division (KIDD) is responsible for implementing the project. The project aimed to construct new weir across the Banganga River for supplying water to both the canals.

The WUA of the Banganga Irrigation System however objected the construction saying that the new weir will reduce water availability at intake of Banganga I. S. which is located about 4.4 km downstream from the proposed headwork. Banganga I. S. is being managed by Banganga Irrigation Management Division under the Irrigation Management Directorate of DoI.

With this complaint lodged by Banganga I. S. WUA, Kapilvastu Irrigation Development Division postponed the procurement process of civil works contractor. Thereafter, the case was referred to DoI. On behalf of DoI, a senior divisional engineer visited the site for investigation. On 14 June 2016, all political party meeting (Sarbadaliya Baithak) was organized at the Kapilvastu District headquarter. This meeting formed a 6 member technical committee. The technical committee meeting was held on 19 June 2106. The meeting focused its discussion on the core wall across the river and its impact on subsurface flow. After field observation the committee members decided that the construction of core wall will not influence subsurface flow along the river, thus there will not be any impact on availability of water for Banganga I.S. Accordingly, the meeting decided to go with the construction of the diversion weir across the Banganga River.

Impact of climate change on Irrigation Management and local adaptation

The impact of climate change on irrigation management understands climatic variations on temperature and rainfall. The impact of climate change on rainfall has two major impacts – influencing the amount of water in the river and influencing the water deficit which needs to be compensated by irrigation.

Impact on water availability

The availability of water in the river, especially during the post monsoon and other dry seasons has decreased significantly in recent past. Subsequently, availability of water in canals has also decreased. The above two case study also support this finding. Farmers believe that some of the causes of decreasing water availability are: less rainfall, changes in rainfall pattern, land use changes in watershed, and more water use in upstream. Fig-1 present relationship between rainfall and canal flow in Julphe I. S.

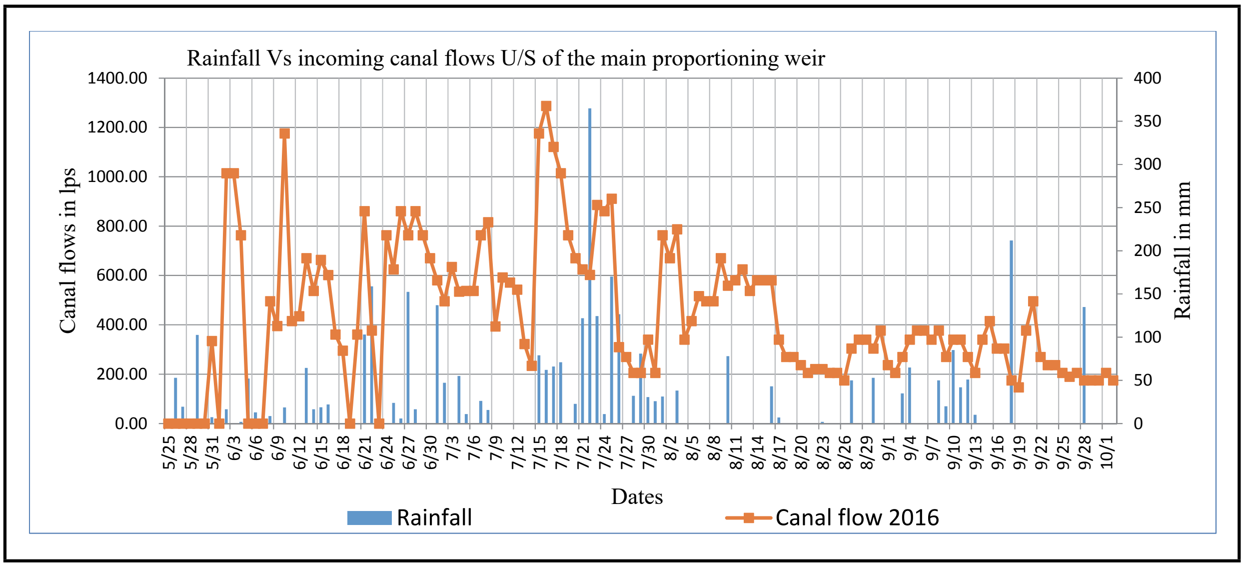


Figure 1: Rainfall vs main canal flows of JIS

Main canal flows depend very much on rainfall in their catchments. Almost continuous rainfalls between 15 July to 02 August resulted larger canal flows. A similar pattern can be seen for Sringeghat I. S. (Fig-2)

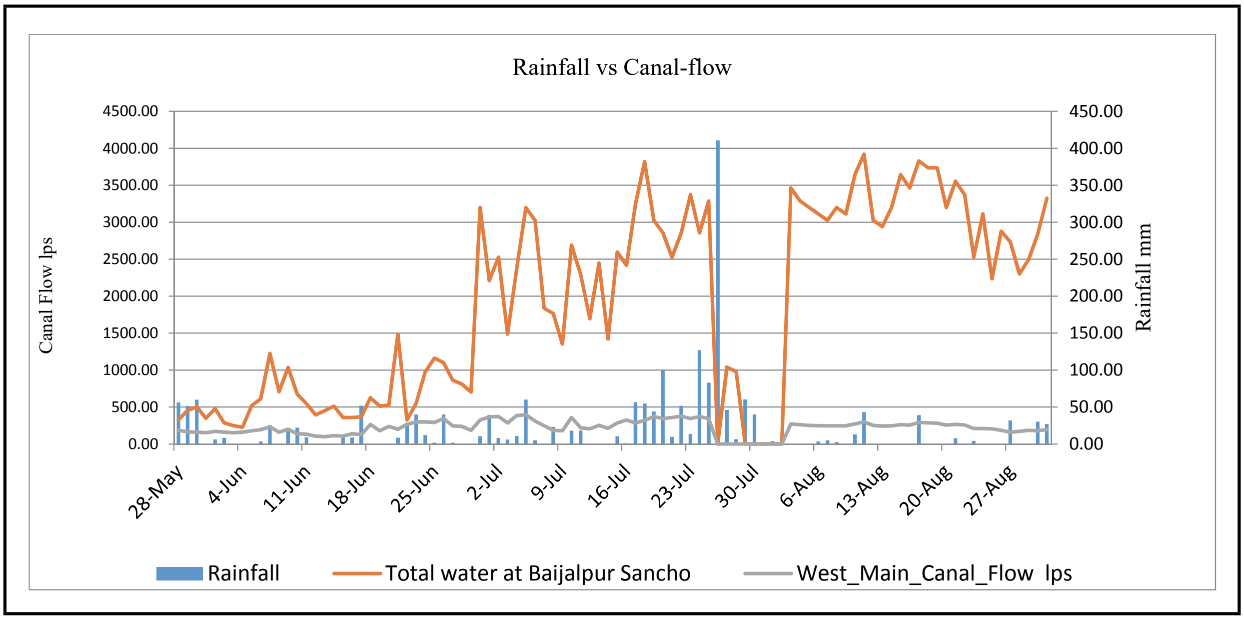


Figure 2: Rainfall vs main canal flows of SIS

Similarly, canal flows measured during the field study in 2016 at three proportioning weirs of Julphe I. S. were compared with the flows measured in 1997 at the same locations.

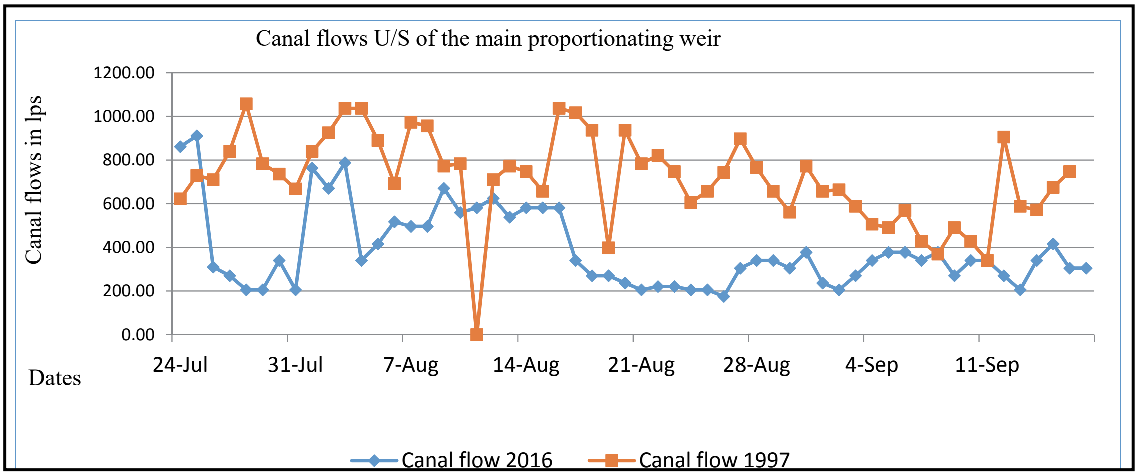


Figure 3: Canal flow at main proportioning weir, JIS (Head)

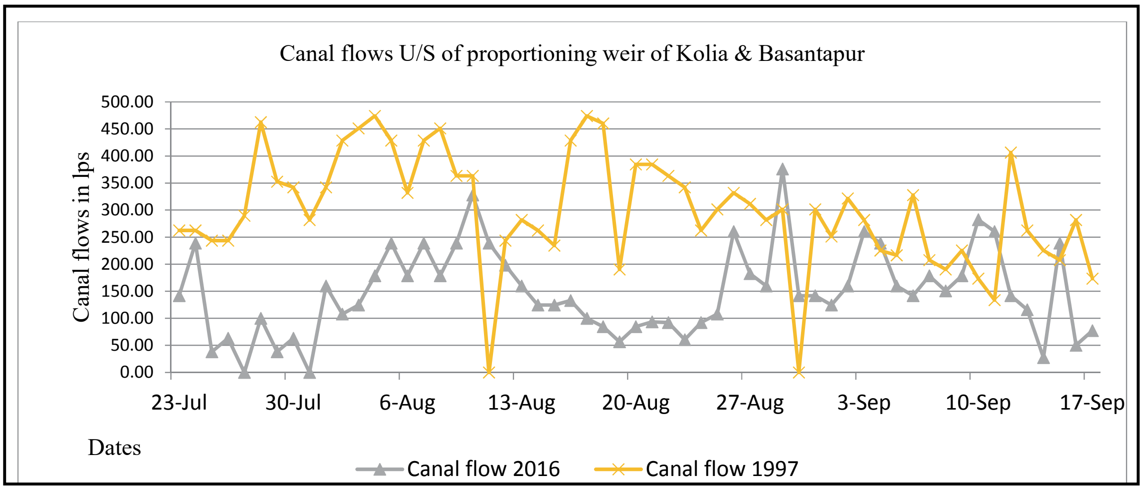


Figure 4: Canal flow at Hattigaunda, JIS (Middle)

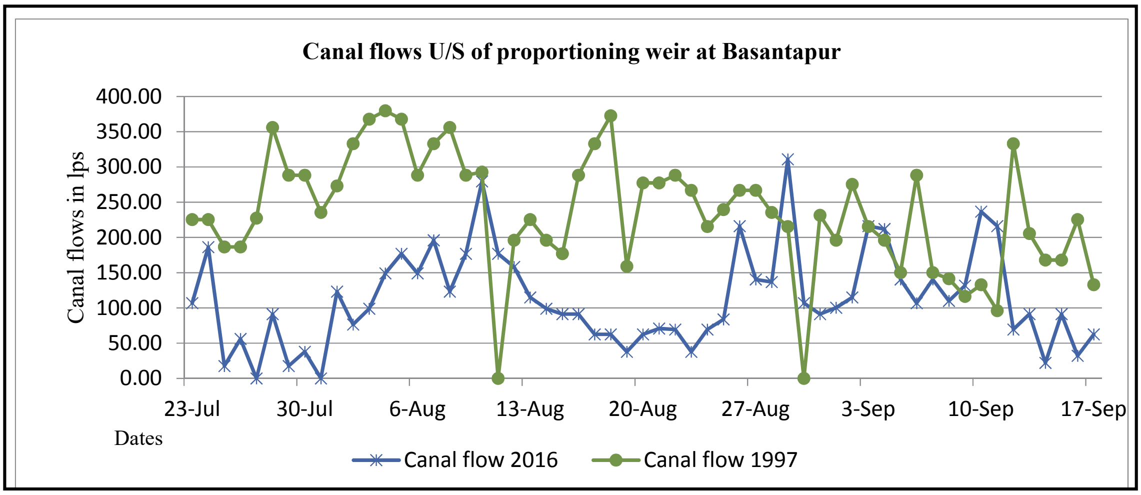


Figure 5: Canal flow at Pindaluchowk, JIS (Tail)

Figure-3 to 5 suggest that the canal flows in 2016 have been decreased substantially compared to the canal flows in 1997. This supports farmer's perception of declining incoming canal flows over the period.

LOCAL ADAPTATION MEASURES

Institutional Strengthening

In many irrigation systems, where infrastructure is week, institutional arrangements shape irrigation management. Thus shaping and reshaping of "rules in use" is one of the strategy being adopted by farmers to cope with declining water availability. Some of the examples are:

- Revitalizing the Girwari Irrigation Coordination Committee for canals operation at the source river.
- Different modes of water distribution being adopted by farmers for varying supply situation.
- Formation of new rules as needed.

Augmentation of Supply

Augmentation of water supply is one of the coping strategies being adopted by farmers. Above case studies on "farm level water management" suggests that 2 out of 5 canals have augmented their water supply by increasing water shares, while 3 canals have augmented their water sources through tube wells.

Table-4: Augmentation methods adopted by canals

Sub branch or tertiary canal	Sources of water augmentation	
	Water Shares	Tube wells
Naubighako Kulo	Yes	No
Bhandari kulo	Yes	Yes
Baijalpur east Kulo	No	No
Bathanpur Kulo	No	Yes
Laugai Kulo	No	Yes

The Baijalpur east canal has not done any augmentation of water. But, this is located at the head reach of main canal system.

Changing the cropping calendar

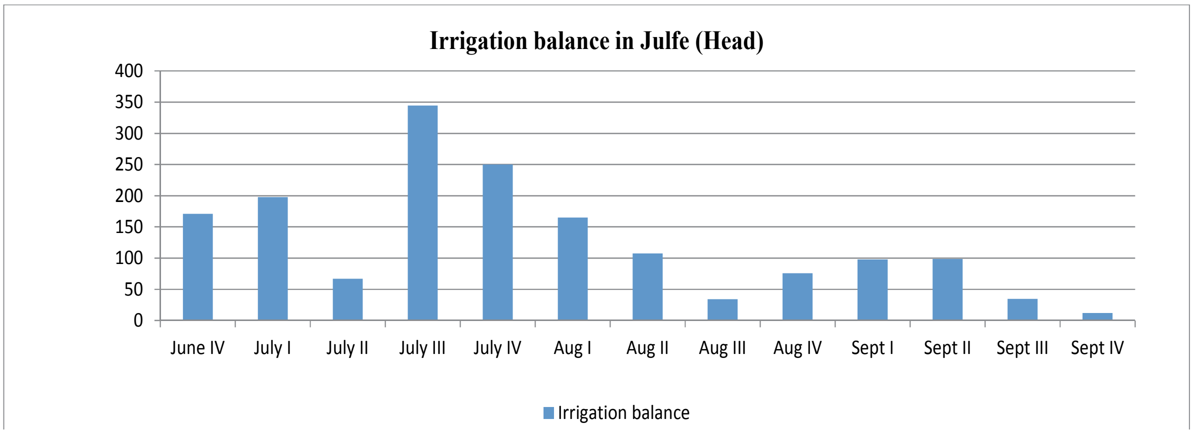
Paddy transplantation shifted earlier: In the past, paddy transplantation used to start by Mid July and continued over a period of about 3-4 weeks (1997, U.N. Parajuli). But presently, it normally start in early July and continues about 3 weeks (FGD, 2016). This suggests that the transplantation of paddy has shifted earlier by about two weeks. It is supported by the facts that (a) there is a small but significant pre-monsoon rainfall (Mott Interim Report, 2016), and (b) tube wells water being used for paddy transplanting in many paddy fields.

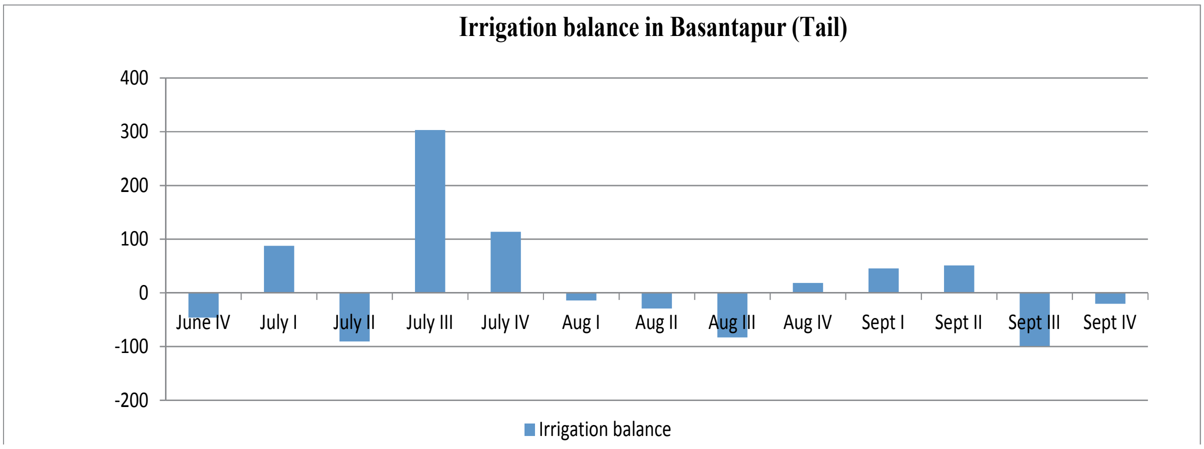
Land management

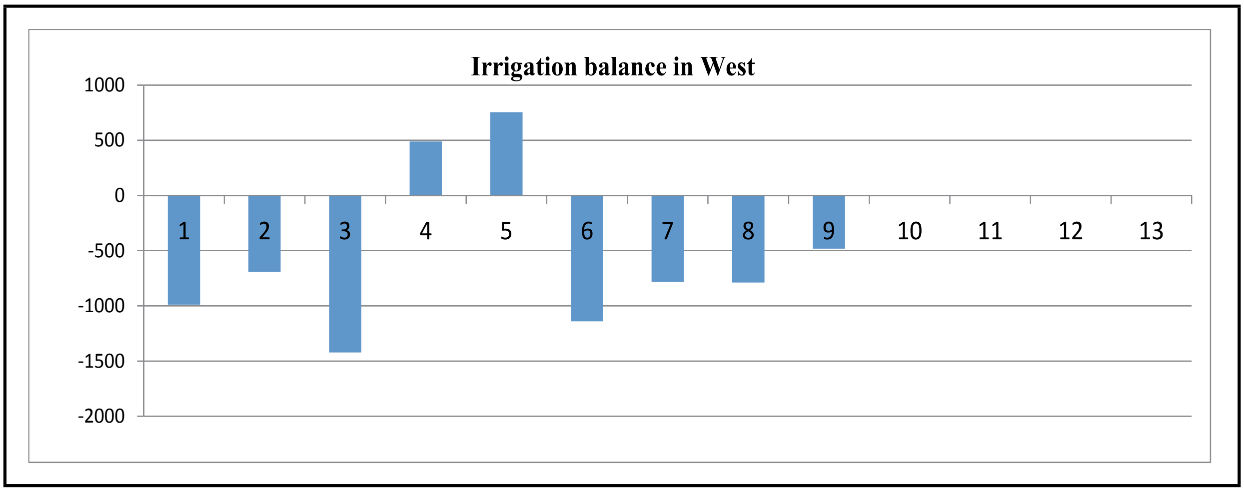
It has been reported (or observed) that the animal drawn power is being replaced by tractor for ploughing, puddling and transplanting. This change has implication on irrigation and land management. The tractor cannot plough a narrow and small terrace. As a result, farmers have developed their small and narrow terrace land into wide and large for facilitating tractor operation. This is because water requirement per unit of land for growing paddy reduces in case of a large and wide terraces compared to a small one.

Increasing the level of risks by adapting deficit irrigation

Farmers know that canal water is decreasing. So, they are taking risks by adapting deficit irrigation. Expecting rain increases the level of risks. Farmers say if they get good rain during flowering and grain formation periods, they get higher average yield of about 2 to 2.5 muri per kattha (3 to 3.7 t/ha). In case of no rain, they have to depend on canal water under deficit irrigation. Accordingly, paddy yield will be about 1.5 to 2.0 muri per kattha (2.2 to 3.0 t/ha). This means variations in paddy yield with and without adequate and reliable irrigation are about ±25%.







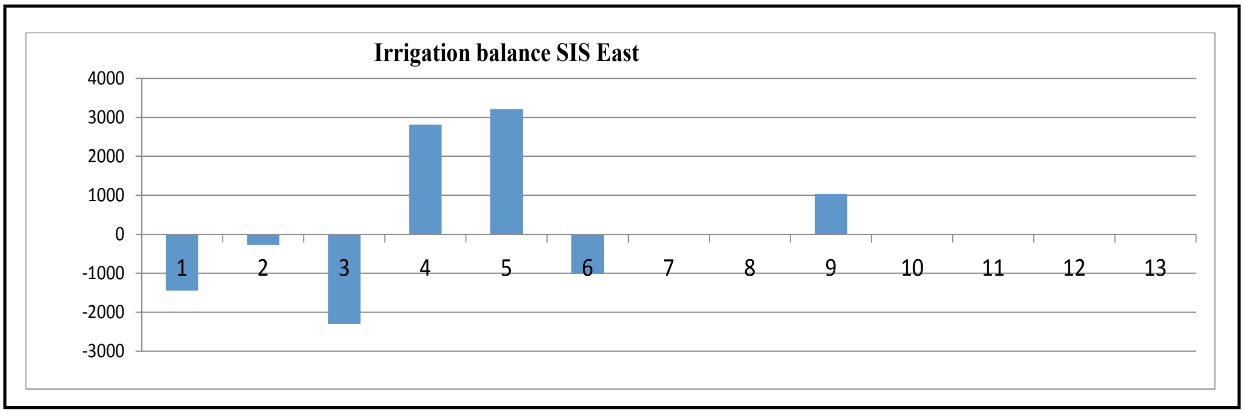


Figure 6: Irrigation balance in Head & Tail of JIS

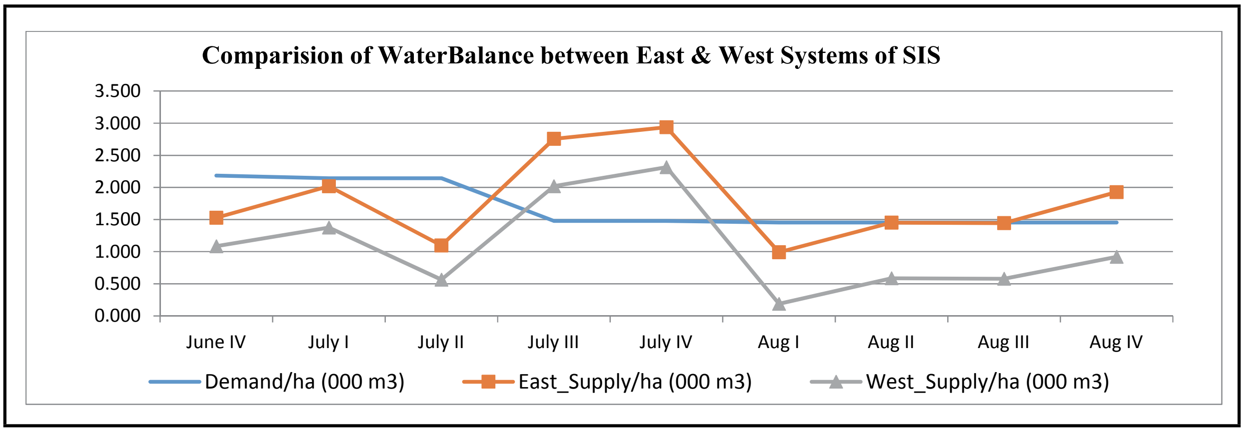


Figure 7: Comparison of water balance between East & West subsystems of SIS

Improving irrigation infrastructure

Infrastructural improvement enhances reliability and efficiency of water delivery. So farmers are gradually improving irrigation infrastructures as one of the adaptation measures. Some of the infrastructural improvements made in recent and past are;

- Merging of Intakes
- Canal lining for efficient transport of available water
- Replacing temporary infrastructure by more permanent ones.
- Developing water control structures

CONCLUSION AND RECOMMENDATIONS

The availability of water in the river especially during the dry season has decreased in recent past. This may be due to climate change or socio environmental changes. We may believe that some of the causes are: less rainfall, land use, change in watershed and more water use in upstream.

The observation of water measurement showed that canal flows depend very much on the rainfall in that area. With the uncertainty of rainfall the farmers have to compromise with their agricultural produce. The tail-end farmers suffer more than the head-end farmers. So more focus should be provided to enhance irrigation supply through infrastructural intervention like tube wells, rainwater harvesting. We can direct on minimizing irrigation demands and management improvement in farm level.

The peak flood in the river in recent years has increased as compared to past. So the vulnebility of irrigation system has also increased. The changes in rainfall pattern have been observed. So we have to think about design parameters (flood flow, low flow, effective rainfall etc).

WUA and federations of WUAs are managing canal operation and maintenance. They have their own "Rules in Use" for utilizing river water. The integration of canals into one system can improve irrigation management.

The tail-end water users have augmented their water sources through tube wells. The water users within the hydrological boundary, have adopted different modes of water distribution and established new rules for canal operation. Rice being the most preferred staple crop, the farmers are taking risks in its cultivation even under deficit irrigation. The farmers are improving irrigation infrastructures to enhance reliability and efficiency of the system. The adaptation measures in above two cases are examples of Climate Resilience of Irrigation in Nepal.

REFERENCES:

Mott MacDonald, Jan2017, Climate Resilience of Irrigation in Nepal, Final Report

2.4 PERCEPTION ON CLIMATE CHANGE AND REALITY IN SMALL AND MEDIUM IRRIGATION SYSTEMS IN NEPAL

PRAVAKAR PRADHAN[1]

INTRODUCTION

The climate change is a growing concern for developed and developing countries in the world. IPCC (2007; 2013; 2014) shows that each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850. The globally averaged combined land and ocean surface temperature, show a warming of 0.85 [0.65 to 1.06]°C, over the period 1880 to 2012. In 2015 the annual global surface temperature anomaly reached 1.2°C above pre-industrial level, making it the warmest year on record (WMO, 2016). By the end of the 21st century, the global surface temperature is expected to range from 0.3°C to 4.8°C for all Representative Concentration Pathways (RCPs) (IPCC, 2014). In a summary, climate change causes a rise in global temperature, which can have tremendous impact on global water cycles and precipitation patterns (Bates *et al.* 2008; Nelson *et al.* 2009;Shrestha and Aryal, 2011; IDS-Nepal *et al.* 2014;Sharma, 2015; Pandey *et al.* 2016;Shrestha *et al.* 2016). However, the precipitation trends are very variable spatially, with increasing and decreasing trends in different parts of the world (Bates *et al.* 2008; UNEP/GRID-Arendal, 2009). According to the IPCC AR5, it is virtually certain that, in the long term, global precipitation will increase as the global mean surface temperature increases. Total precipitation is likely to increase by 1% to 3% per degree rise in temperature.

As climate changes,extreme weather events such as cold days, cold nights and frosts that have become less frequent over most

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land areas, and hot days and nights more frequent. It is likely heat waves have become commoner over most land areas, that heavy precipitation event (thunderstorms, for instance) have increased over most areas, at the same time, drought events have increased as well (IPCC, 2007; UNEP/GRID-Arendal, 2009; Singh *et al.* 2011; IPCC, 2014).

It has now been established that climate change possess a greater challenge to countries like Nepal, where the topography varies drastically from the north to south along with changes in altitude (from above 8000m to less than 100m). According to the Government of Nepal's Second National Communication to the United Nations Framework Convention on Climate Change (UNFCCC), the temperature across most of Nepal has increased by up to 0.55°C per decade (MoSTE, 2014). Similarly other study shows that the temperatures between 1977-1994 rose between 0.5°C-0.6°C per decade (Shrestha *et al.*1999; WB, 2011; Singh *et al.* 2011; Shrestha and Aryal, 2011; MoE, 2011& 2012). It shows that temperature in Nepal is increasing at a faster rate compared to the global rate of warming i.e., 0.12°C per decade (MoSTE, 2014; IPCC, 2014). Thus, the annual number of cold days and nights has decreased significantly since 1960[2]. Occurrences of fog and frost have been a declining trend during peak winter mornings (McSweeney*et al.* 2010; WB, 2011; Poudel, 2012; Shrestha and Sada, 2013; ADPC, 2013).

Similarly, the precipitation trend varies with geographical location in Nepal. Annual precipitation distribution is high in eastern high altitude regions compared to rest of the country. Average annual precipitation of Nepal falls during the summer monsoon[3], i.e., around 80% of annual precipitation (MoPE, 2004; MoE, 2011; WECS, 2011; Mehta and Shah, 2012; MoSTE, 2014). The precipitation per decade data over Nepal is varied where some data indicate a decrease and others suggest an increasing trend (Shrestha*et al.* 2000; MoPE, 2004; McSweeney *et al.* 2010; Sharma, 2010; WECS, 2011; WB, 2011;Singh *et al.* 2011; MoE, 2011; Mehta and Shah, 2012; MoSTE, 2014; IDS-Nepal, 2014).The highest extreme rainfall is observed mainly in the foothills of Chure/Siwalik region in the central and western Nepal during the middle of monsoon season (MoSTE, 2014). Usually, this season is a major cropping season in Nepal. In general, paddy transplantation used to be accomplished by the June 30 years ago, but the delay in monsoon rain, July becomes the peak season for paddy transplanting now a day. This delay in paddy transplanting affected ripening and harvesting, especially, for up-hill farmers and further disturbing the sowing of winter crops (Pandey, 2012; Shrestha and Sada, 2013). So, it could be assumed that rising temperature and changes in rainfall patterns have direct effects on crop yields. This is more severe for rain-fed cultivation than irrigated cultivation (Nelson *et al.* 2009; Shrestha and Sada, 2013).

At present, Nepal has a cultivated area around 18% of its total land area. Out of this, two-third of land area is potential for irrigation. Among these areas, higher percentage of the cultivated area has some sorts of small and medium scale irrigation [4] (i.e. about 75% of the

2 Days with an average temperature below 12°C are considered as cold days
3 Monsoon months lies from June to September in Nepal
4 Agriculture land area less than 100ha in the hills and less than 2,000ha in the Tarai (Mott MacDonalet al. 2017).

irrigation in the country) but only few percentage of the cultivated area has year-round irrigation (WECS, 2011; Mott MacDonal*et al.* 2017). Most of the small and medium scale irrigation systems draw water from small rain-fed tributaries of the major Himalayan Rivers (Mott MacDonald *et al.*2017). These streams are very vulnerable to climate change, because climate change will significantly increase the intra-annual[5] variability[6] of stream flow (Agrawala *et al.* 2003; WECS, 2011; Mott MacDonal *et al.* 2017).

STUDY AREAS

Nepal's major portions of irrigated areas are situated in the fertile lowlands of the Terai. It is assumed that this area might be the suitable location to study the climate change impacts (both positive and negative) on small and medium-scale irrigation system. Hence, the study areas have been selected from two districts which are Sringeghat Irrigation System from Kapilvastu District and Julphe Irrigation System from Nawalparasi District. Some detail description of these two irrigation systems are illustrated as follows:

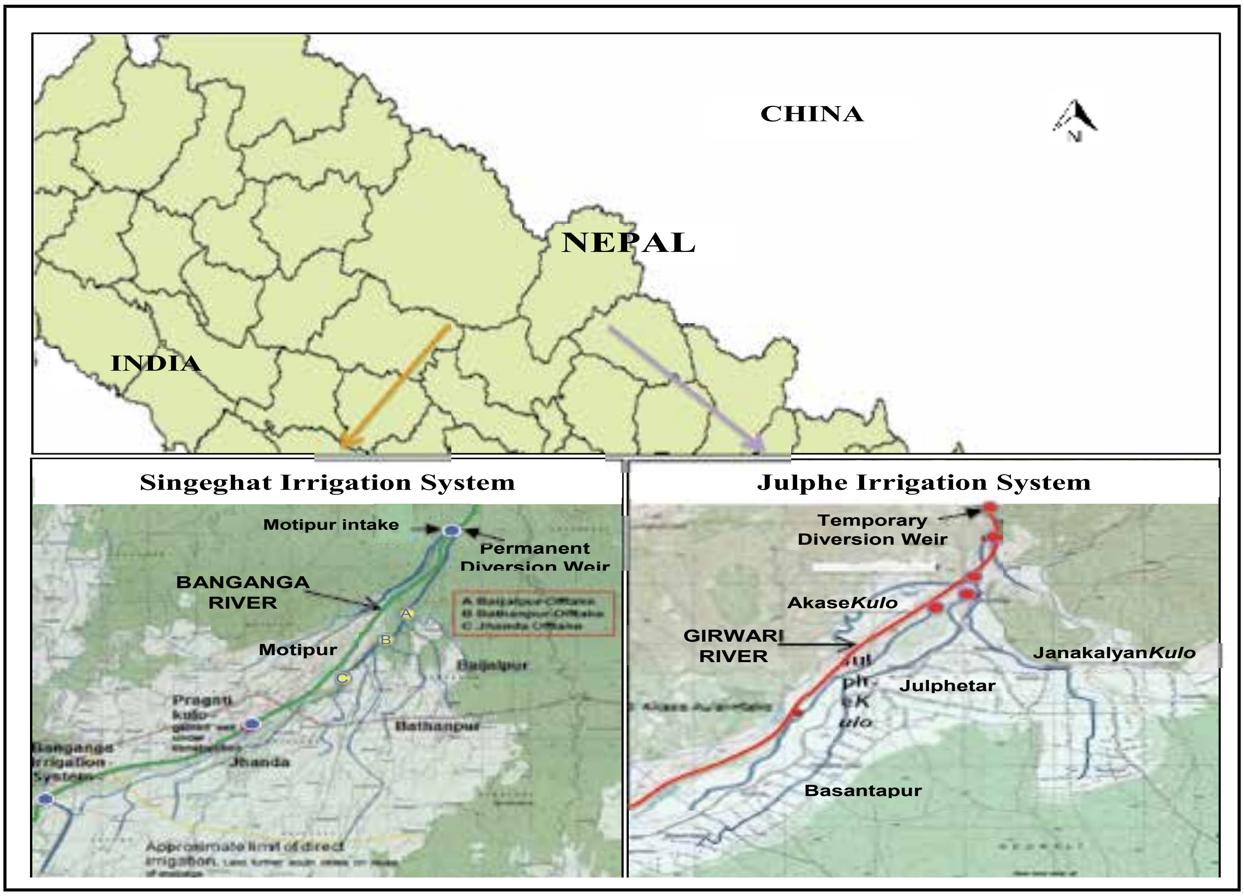


Figure 1: Location map of the Singeghat Irrigation System andJulphe Irrigation Systems

5 Events occur on a time scale of less than 1 year but more than 1 month

6 Climate change can affect frequency and intensity of flooding and droughts; changes in timing and intensity of precipitation; glacier retreat; debris volume; sedimentation, etc.

SRINGEGHAT IRRIGATION SYSTEM

Figure 2: Permanent intake of SIS

The Sringeghat Irrigation System (SIS) lies in the Kapilvastu District in the Western Development Region of Nepal. The SIS's intake is situated from 27°43.889′ in north and from 083°11.886′ in the east that has an elevation of 174 meter. It's command area is located in both the right and left banks of the Banganga River which extends from the North to the South of the East-West Highway. SIS is about 30 km west of the Butwal town. In 2000, the permanent intake was constructed at Sringeghat by integrating eleven-irrigation systems[7] with the command area of about 2,500ha (see Figure 2). In addition, it has around 400 meter-lined canal, especially, in main canal and water divider sections, but large portion of canal is still earthen. Now, the system covers Motipur, Banganga, Kopuwa, and Gajehada Villages under the Banganga Municipality (see Figure 1). In addition, SIS has number of deep tube wells (DTW), which help for supplementary irrigation during dry spells in monsoon.

Physiographic location of the SIS falls at the foothills of the Mahabharat mountain range in the river valley characterized as Siwaliks or Doon valley. The system is more vulnerable to sediment, which is likely to increase as a result of expected high intensity rain. This area has a sub-tropical climate.

JULPHE IRRIGATION SYSTEM

Figure 3: Temporary intake of JIS

The Julphe Irrigation System (JIS) falls under the Jhyalbas of Deurali Village Development Committee (VDC) and the Madhyabindu Municipality in the Nawalparasi District in the Western Development Region of Nepal. The JIS's intake is situated from 27°41.628′ in north and from 084°03.549′ in the east that has an elevation of 256 meter. It is located at the foothills of the Mahabharat mountain range, about 6 to 10 km north of *Chormara* village located along the Narayanghat-Butwal Highway about 40 km west of the Narayanghat town. This area has a sub-tropical climate. The JIS has a temporary intake

7 11 irrigation systems in SIS are: SIS-East: Baijalpur, Tinaiya, Pipara, Rajapur, Bathanpura, Gajahara, Jitpur, Jhanda and Dugaha and SIS-West: Satgaon and Madhuban.

with earthen canal which serves about 200 ha of land (see Figure 3). From the perspective of irrigation management, the system is divided into three sub-systems, namely Julphetar, Koliya and Basantpur located at the head, middle and tail ends of the system's command area respectively (see Figure 1). Basantapur has established six DTW (2 non-functioning) to get supplementary irrigation water in dry season.

The Girwari River, a perennial river, is the main source of water for the system. It is a tributary of the Narayani River, and flows from north to south. The average overall width of the river at the diversion point of the Julphe Irrigation System is about 200 m.

Five other irrigation systems (*kulo*) listed below also divert water from this river, which are as follows:

- Jhyal Bas*kulo*
- Janakalyan*kulo*
- Tribhuvan Tar*kulo* (not shown in the Figure 1)
- Goyari*kulo*
- Aakase*kulo*

Only the Goyari*kulo* irrigates lands on the right bank of the Girwari River, while the remaining *kulos* irrigate lands on the left bank (see Figure 1). All above irrigation systems have temporary diversion weirs like JIS.

METHODOLOGY

The methodology adopted for the study is shown in Figure 4. Firstly, the potential two irrigation systems i.e. Sringeghat and Julphe, were selected for the study. Each irrigation system was sub-divided into three sections i.e. head, middle and tail, to collect the various information on climate change related to irrigation system and agriculture practices. By consulting with water user associations (WUAs) and farmers, each section's farmers were divided into two groups who could represent the farmer holding land more than half a heactor (ha), categorized as rich, and less than half a ha categorized as not rich. Similarly, the senior citizens group, who has stayed more than 20 years in the command areas, was also formed. Altogether, SIS and JIS had FGDs with land holding less than ha. and land holding more than ha. were 8 and 6 respectively[8], and each system had an one senior citizen FGD. Each FGD group consisted of 10 -12 people inclusive of women representatives. In a total 16 FGDs were conducted in these two irrigation systems.

Accordingly, the checklist was prepared to guide the focus group discussion (FGD) with farmer and senior citizen. The farmer groups provided information on climate change, irrigation system and its impact on agriculture land size. Similarly, the senior citizens group, who has stayed more than20 years in the command areas, provided historical scenarios of

8 SIS had two locations for head (i.e., Baijalpur and Motipur), middle (Bathanpur) and tail (Jhanda), where JIS had head (Julphetar), middle (Koliya) and tail (Basantapur) (see Figure 1).

each command area that included history of irrigation system, agriculture practices and changes in climate during the period, etc. Outcomes of the FGD have been recorded into numerical values to identify the monthly/annually climate change scenarios in the irrigation system.

Finally, the outcomes of the farmer perception on climate change were compared with locally available scientific data (i.e., hydrological and meteorological) to assure the percentage of similarity in both irrigation systems.

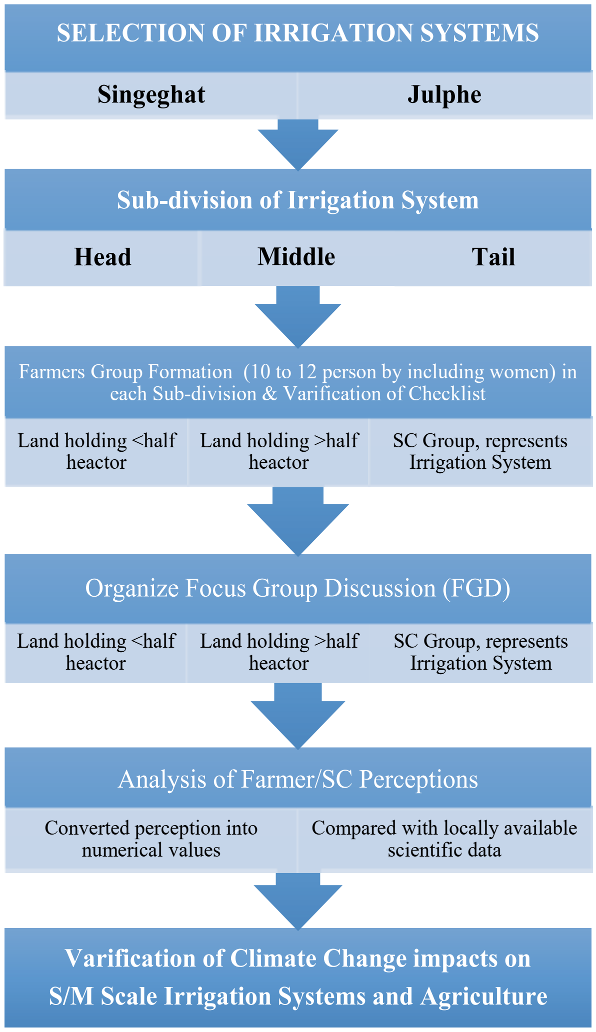


Figure 4: Study methodology steps in two irrigation systems

Note: SC-Senior Citizen; S/M-Small and Medium

RESULT AND DISCUSSION

The study presents the findings of FGD on perceptions and experiences of the farmers/senior citizen on temperature, rainfall, agriculture practices, cropping pattern and the impact of climate change on crop choices and crop coverage. Obviously, the temperature and rainfall pattern differ from on geographical location to other like SIS and JIS. Outcomes of the FGD have been quantified in numerical values to identify the monthly and annual climate change scenarios in both irrigation systems. The analysis shows that the temperature has a trend of slightly increasing for whole twelve months, compared to 10 years ago in both irrigation systems. Whereas, the analysis of rainfall pattern is totally different compared to temperature trend, and is decreasing more than 10 months in a year, compared to 10 years ago. Hence, the outcomes of these analyses show that the climate is changing in both the irrigation system, compared to 10 years ago.

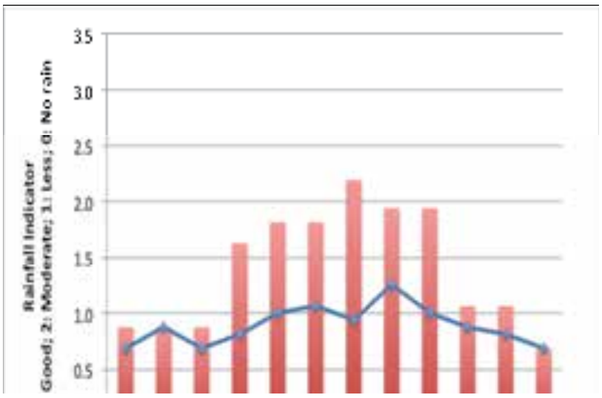
Temperature Variation

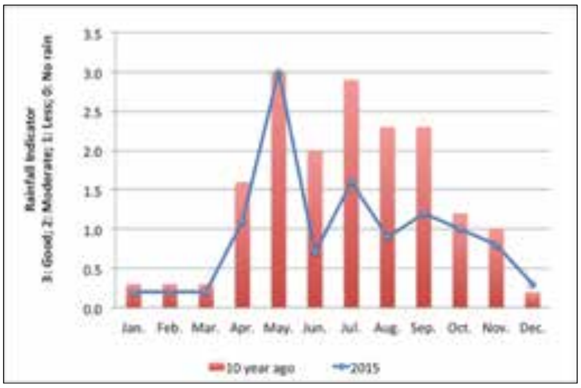
Most of the participant farmers in the FGD reported that they have experienced changes in temperature compared to a decade ago. They have experienced the rising temperature both in summer and winter period. During summer, it is burning hot. In winter, the cold temperature has decreased and duration of cold days decreased. A few years ago, they would experience the fogs but they are not there during winter. According to them warm temperature has increased (see Figure 5).

Singeghat Irrigation System	Julphe Irrigation System

Rainfall Variation

The farmer group felt that rainfall pattern has also changed (see Figure 6). They felt delayed monsoon and less rainfall in winter compared to the previous years . The farmers reported that there have been variations in rainfall such as short duration of heavy rainfall and long duration of dry spell even during monsoon. In winter, farmers had experienced less rainfall or no rainfall (see Figure 6). They related their experience of 2015 when there was long duration of no rainfall after monsoon affecting the winter crop .





Singeghat Irrigation System	Julphe Irrigation System

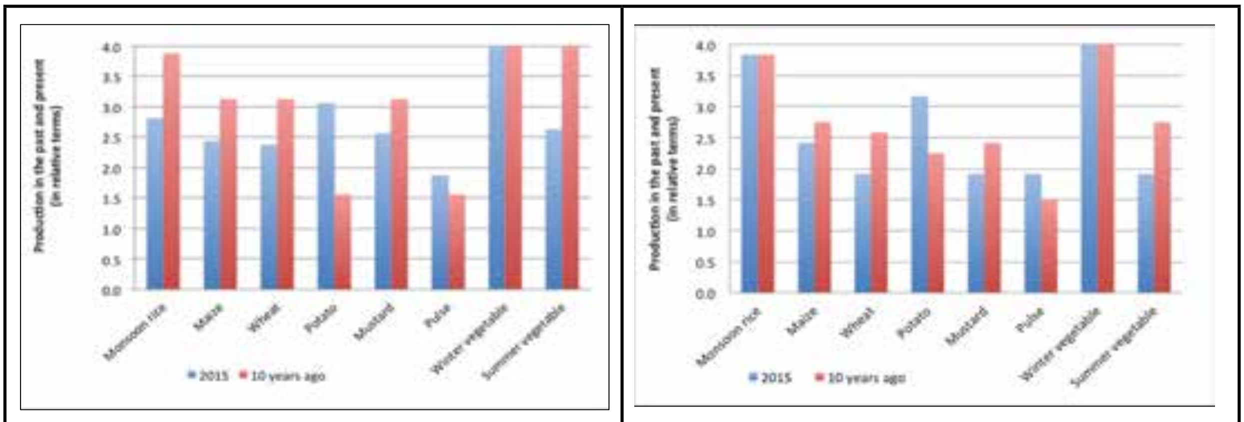
Figure 6: Rainfall variation between 2015 and 10 year ago

AGRICULTURE ACTIVITIES

The agriculture-cropping pattern and crop calendars are different between SIS of Banganga River and JIS of Girwari. Climate change and its impacts on monsoon paddy, winter and spring crops are briefly illustrated, and also analyzed by numerical values (see Figure 7).

Monsoon Paddy

Farmers reported that there had not been much change in monsoon paddy cultivation. The coverage of paddy cultivation has remained the same where as the paddy cultivation practices have changed based on water status of the command area. Where there is irrigation water and supplementary water supply from groundwater, the farmers prepare the seedbed, transplantation and other activities in early June. The farmers do not have to depend on the rainfall. Farmers felt that there had been delayed rainfall, they had to match their agriculture activities with the rainfall (see Figure 6). They will have delayed paddy transplantation. This practice would have impact on the yield of paddy as well (see Figure 7).



Singeghat Irrigation System	Julphe Irrigation System

Figure 7: *Agriculture production variation between 2015 and 10 year ago*

Winter and Spring Crops

The winter and spring crops are usually affected by changes in temperature and rainfall patterns. It has been mentioned that winter has cropping intensity of only 50%. Not all area is covered by crop due to the less water in the canal. Instead of wheat, they have opted for potato and mustard cultivation. The change in crop pattern is attributed both to climate change, function of market and cost of production. In winter, they have wheat and potato. Wherever farmers can get irrigation water during Januray, they will have these two crops as cash crops. They also broadcast mustard and lentils (see Figure 7).

Maize in spring is main crop. Farmers grow maize with the help of DTW water. Water will also be used for paddy seedbed preparation so that as soon monsoon rain starts they can start paddy plantation with the help of irrigation water. It was reported by the farmers that even less water in the intake of the canal could come up to the command area if permanent canal structures had been constructed in many parts. It will stop water seepage in the canal and volume of water flow will be increased for irrigating the agriculture land. This would help to yield more agriculture products compared to current situation of canal.

Two factors have discouraged the farmers to undertake agricultural activities. They are uncertain of climatic effects. In 2015, there was dry spell, so almost 70% land could not have paddy transplantation on time. Secondly, the farmers do not get right price for their agriculture produces because the paddy price will be fixed by the mill owners which will be often less than the production cost.

Verification with Local Hydrological and Meteorological Data

There were no Hydrology and Meteorology station in the study areas. Hence, temperature and precipitation data were analyzed from the nearest Department of Hydrology and Meteorology (DHM) stations within the vicinity of study area to assess climate trends. The long-term climate trend results were compared with farmers' perception on climate change to confirm the actual reality in these two irrigation systems. For the precipitation data, Patharkot DHM station represents the Sringeghat Irrigation System and Beluwa-Girwari DHM station represents Julphe Irrigation System, whereas for the temperature data, Kathmandu Airport and Bhairahawa Airport DHM stationswere selected to represent both irrigation systems[9].Kathmandu and Bhairahawa station have relatively long records and is believed to be reliable. Other nearby DHM station's time series data (1954-2015) on precipitation have also been collected to verify the climate trends similarity in that location. It shows that an average of annual rainfall and monsoon rainfall have been slightly increased, similarly, daily extreme and dry season average have been also slightly increased (see Table 1).

Table 1: Precipitation trend in neighboring DHM stations

Index No.	Location	Period of record	Annual mm/year	Monsoon mm/year	Daily Extreme mm/day/year	Dry Season mm/year
703	Butwal	1954-2014	-7.4	-7.1	-1.5	0.4
704	Beluwa	1958-2015	6.4	3.7	-0.1	0.8
705	Bhairahawa Airport	1966-2015	-0.5	8.0	0.2	0.9
707	Bhairahawa Agri. Stn.	1968-2014	5.0	5.6	-0.7	0.3
716	Taulihawa	1979-2014	-5.8	-5.2	-0.5	-1.0
721	Patharkot	1972-2015	-4.3	-5.4	0.4	1.0
728	Simari	1981-2014	7.7	0.9	2.4	0.9
Average value			**0.16**	**0.07**	**0.03**	**0.47**

Source: DHM Data

The temperature trend in Kathmandu and Bhairahawa stations give clear and well-define with small but significant rising trends between years 1965/1970 to 2015. It also shows that cold winter seasons are in decreasing trend (see Figure 8 and 9). These phenomenons of the temperature trend support the farmers' perceptions on hot temperature increasing in summer and cold days are decreasing in the winter compared to decade ago.

9 Study areas and nearby DHM stations do not have temperature-recoding tools and data during the study period.

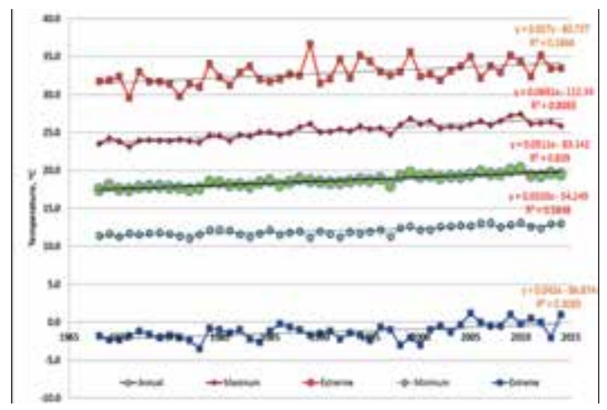
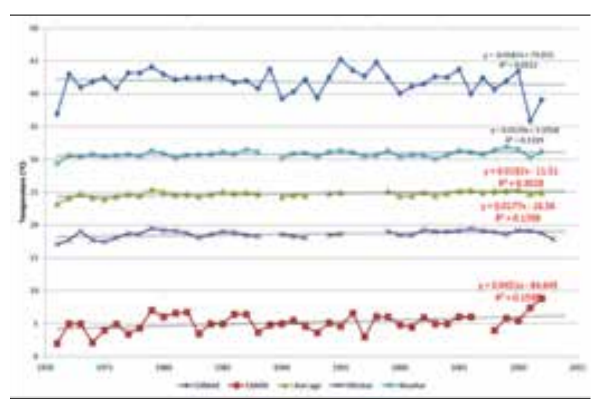
	

Figure 8: Temperature trend from 1965-2015 in Kathmandu Airport	Figure 9: Temperature trend from 1970-2015 in Bhairahawa Airport

Source: DHM Data

Rainfall is recorded at the nearby Patharkot station (see Figure 10), which suggests a declining average and monsoonal rainfall. Rainfall appears to be increasing since 2001, apart from very dry years in 2014 and 2015. However, these trends are not significant and likely to represent short-term fluctuations rather than climate change. Farmers perceive a more severe decline than this data suggests, but this may reflect an overall shortage of water as the irrigation system only provides part of their needs and any short-term change in rainfall will have a direct impact on their crops.

The days with smaller rains (up to 50mm) are decreasing in Patharkot station (see Figure 11). In other side, annual extreme of daily rains are in increasing tendency and dry season precipitations are in increasing trends. These patterns of rainfall adversely impact on crops production. However, these data support farmer's perceptions on rainfall change compared to decade ago.

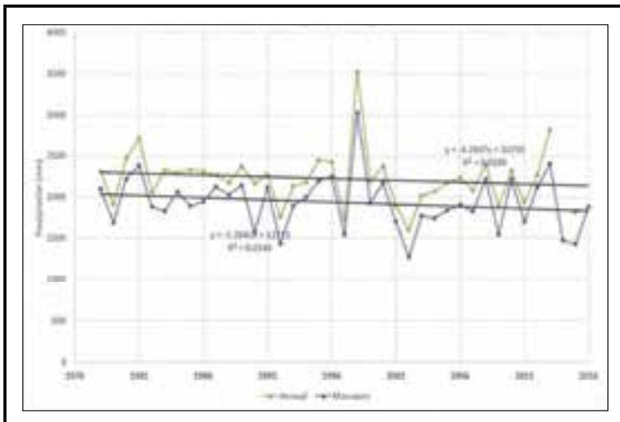
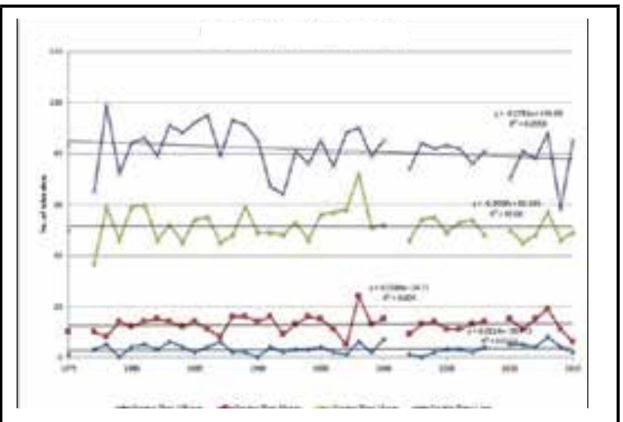
	

Figure 10: Precipitation trend from 1976 to 2016 in Patharkot	Figure11: Days rainfall patterns from 1975 to 2015 in Pattharkot

Source: DHM Data

Rainfall characteristic of the Beluwa-Girwari station shows a slight increasing trend of average annual and monsoon rainfall (see Figure 12) which is very small, compared to the annual variation. However, the trend of average annual monsoon rainfall as presented in Figure 12, is against the farmer's perception on rainfall variation, which however may also have been influenced by an unusually dry years from 2012 to 2015. The rainfall in 2015 was barely half of the long-term average. The timing of rainfall was also adverse in these years, with prolonged dry periods in the critical month of September. In a contrast, 2016 has been a much wetter year, but this has included several unusually intense events which caused flood and damaged irrigation infrastructure rather than alleviate water shortages for crops.

Small and timely rains are highly effective for meeting the agricultural needs of water compared to high intensity erratic rains. The days with smaller rains (up to 50mm) patterns are decreasing in Beluwa-Girwari station (see Figure 13). This phenomenon of the decreasing small rains supports the farmers' perceptions of decreasing rainfall compared to decade ago. In addition, Beluwa-Girwari indicates increasing tendency of annual extreme of daily precipitation; had increasing trends of dry season precipitation (see Figure 13). These behaviors of rainfall usually damage canal and crop productivity as well.

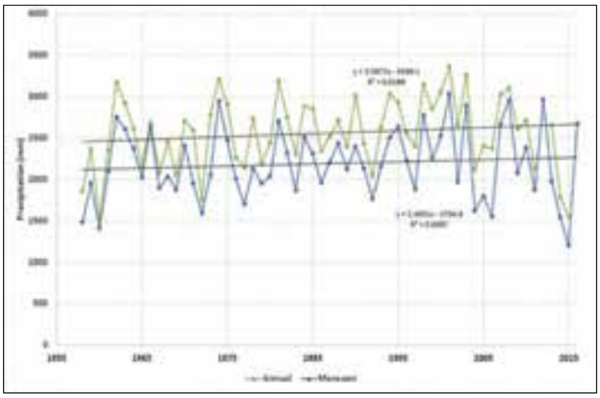


Figure 12: Precipitation trend from 1958 to 2015 in Beluwa-Girwari

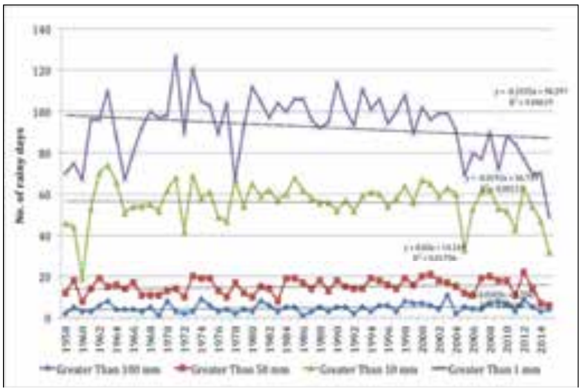


Figure 13: Days rainfall patterns from 1958 to 2014 in Beluwa-Girwari

Source: DHM Data

Hence, the records of selected stations to the greater extent confirm with the farmers observations on temperature and precipitation. These changes have also impacted on cropping pattern and yield quantity especially in winter time.

CONCLUSION

Farmers' perception on climate change is varied between the study areas. Even it is different in head, middle and tail sections of each irrigation system. However, there are no doubts that climate change and its impacts are happening in both study areas. Hydrological

& meteorological data also provide evidences on it. Similarly, there is an evidence of increasing risk of declining crop yields due to the insufficient irrigation water in the canal, especially in winter and spring seasons.Nowadays, farmers cultivate improved verity of crops instead of traditional crops. According to them, new variety of crops grows within shorter time duration and produces more yield compared to old crops. Farmers are also attracted to cash crops cultivation such as potato and other vegetables, instead of wheat and maize.

The study found-out that several non-climatic change aspects, such as landuse change, increase in upstream new settlements, deforestation, excavation of sand and stones from river bed, etc., are equally responsible for the compounded negative impacts on the irrigation sector. There is evidence of increasing peak flood flows due to the heavy precipitation within a short duration of time. It damages riverbank as well as canal structure. Sometimes huge amount of sand and debris enter into the canal due to the flood. This event creates difficulty for farmers to excavate sand and debris from the canal during a peak season.

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3. MUS : CHALLENGES AND APPLICATIONS

3.1 UPSCALING MUS AT GLOBAL LEVELS: LESSONS FROM THE PAST AND OPPORTUNITIES FOR THE FUTURE

BARBARA VAN KOPPEN[1]

INTRODUCTION

This paper analyses recent trends in the uptake of Multiple-use water services (MUS) approaches by policy makers and service providers (or 'water and development professionals') across the world, and especially in low- and middle-income countries. In these areas, small-scale water users depend in many ways on water for domestic uses and various productive water uses, including irrigated cropping and horticulture, livestock, fisheries, tree-growing, crafts and small-scale enterprises. These multiple uses are vital for multi-faceted, vulnerable livelihoods. For communities, it is a no-brainer to use and re-use their multiple water sources to meet their range of multiple water needs; for them, there is no single priority. Since the early 2000s, service providers have responded by exploring the so-called multiple-use water services (MUS) approach, defined as a participatory approach to planning and providing water services that seeks to meet people multiple water needs (see www.musgroup.net). These experiencesconfirmed that policy makers and implementers of public water service provision can also improve their services: there are proven and plausible, often 'no-brainer', positive answers to the question: 'what is in the MUS approach that enables me to deliver better services?' Various innovative MUS projects across the world have generated substantive evidence on 'how to do, and why MUS?'After this 'proof of concept' the question has increasingly become: 'how to move from – often donor-funded - MUS innovations as 'islands

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of success in oceans of misery' to the uptake of MUS in the mainstream governmental and non-governmental public water services and water management structures?'.

As this experience over the past 15 years has learned, the main challenge for the wider uptake of a MUS approach is the fragmented, top-down administrative structuring of public service provision. This administrative structure tends to promote single-use approaches, so with a focus on either domestic water uses (in the Water, Sanitation and Hygiene, or WASH, sub-sector), or irrigation (in the irrigation sector), or hydropower, or other productive uses.The more recent nexus approaches provide only a partial response to this fragmentation. They pick two or three single uses (e.g., food, energy, water) and unravel their relationships. However, this selection is still made in a top-down manner and water uses are still conceptualized as monolithic siloes without looking at intra-sectoral differences and without looking at other uses and users, in particular those relevant for poor small holders in rural areas. The latter often remain ignored. Moreover, with growing competition for water by growing populations with growing demands, sectoral approaches increasingly fail as well. These single-use approaches also continue suggesting that this competition is a matter of single-use siloes competing with each other, instead of people competing with each other, each with multiple water needs but with very different powers also within sectors. Hence, the search for people-driven, integrated and pro-poor water services approaches continues and MUS is there to stay as one of the most promising responses.

Important lessons in upscaling MUS can be derived from the experiences of such upscaling of MUS since the early 2000s. In section 2, these past experiences are summarized, starting with the typical sequence of professionals' responses across the sub-sectors to the universal observation that 'it happens anyhow': infrastructure designed for a single use in in reality almost always used for non-planned purposes as well (Renault 2008). In response, a domestic-plus, irrigation-plus and MUS by design approach evolved within the water sector. Moreover, outside the water sector, an implicit MUS approach emerged in development programs in which decentralized decision-making aligns with local realities and needs. Such decision-making spontaneously led to multi-purpose infrastructure with the use and re-use of multiple water sources. Section 3 synthesizes the no-brainers that can be derived from these experiences (and from common sense), both for communities (in 3.1) and for service providers that seek to ***plan*** their services for multiple uses in the MUS approach according to decentralized participatory planning approaches (in 3.2). Section 4 seeks to deepen understanding of the administrative issues at stake by identifying an 'accountability paradox' as one of the factors underpinning centralized sectoral specialist approaches versus genuine bottom-up planning. This further points at the untapped potential to upscale participatory planning of public support to improve access to water for resilience, health and wealth in a more cost-effective and sustainable manner than before.

LESSONS FROM THE PAST FOR UPSCALING MUS

From Obstacle to Opportunity:

The search for professionals' more integrated water service delivery has started, and continues to typically start with the universal observation that infrastructure designed for a single use is, in reality, also used for non-planned uses. Initially, this is seen as an obstacle. Renault (2008) identified as follow show this observation leads to typical responses which increasingly recognize multiple water uses as an opportunity instead of an obstacle. While he identified this sequence in the irrigation sub-sector, it appeared equally valid in the WASH or other sub-sectors (Van Koppen et al 2014).

The observation that 'it happens anyhow' is initially seen as an obstacle because it fails to fit the end-purposes of public investments in infrastructure that was paid within a well-defined department of either health, or agriculture, or hydropower and with well-defined, narrow aspects of wellbeing, for example, that aspect of health that is mainly determined by drinking clean water, or by yields of –often predetermined- crops at –often predetermined- fields. These promised end-results justified the allocation of public funds, for which departments continue to be held accountable by treasury. Achieving those targets is the main goal in job descriptions of the 'frontline staff' who is most directly confronted with the realities of unplanned uses, but upward accountable to those paying their salaries and defining their jobs. Moreover, the specialists of each specific department know best how to turn water use into that specific aspect of wellbeing, whether hygiene or agronomy for higher yields or marketing skills. Their professional and university trainings fostered that specialism. This render any water use that diverts from achieving that narrow goal an obstacle. Therefore, the first response is that such uses should be forcefully removed. Women can be chased away when they use canal water for washing the cloths of their husbands with plots in the same irrigation scheme. Whenever officials see that water for 'domestic' supplies is used for gardening, they can take out the plants. However, in most cases, professionals' enforcement power is too weak to continue taking such actions. So the next response is to just declare non-planned uses as illegal and foster the norms, but leave the practice unchanged often by lack of enforcement capacity.

A third response is to turn a blind eye, certainly when no harm is done by these unplanned uses. However, professionals may turn a blind eye, but they still maintain that it is not their job to cater for such other uses. Even if people have to drink from the irrigation canal by lack of better alternative, the responsibility for creating such better alternative is not with the irrigation scheme designers and managers. Their job 'is already complicated enough for a single use, so please, do not complicate it even further', is the persistent argument. A next step is that especially frontline staff support such other uses in an ad-hoc manner, but without mentioning it in their monthly reports upwards.

A real change among professionals took place in the 1990s when both the WASH sub-sector (Moriarty et al 2004) and in the irrigation sub-sector (Meinzen-Dick 1997; Renwick 2001) took the next step. They started recognizing and valuing these non-planned uses as an opportunity, so as substantive benefits and returns on investments. As bankers do, water professionals started calculating all returns on investments. Thus, FAO calculated for example that over 50 percent of the value created in irrigation schemes was for non-irrigation uses (FAO 2010). These calculations continue to be made (for example Hall et al 2013) and provide fertile ground for the last step: *planning* for such multiple uses in the design or rehabilitation of water infrastructure. The latter is the MUS approach. Instead of avoiding to 'step on others professionals' toes', professionals from different sub-sectors started to collaborate and look for opportunities to meet people's multiple water needs. This led to many initiatives from many different angles, or MUS modalities, each with own opportunities and own partners for further upscaling. We distinguish the following four 'MUS modalities': domestic-plus, irrigation-plus, MUS by design, and implicit MUS in community-driven development approaches (Van Koppen et al 2014).

Domestic-plus:

In this 'plus' approach, the sub-sectoral single-use mandate, financing streams, expertise, legitimacy and power are maintained, with a continued priority for the mandate's single use. However, the narrow earmarks for the single use are pro-actively widened up. Thus, the domestic-plus approach in the WASH sub-sector continues prioritizing basic drinking and other domestic water uses for all, and, hence, water uses around homesteads, but also promotes productive uses of the water supplies to homesteads. Domestic-plus is about increasing service levels, or 'climbing the water ladder' to 50, 100 or 200 or more litres per capita per day. Out of this, 5 litres per person per day should be safe for drinking and cooking. As various calculations have shown, the incremental costs to move to higher service levels are relatively low, while the incremental benefits are high (Renwick 2007; Adank et al 2008). Water services to homesteads will enable everybody to use water productively, including the landless and land-poor, elderly, disabled, and sick for whom the homestead is the only site where they can use water for nutrition food security and income. The domestic-plus modality is also appealing because the income gained from productive uses can be used to finance water service delivery. It is noted that the domestic-plus approach raises the issue of differential pricing because productive water uses tend to widen differences in water uses. Some people use considerably more water than others, because they have more land, or are more motivated, or for other reasons. For domestic water uses, the diversity in quantities is considerably less.

In Nepal, the Rural Village Water Resource Management Project and Water Supply and Sanitation Program West Nepal have adopted such domestic-plus approach, and sometimes apply an irrigation-plus or MUS by design modality, all explicitly using existing local government structures (Rautanen et al 2014).

Main objections within the global WASH-subsector to further upscaling are the sub-sector's strong focus on impacts on health through safe drinking water (but not, for example, better nutrition and food security from homestead gardens). Even equity considerations can turn into an objection with the argument that the WASH sub-sector should first serve everybody with just basic domestic water services, before spending money to give more water. Within the constraints of the top-down earmarked finances, it is true that the domestic-plus would require some incremental costs. However, the higher benefit-cost ratio from synergies that would cost-effectively meet both priorities are ignored; such incremental benefits of productive water uses are 'not my job'. Also, the option of targeting the unserved with *better* services of domestic-plus to bridge the gap between the haves and have-nots even more effectively is not considered.

Irrigation-plus

Since long, the integrated nature of water resources to meet multiple needs has been noticed in large-scale irrigation schemes in arid and semi-arid areas. Canals, which also replenish groundwater, are often the main source of water, also for surrounding areas and their users and livestock. The FAO has championed an irrigation-plus approach as part of rehabilitation and modernization of large-scale schemes and developed MASSMUS guidelines (Renault et al 2013). Bridges, washing steps, cattle entry points are the add-ons that enable such other uses, at very low incremental costs. For the many inhabitants of irrigated areas without plots in the scheme, these non-planned water uses area the only way to access the available water resources. As domestic water uses are typically only a fraction of water used for irrigation, domestic water uses are not seen as competing for water resources or risking to widen inequities. But crops remain the priority for the water provided; public support focuses on agronomic training and the provision of inputs and marketing. An often-heard objection against further upscaling of an irrigation-plus approach is that 'an irrigation job is already complex enough'. Equity considerations hardly play a role in the irrigation sub-sector, which, by definition, targets those with land and generally accepts that those with more land are proportionately entitled to more water.

MUS by design

In the modality of 'MUS by design', the explicit intention and funding earmarks are to simultaneously meet people's multiple water needs according to the local conditions. IDE Nepal started this approach in 2001, with pro-active support to improve horticulture and the marketing of produce (Mikhail and Yoder 2008). Winrock International implemented MUS in Tanzania, Niger and other African countries (see Van Koppen et al 2014). From the early 2000s onwards, the development of appropriate technologies and market-led supply chains has been particularly instrumental for the upscaling of MUS by design. Engineers promote all possible uses of water technologies. Solar energy for pumping and other uses is the most recent promising example.

The integration of MUS by design into decentralized local government structuresto enable upscaling is the explicit focus of the project 'Operationalizing community-driven MUS in South Africa', supported by the African Development Bank. The need for an intervention approach that meets rural communities' domestic and productive needs is well recognized in South Africa's National Water Resource Strategy (DWA 2013). This project implements community-driven MUS to learn and to demonstrate and generate the evidence base for later integration in existing local planning processes and financing streams for downstream investments by municipalities and line departments of water, agriculture and rural development, and other organizations.

Implicit MUS in participatory development

Last but not least, in programs that are bottom-up and demand-driven, water interventions that meet multiple needs through multi-purpose infrastructure that is fed by water from multiple sources appeared to emerge spontaneously. This 'implicit MUS modality' was found in India's National Rural Employment Guarantee scheme (Shah et al 2010; Verma et al 2011). The authors describe how this program provided more than two billion person-days of employment to roughly 50 million persons, about half of them women. These workers implemented small, demand-driven and locally appropriate projects of asset creation as defined at decentralized levels. Two thirds of the assets that communities and local government prioritized were for water and drought proofing for multiple uses, managing multiple conjunctive water sources. This included digging and excavation of wells and ponds, pit-latrine digging, irrigation canal rehabilitation, watershed management, groundwater recharge structures, river weirs, forestry, soil conservation, land erosion prevention, flood control, drainage of waterlogged areas, and gulley treatment. With a total value of about USD 3 billion per annum for water, NREGS is arguably the world's largest rural water program *and* implicitly the world's largest MUS program as well.

Other social safety net and employment generation programs but also climate adaptation funds that seek participatory bottom-up formulation of interventions, hold a similar potential. In Zambia, for example, the Pilot Program on Climate Resilience is designed to strengthen local government processes and structures as part of climate resilience interventions. The main activity was the clearing of multi-purpose natural and human-made small drainage canals in the flood plains, used for irrigation, livestock, domestic and other purposes.

Thus, MUS entirely fits the global move towards decentralized decision-making, including public fund allocation. As experiences have learnt, the MUS approach mobilizes more local wisdom than any single-use approach has done. The merits are straightforward, if not 'no-brainers', as follows.

MUS 'NO-BRAINERS'

Communities' water wisdom

MUS is essentially based on what rural communities have been doing since time immemorial to survive and improve their livelihoods and resilience in often harsh ecological conditions. They use water for multiple domestic and multiple productive uses. Obviously, there are priorities, but already at - what are called – 'basic domestic' needs of some 10 litres per person per day, they prioritize the watering of their goats or irrigating homestead crops over an indoor shower, let alone flushing toilets (Jeths 2006; Hall et al 2013). In order to meet these needs, communities take water from multiple water resources, according to their seasonal and annual, and climate-dependent availability: rain, run-off, ponds, soil moisture, wetlands and groundwater. Back-up sources buffer and provide the resilience when main sources are failing. The use and re-use of combinations of these sources taps into the local hydrological cycle, and, as needed, influences this, for example, by groundwater recharge.

Communities invest in infrastructure for self-supply, which is often costly. When they invest they try to meet as many needs as possible to optimize the returns of the investments. For communities, multi-purpose infrastructure is the rule and infrastructure installed for a single use is the exception. An example of a single-use technology could be a groundwater pump in a distant field. This is the logic underpinning the universal observation by professionals: public infrastructure that is designed for a single use is, in reality, also turned into a multi-purpose infrastructure.

The closer look at people and their water uses and needs reinforced the recognition of local water development and management practices, often informally and outside the ambit of the state. Indeed, as both the WASH sub-sector and the irrigation sub-sectors also increasingly recognize, own investments in infrastructure for self-supply remain vital to access water. Building on such self-supply has become a widely endorsed policy.

Moreover, in communities, norms and rules and some specialized organizational arrangement crystallized as local or indigenous water law. Negotiations over access to water between people, each with multiple needs, tend to first aim at synergies and holistic win-win solutions in the broader social context of both hierarchies and mutual dependencies. Negotiation are shaped by the differences within communities, where people have different social and political powers, besides differences based on location near upstream or downstream water sources or groundwater aquifers.

This is not to romanticize all these forms of water wisdom. Dependency on weather and climate remains high and poverty widespread. Socio-economic hierarchies continue, and gaps along gender, class, caste, and migration and settlement lines widen. In sum, public support remains needed. The delivery of such water services can improve if it recognized and built on this water wisdom, for the following reasons.

MUS 'no-brainers' for service providers

In theory, the benefits for service providers of adopting a MUS approach are also no-brainers. They have partly been proven, and are otherwise highly plausible. The question for policy makers and service providers from many backgrounds 'what is in it for me' has at least four positive answers.

First, local knowledge of the hydrological cycle, any existing infrastructure, whether privately initiated or as a result of earlier public investments, and local arrangements about sharing water, pollution prevention and conflict resolution, represent precious assets. Building on these assets is more cost-effective and sustainable than providing water services with the assumption that there is no access to water at all, and that all has to start from scratch. Moreover, starting with what exists ensures locally appropriate interventions that enable next incremental steps. This overcomes designs and practices according to ideal norms (often of an urban middle-class). For example, spring protection and development is likely to lead to cleaner than water from a downstream river that was used for drinking, but may still not meet the high international water quality norms.

Second, following people's needs and priorities for next incremental improvements is a necessary condition for any sustainability of public investments made. That recognition has led to the global move towards decentralization to local government and towards community-driven development approaches, whether as general development program, employment creation program or social safety net programs, or the increasingly more participatory WASH and irrigation projects. Today's development paradigm is clear: nothing about the poor without the poor.

Third, multi-purpose infrastructure generates more livelihood benefits and the incremental costs of moving from a single-use design to a multiple use design are relatively low, for example as a slightly bigger pipe or reservoir; or a cattle through or washing steps in irrigation canals. At higher aggregate scales, no-one would design one big reservoir for domestic uses only; another reservoir for irrigation only, and again another reservoir for hydropower. At community and household level, the same principle applies.

Lastly, planning for multiple water needs can prevent the possible damage and allocation problems of non-planned water uses. By anticipating these needs, and seeking to find solutions upfront, rules can be discussed and integrated in technical designs to better ensure that both head-end and tail-end users get water for domestic and basic productive needs.Such discussion and rule setting during the planning stage greatly enhance the ability to enforce as well.

If the benefits of participatory planning in water development are so obvious, it is even more puzzling why MUS isn't being spreading like wild-fire. We end the paper by exploring this question in some further depth.

THE ACCOUNTABILITY PARADOX

In order to better understand and, hence, to be able to overcome obstacles of the administrative structures to the MUS approach, or to decentralization in general, we focus on the dilemmas faced by even the most honest and competent civil servant or service provider, who seeks to be genuinely accountable about his or her actions, at any national, intermediate and local level. That civil servant or service provider faces 'an accountability paradox' related to public financing streams. Obviously, in the public sector and service provision many other processes of power, politics, colluding interests and corruption take place at the same time. However, as argued below, some of this is strongly related to the current structuring of the public sector, so addressing this paradox can both improve integrity and tap the above-mentioned benefits of decentralized MUS approaches. According to the World Bank (2004), citizens have two ways to exert their power to hold the state and public sector accountable: the long and the short route to accountability (see figure 1).

In order to ensure accountability of the allocated money, departments first have to make proper plans and budgets for envisaged activities that can be monitored to at least some extent. As infrastructure is both the most expensive item in water service delivery and the most visible output, number of boreholes and kilometres of rehabilitated canals promised and factually realized are tangible and meaningful indicators. Implementation planners make ambitious promises to obtain the higher budgets for their departments and personnel. This remains the best negotiation strategy to get the funding.

Once funding is obtained, accountability of spending remains entirely upward. However, processes change. The most efficient way to realize the good scores for the indicators is to focus on the rapid construction of infrastructure. At local levels, envisaged targets are achieved most quickly and cost-effectively through those who already have experience with earlier projects and can well command the mobilization of required labour and, if needed, smooth expropriation of land and water resources already in use. This is the local male elite. Frontline staff that is implementing the projects is not even accountable to these authorities; they are only accountable upwards to their bosses, whether in state structures or private service providers. Any other uses are 'not their job'. In state subsidized schemes, water users have little other power than voting with their feet and underusing or abandoning such infrastructure. In cases of payment of services, users' power may be stronger.

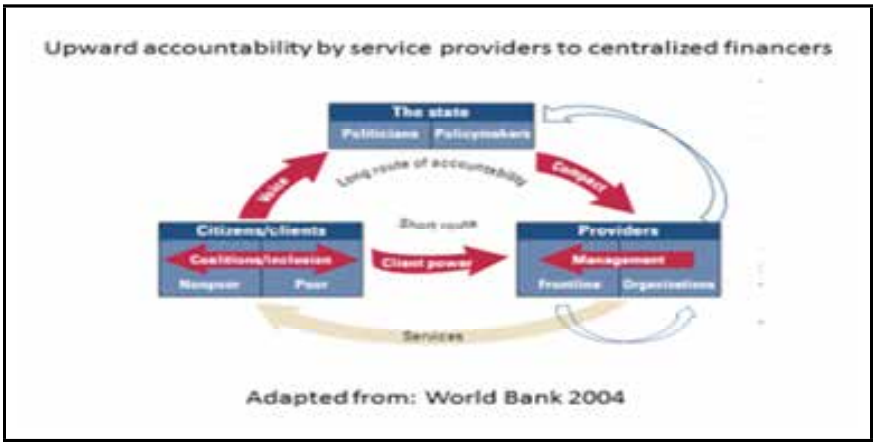

Figure 1. Accountability triangle: upward accountability in sectoral approaches

In sum, continued upward accountability of service providers to realize agreed targets that are defined at central levels in a highly compartmentalized context that sought to avoid overlap and ensure technical expertise. Ironically, this upward accountability among service providers relegates any accountability downward to the long route to accountability.

Participatory planning and its integration in existing government structures, as envisaged by MUS approaches, drastically change these accountability relationships. As indicated in figure 2, downward accountability to users, from the planning phase onwards implies that budget allocation *follows* a phase of participatory planning and funds the outcomes of that process.

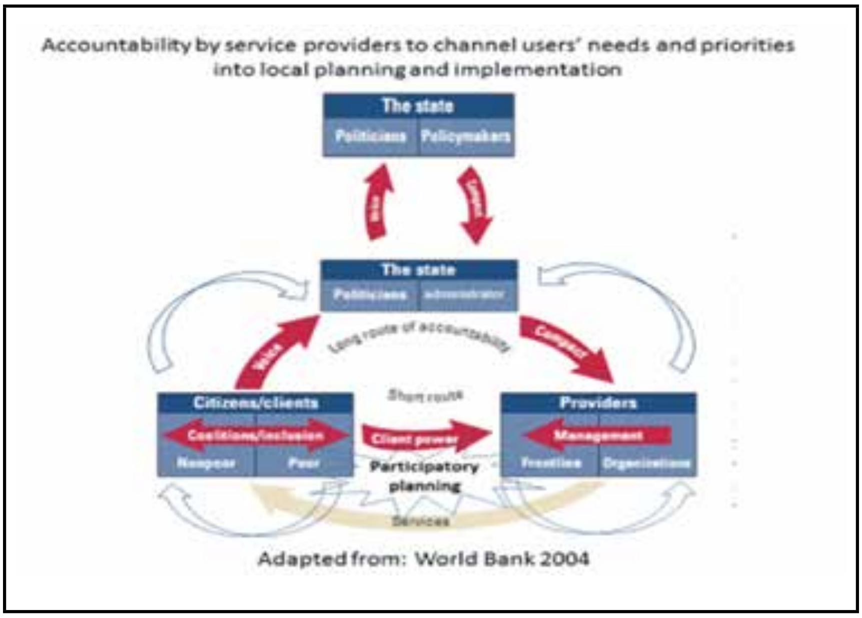

Figure 2. Accountability triangle: downward accountability in decentralized decision-making

For service providers, their roles shift to one of facilitation and strengthening of participatory planning processes, which themselves are embedded in the existing local government and – more or less accountable - leadership structures. Ultimately, the latter will decide, supposedly on behalf of the community. Therefore, accountability downward in service provision includes facilitating participatory diagnosis and problem analysis; informing about the range of technical options and their implications; facilitating communities' decision-making about a specific time- and budget-bound priority; and assistance in procurement and implementation, and monitoring, which, ideally again, would also be driven by communities.

In this process, budgets are allocated at the end of the participatory planning phase. Accountability upward to public funders around pre-determined indicators, is replaced by the guidance and monitoring of a robust, transparent and equitable process over the entire project cycle that is accountable downward to citizens. Accountability requirements of available grants focus on transparent accountability in the processes instead of too narrow goals. This requires unconditional grants or discretionary powers of intermediate-level bureaucrats to combine financing sources from different funding streams. Similarly, expertise remains needed, but should define the scope of the support upfront. Instead, local decision-makers should be able to call in expertise as needed. As for any decentralization of fund allocation, the transformations at stake for community-driven MUS will take decades of learning.

CONCLUSIONS

Communities continue using and re-using multiple sources according to the local hydrological cycle to meet their multiple needs through multi-purpose infrastructure as the rule and single-use as the exception. Villagers, each with multiple needs, negotiate with others to tap synergies and settle trade-offs in accessing water. However, when doing this, class, caste and gender hierarchies may widen, while poverty levels are only partially improved.

This paper highlighted how all water sub-sectors and participatory development programs that seek to alleviate poverty, can benefit from these precious local assets or 'water wisdom'. When the conventional sub-sectors plan for incremental add-ons through domestic- and irrigation-plus approaches, they can tap the high benefit-cost ratios of these incremental investments. Cost-effectiveness and sustainability of public investments are further enhanced by participatory approaches that build on existing assets and follow people's priority needs and solutions. In this way, community-driven MUS renders the global move to decentralization even more relevant, and vice versa: it discovers and taps these assets. Water flows through many dimensions of people's environment and wellbeing in ways that are very location-specific. Public administrations tend to be generic and lack incentives for coordination. Decades of efforts to integrate water management from the top have been largely unsuccessful. People-driven MUS approaches overcome the lack of coordination as well: they mobilize a demand-driven, bottom-up pull for coordination according to people's integrated livelihoods and integrated local water cycles.

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3.2 ECONOMIC IMPACT OF THE MULTIPLE USE WATER SYSTEM APPROACH IN FAR WEST NEPAL

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ABSTRACT

Moving beyond conventional barriers between the domestic and productive sectors, community-based Multiple-Use Water Systems (MUS) provide sufficient water for domestic needs and productive use.[1] This study uses data from the USAID supported Market Access and Water Technologies for Women (MAWTW) project to determine the impact of MUS adoption on smallholder livelihoods, independent of other factors and interventions. Using propensity score matching in a quasi-experimental model with a controlled random sample of project households, we determine that all else equal, having access to water from a MUS contributed US$70 in average household income, which rose to US$190 for MUS farmers who used micro irrigation promoted by the project. In a subsequent study using follow-up data matched to baseline households, we employ a fixed effects model and control for project activities and socioeconomic conditions. We determine that households adopting a MUS earn approximately 51.7% greater income than equivalent households, holding all else equal. Our findings also indicate that MUS have measurable economic benefits beyond agriculture, which may be due to time savings, reduction in water-borne infection, and increased marketing power due to scale of production within a community. MUS also have additional benefits for health, nutrition, and women's empowerment.

[1] Marieke Adank, Barbara van Koppen, and Stef Smits, on behalf of the MUS Group (Feb 2012). Guidelines for Planning and Providing Multiple-Use Water Services.

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3.3 INSTITUTIONALISATION OF MULTIPLE-USE WATER SYSTEMS (MUS) IN NEPAL

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SUMMARY

Multiple-use water systems (MUS) are systems designed to address local people's multiple water needs through a participatory planning approach. Proponents of MUS argue that MUS are more cost-effective and sustainable than single-use systems. In the past, many farmers-managed irrigation systems (FMIS) were also 'MUS' and provided water for a wide variety of purposes, e.g. for livestock, washing clothes and even sometimes for drinking water. However, modern local water systems developed by the government and international funding agencies have been designed for single uses.

For the last decade, several hundreds of MUS that provide water to communities for irrigation, drinking water, micro-hydro, water mills etc, have been piloted and implemented but this implementation has been largely limited to donor-funded projects and there is still little buy-in for MUS from government agencies that are involved in local water resource planning and development.

This study explores the barriers and opportunities for a formal recognition and integration of MUS in water resource planning and development in Nepal. We explore the multiple perceptions of a wide range of stakeholders on what is MUS and the institutional barriers and opportunitiesto upscale MUS sustainably. Our findings show how perceptions are tied to different visions and organizational interests, resulting in a lack of common framing on MUS.

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INTRODUCTION

Traditional water systems that could qualify as multiple-use water systems[3](MUS) have been present in Nepal for centuries, providing with one system water for a variety of uses, ranging from irrigation, livestock, drinking water, water mills and cultural and religious uses. In contrast, the concept of MUS as found today in international water security discourses is relatively recent. It largely came as a reaction of some water professionals in the early 2000s to the observed shortcomings of top-down planning and approaches. These water professionals defended the need for an alternative model for water service provision (van Koppen et al., 2006). Although the concept of MUS has been implemented according to a variety of approaches, it typically involves participatory planning, finance and management of water services for multiple domestic and productive uses and taking people's multiple water needs as a starting point (Renwick et al., 2007). In Nepal, MUS have been championed by International Development Enterprises (iDE), an international non-governmental organization (INGO). iDE has implemented almost 400 MUS as of March 2017. A few other international externally-funded programmes in Nepal have implemented MUS, either providing water for irrigation and domestic uses, micro-hydro or water mills.

Although the benefits of MUS in terms of income generation and sustainability have been documented (Mikhail and Yoder, 2008; Clement, Pokhrel and Sherpa, 2015), its Implementation in Nepal remains largely limited to the realm of international development assistance. There has been little recognition of the concept of MUS within national policies and government agencies, especially in the WASH sector, thereby hindering the implementation of MUS at a large scale. Some funding agencies have also been reticent to invest in MUS, because of a perceived higher complexity compared with single use systems.

However, there are signs of a growing momentum to upscale MUS today, notably following the International MUS workshop held in Kathmandu in February 2016 which led to the creation of a MUS Nepal network. iDE and the Ministry of Population and Environment (MoPE) of Nepal developed a set of MUS guidelines to introduce and upscale MUS as a climate smart technology. At the local level, partnerships between iDE and local government agencies have increased government support to initial MUS investments, notably through village development committee (VDC) block grants.

Recognizing the need to combine a bottom-up and a top-down approach to foster the institutionalization of MUS, IWMI has conducted a study on the institutionalization of MUS in Nepal under the DFID-funded project BRACED-Anukulan, led by iDE. BRACED-Anukulan aims at '*Developing Climate Resilient Livelihoods for local communities through public-*

3 'MUS' has also been used as an acronym for 'multiple-water user services'. In this report the 'S' of 'MUS' refer to 'systems' rather than 'services'

private partnership for 500,000 poor people in western Nepal that suffer from climate extremes and disasters'. MUS is an important component of the project activities as a climate smart intervention. IWMI is a research partner of iDE on this project, conducting independent studies on women's empowerment and on the institutionalization of MUS in Nepal. This report presents the findings related to the identification and mapping of the perceptions of various stakeholders associated to MUS, conducted between December 2015 and March 2017.

ANALYTICAL FRAMEWORK AND METHODOLOGY

We relied on an existing framework on institutional change, which we slightly adapted. Institutional change is understood « *as a difference in form, quality, or state over time in an institution* » (Hargrave and van de Ven, 2006). The literature distinguishes four models of institutional change » institutional design, institutional adaptation, institutional diffusion, and collective action (Hargrave and van de Ven, 2006).

The collective action theory is particularly relevant to the context of this study. It draws from two distinct approaches to study institutional change : how social movements lead to institutional reforms and how technological innovation happens through institutional bricolage. Thecollective action theory posits that change happens through a series of political events that mobilise/frame structures for institutional reforms, brought by networks of distributed actors who interact and engage in collective action. The triggering factor for initiating collective actionis the recognition of an institutional barrier(Van de Ven & Hargrave, 2004).

We draw on the framework developed by Hargrave and van de Ven (2006) for our study (Figure 1). The main components shaping collective action are : 1) framing ; 2) networks and 3) institutions. We added the influence of the political economic context which influences both these three components and the forms of collective action that can take place.

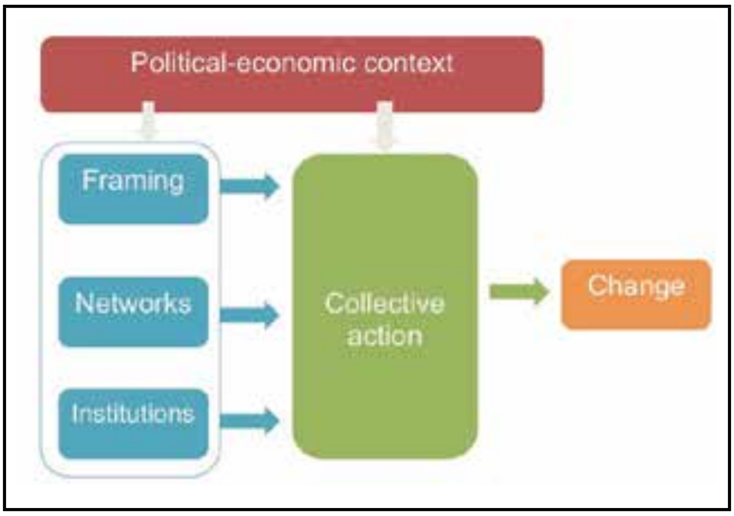

Figure 1. Theoretical framework, adapted from Hargrave and van den Ven (2006)

The way environmental and development issues are framed and defined significantly influences the direction given to institutional change (Hajer, 1995). For instance, framing food insecurity as a result of low agricultural productivity or as a lack of entitlements to food (Sen, 1981) is likely to lead to a set of different policies and institutional arrangements to address this issue. Framings are discursive devices that give meanings to institutional arrangements, notably, by defining which institutions are seen as legitimate to address the problem considered, allocating specific roles to different actors and providing a normative basis for policy action.

Networks of actors are seen as playing an important role in creating and mobilizing organisations and structures. Even though pursuing a common objective, such networks are not homogeneous and have to address tensions related to unequal power relationships, identities and a balance between grassroots participation and top-down authority (Hargrave and van der Ven, 2006).

By Institutions, we mean «...*the prescriptions that humans use to organise all forms of repetitive and structured interaction* » (Ostrom, 2005 : 3). We distinguish institutions from organisations as per the new institutional economics' approach (North, 1990). Existing institutions affect the ability of actors to constitute networks and the rules of engagement of networks of actors to develop collective action.

Lastly, collective action is seen as a political process to give legitimacy to a social or technical innovation. Hargrave and van der Ven (2006) propose to distinguish between two types of legitimacy : the cognitive legitimacy depends on how institutional change fits with existing norms and values whereas the sociopolitical legitimacy relies on endorsements and support of important political actors.

For our study, we conducted semi-structured interviews with a range of stakeholders from government agencies, international and national non-government organisations (INGOs and NGOs respectively), experts and farmers using MUS (Table 1). Stakeholders were selected based on the relevance of their mandate to MUS for government agencies and on their present involvement on piloting MUS in Nepal for INGOs and NGOs. The local interviews with VDC and community were led in Kaski district. Interviews with government agencies and iDE project staff at the district level were conducted in Dadeldhura, Kailali and Kaski districts.

Table 1: Number of informants disaggregated by organizational affiliation and sex

	Gvt	INGOs	NGO	Other	M	F	Total
Central	5	3	4	3	13	2	**15**
Region/District	11	22	-	-	25	8	**33**
VDC	1	-	-	-	1		**1**
Community	/	/	/	8	5	3	**8**
Total	**17**	**25**	**4**	**11**	**44**	**15**	

The interviews explored the definitions and perceptions of MUS among actors, what type of institutional change is needed for upscaling MUS and the perceived constraints and opportunities to institutionalize MUS.

FINDINGS

Framings

MUS is a concept that was 'imported' to Nepal, the use of MUS as a concept to address water management problems in Nepal discourses could be tracked back to iDE's operations in the early 2000s. However, some informants stressed that water systems were already designed for multiple uses long before the concept of MUS enters international and national discourses: "there has always been an effort, at least on the engineering part, to save water so as to maximize the use of water by introducing a simple double tap technology or others in rural areas. This effort was on even before iDE-supported projects introduced MUS formally in some parts of Nepal" (interview, Kathmandu, Sept. 2015). "In the late 1990s, well before the notion of 'community-based MUS' was coined, Helvetas introduced that modality, under the water use management plan or 'WUMP'.

The definition and understanding of MUS varies from one organization to another (Table 2). These perceptions have been documented based on individual interviews and the views are personal to their understanding based on interviews conducted in February 2016.

Table 2: Definitions of MUS from informants

Organisation	Definition of MUS
Department of irrigation (DoI)	MUS could be defined in a manner where we integrate water supply and micro-hydro into an irrigation project and focus on providing irrigation to non-irrigated areas. The same water could be filtered and used for drinking purposes and other usages.
Ministry of Agriculture (MoAD)	MUS is a way to balance competing water uses, to explicitly allocate water for productive uses and it is more resilient because of benefits but needs to be relatively fairly distributed
Department of Water Supply and Sanitation (DWSS)	MUS is a concept which provides drinking water as the first priority to accessing water that is clean and safe, improving the health of communities, protecting environment by managing waste and saving people's time by providing tapped water at the household level. We encourage communities to use wastewater or reuse water for vegetable production.

Department of Local infrastructure Development and Agricultural Roads (DoLIDAR)	MUS is currently linked with small micro irrigation to irrigate kitchen garden. MUS needs to be defined in engineering terms for the water sector in a more planned manner. The main sub-sectors, irrigation, water supply, hydropower generation, need to be linked up in order to provide better services since water is scarce.
NCCSP, Ministry of Population and Environment	Generating employment opportunities and livelihood options in view of the existing water conditions at the local level, this is MUS.
iDE	MUS is defined by iDE as a community led approach where people are at the center of receiving the benefit. MUS was developed with the view that of providing people water through a single water source identified in a village which could be utilized for multiple purposes such as irrigation, drinking and other domestic purposes.
SAPPROS	MUS is different from other existing water systems in Nepal mainly on one count: in this system, issues are led by communities and, in many ways, solutions to the existing problems are solved through their participation. This makes MUS distinct from other systems. The latter may not give space to communities to raise their issues and seek solutions to water problems.
RVWRMP	"A participatory, integrated and poverty-reduction focused approach in poor rural and peri-urban areas, which takes people's multiple water needs as a starting point for providing integrated services."
IWMI	"A participatory, integrated and poverty reduction-focused approach in poor rural and peri–urban areas, which takes people's multiple water needs as a starting point for providing integrated services, moving beyond the conventional sectoral barriers of the domestic and productive sectors" (van Koppen et al., 2006). The rationale for MUS is that most water systemsare anyway used for multiple needs.

Source: Interviews, 2016

The definitions outlined in Table 1 clearly reflect the different mandates and interests of government agencies. For instance, the DWSS stressed the priority to provide drinking water supply whereas the DOI emphasized the irrigation objective and the MoPE view MUS 'as a climate change adaptation option' (interview, Kathmandu, Dec. 2015). In contrast to government agencies, INGOs and NGOs stressed the participatory and community-driven approach of MUS. There are also a few common features in how MUS is framed in Nepal. One of them is that MUS are water systems that support income generation. It is also seen as a cost-effective way to provide water, by providing water for multiple uses through a single infrastructure and system. Lastly, most informants agreed on the lack of awareness of communities on MUS.

Despite mostly being acknowledged as a promising option, the concept of MUS also raises some concerns, ranging from sustainability to equity and water scarcity. In particular, some informants feel that water scarcity is the main constraint to develop MUS in Nepal: '*We try our best to design MUS but it is difficult to get enough water. If water is not enough for drinking water, then a MUS is not possible*' (interview Dadeldhura, Dec. 2016).

Networks

Currently the actors willing to promote institutional change for MUS are INGOs and NGOs who follow different approaches to MUSand have with little exchange/coordination on their understanding of MUS and approaches.In addition, these (I)NGOsengage in their projects with differentgovernment organisations, ranging from VDC to MoWSS and MoPE, with different mandates and interests. There is however a timid move towards a stronger MUS network, initiated by the International MUS workshop held in February 2016. The latter organised by iDE, IWMI and FMIST with the support of the MoPE and the MUS Global Group, gathered all important stakeholders engaged in MUS research and implementation in Nepal and beyond. It formally marked the launching of a MUS Nepal network. One year after the workshop, the MUS Nepal network met for the first time to exchange on experiences and practices and closed on intentions to pursue exchanges and communication on MUS in Nepal through the creation of a website, presence on social media and technical workshops.

Farmers however are not engaged in networks promoting MUS. First, there is no articulated demand of farmers for MUS, as MUS is a foreign concept imported by INGOs. But even if that demand was articulated, there are no local federations that has the capacity, interest and legitimacy to promote the institutionalization of MUS from the grassroots to the national level. Water users federations, namely FEDWASUN and NFIUWAN, are divided by the same institutional siloes than government agencies and have uneven coverage across Nepal and limited representativity compared with their equivalent in the forestry sector, FECOFUN. There are also no federations of farmers organisations that could move the MUS agenda forward.

Institutions

There are different views on the current institutional barriers to upscale MUS. On the one hand, the most active proponent of MUS in Nepal, iDE Nepal country director, feels that major barriers lie in the entrenched institutional siloes that characterise the water sector in Nepal and in the lack ofenabling environment, namely policies. iDE field staff perceive that the main issue is the lack of financial support provided by the government, and notably by the VDC and DDC, for MUS. They also underlined that the Department of Water Supply and Sanitation, the main government agency operating in the WASH sector follows strict guidelines on the design of water supply systems. Their capacity is limited to 45L/capita/day and there is no flexibility to go beyond this.Other development organisations feel the main issue is the lack of monitoring and evaluation of MUS by government agencies,a lack of awareness of the government on MUS or a lack of devolution of funds at the local level.

Most informants from the government feel that the main constraint to upscale MUS is the lack of a legitimate set of guidelines at the central level : '*So far, MUS has not been well grounded on policy. It is being done haphazardly, instead of following a policy. It needs to be moved ahead based on policy*.' '*MUS needs a specific policy for irrigation and water resource policy first. Then they can cover all other related sectors within it*. (interviews, Kathmandu, Dec. 2015 and Feb. 2016).

Whereas IWMI and iDE foresee the need to balance a bottom-up and top-down approach to institutionalize MUS, there seems to limited institutional avenues for a bottom-up movement towards institutionalization as outlined in the earlier sub-section on networks.

Despite these constraints, there are also somewindows of institutional opportunities. Notably iDE has jointly developed with the MoPE national guidelines for MUS. Although their legitimacy is limited to the MoPE – and the MoPE's actions on MUS at the local level are restricted to the Nepal Climate Change Support Programme (NCCSP), the local adaptation plans of action (LAPAs) couldprovide in the future an opportunity to formally recognise MUS as a climate adaptation option and upscale it across Nepal. The viability of this option however highly depends on the sustainability of the grassroots organisations in charge of LAPAs, the District and Village Energy, Environment and Climate Change Coordination Committee (D&VEECCCC) beyond donor-funded projects.

Other INGOs implementing MUS use water user master plans (WUMPs) as the starting point and pre-requisite for MUS planning (Rautanen et al., 2014). Recent guidelines for WUMPs, developed by the Ministry of Federal Affairs and Local Development (MoFALD) and the Ministry of Water Supply and Sanitation (MoWSS) could therefore provide another institutional home for MUS.

CONCLUSION

This study explored the current constraints to sustainably upscale MUS in Nepal based on the analysis of actors' perceptions on MUS. Using the collective action theory to understand institutional change, our analysis highlighted the lack of a shared framing on MUS. This largely reflects the institutional siloes and variety of organisational interests and mandates related to water resource development and management in Nepal.The income generation potential of MUS seems to be however the most prominent common thread and could be used in future discourses on MUS to develop a strong and broad-based narrative. There is also a lack of a clear and common framing on what are the institutional barriers that require to be overcome to upscale MUS in Nepal among stakeholders.The initiation of collective action for institutional change will therefore require actors to initiate a dialogue to identify and agree on required institutional reforms to upscale MUS.

Thenetwork of actors who can promote MUS in Nepal is relatively fragmented. Development organisations, including (I)NGOsand donors, pursue different approaches for MUS and engage with different government partners. Pursuing collective action for institutional change willrequire the network to develop a common identity. Recent activities related to the initiation of a MUS Nepal network mark the recognition of a MUS as a rallying concept for action, at least among (I)NGOs and development agencies. This nascent network will now need to mobilise resources and combine a top-down and bottom-up mechanisms of interaction. The bottom-up approach will probably be the most difficult movement to initiate as farmers do not have the institutional capacity to engage in a network promoting MUS.

Lastly, as collective action is a political process, MUS needs to become an issue for political debate that is given legitimacy by powerful MUS champions.

ACKNOWLEDGEMENTS

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3.4 LOCAL FINANCING FOR FUNCTIONALITY, SUSTAINABILITY AND SERVICE LEVEL IMPROVEMENT – AN OPPORTUNITY FOR MUS?

SANNA-LEENA RAUTANEN[1]

ABSTRACT

This article focuses on local financing of community-managed rural water systems functionality and sustainability in Western Nepal. While Nepal exceeded its Millennium Development Goal target for water supply coverage, in 2014 out of 41,205 piped water supply schemes 68.2% provided services whole year and 25.4% were described as 'well-functioning'. Total 36.1% needed minor repair, 9.2% major repair, 19.8% rehabilitation and 8.6% reconstruction. This equals to 3,791 schemes that needed major repairs, 8,159 that needed rehabilitation and 3,544 that needed reconstruction. This calls for serious attention into existing water supply schemes. This is also an opportunity to bring in the multiple-use of water services (MUS) thinking, should the policy, governance and funding mechanisms allow it. This study utilizes the lessons learned and primary data from the Rural Water Supply and Sanitation Support Programme Phase III (1999-2005), a bi-lateral water supply and sanitation cooperation supported by the governments of Nepal and Finland. These lessons are reflected to the present-day project context, considering the on-going local governance reform in the country. Appreciating the complexity and dynamic nature of the rural water sector, this study provides recommendations applicable for those working with the local governments and communities to integrate and scale up MUS while making the systems functional, sustainable, resilient and adaptive. This article concludes by describing how

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local funding for functionality, service level investments and MUS could be made available at the lowest tier of local governance. This study calls for close collaboration in between the stakeholders working with the farmer-managed irrigation and community-managed water supply systems, also at the policy level.

INTRODUCTION – SETTING THE SCENE

Government of Nepal aimed at universal coverage of basic water supply and sanitation services to its citizens by 2017. While Nepal exceeded its Millennium Development Goal target for water supply coverage, sustainability and full functionality of these achievements remain challenges. Thousands of water supply schemes in Nepal are reaching or have already crossed their expected design period of 15-20 years, and hence call for reconstruction or rehabilitation, or at least service level improvement and/or extensions to respond to the changes in both geo-hydrological and socio-economic environment. Nawalparasi-Palpa WASH Project by the Finnish NGO Water Finns studied 80 water supply schemes supported by the bi-lateral water cooperation Rural Water Supply and Sanitation Project (RWSSP), often referred to as 'Lumibini project' or 'Finnida project'. Here the findings were positive with 68% of the water schemes supported in Phase I (1990-1996), 71% of the schemes supported Phase II (1996-1999) and 64% of schemes supported in Phase III (1999-2005) reported still as 'fully functional'. In this study, 24% needed minor repairs, 34% major repairs and 24% rehabilitation. The most positive finding being that only 5% were reported as not functional at all even if most of them had already crossed their expected design life of 15-20 years. (Adhikari, 2017). The Nationwide Coverage and Functionality Status of Water Supply and Sanitation in Nepal update report in 2014 noted that while the water supply coverage at that time was 83.59%, out of 41,205 piped water supply schemes 68.2% provided services whole year and 25.4% were described as 'well-functioning'. Total 36.1% needed minor repair, 9.2% major repair, 19.8% rehabilitation and 8.6% reconstruction. (Government of Nepal, 2014). This equals to 3,791 schemes that need major repair, 8,159 that need rehabilitation and 3,544 that need reconstruction. All these are opportunities for the retrospective multiple-use of water services (MUS)!

Functionality of the existing water supply systems is a challenge globally. Nepal is not alone with this challenge. Lockwood & Smits (2011) revisited case studies from 13 countries globally, and concluded that *"post-construction support must be adequately addressed and financed, something that has been consistently under-funded to date"* (Lockwood & Smits, 2011). They called for structured systems to support the communities, noting that especially capital maintenance expenditure is "*often ill defined, lacking clarity about who should meet such costs*" (Lockwood & Smits, 2011). Whaley and Cleaver (2017) reviewed literature relating to rural water supply sustainability and functionality. Several studies have been done over the past decade especially in Sub-Saharan Africa. While the dynamics of these water point schemes is different to the piped water networks such as the gravity and lift schemes in rural Nepal, the community management concerns remain the same. Whaley & Cleaver (2017) pointed out that the rural water supply schemes' functionality challenges are not technical-managerial but rather, call for attention to the local socio-technical interface and wider systems of governance.

Overall, there is a lack of long-term financing for water investments in developing countries. Nepal is not an exception: both the national and donor governments invest on capital expenditure, expecting to see new beneficiaries. Capital maintenance expenditure, in turn, is largely ignored. The global policy debate continues about the cost recovery through water tariffs. This paper argues that we cannot expect full cost recovery in rural water supply systems in developing countries, if anywhere at all. We simply cannot assume that once the system is constructed, there is no need for external funding ever, but that community management and water tariff will take care of it forever. The funding support for capital maintenance expenditure is not easily available, if at all. This has led to a situation where it is easier for a community to let its system to degrade beyond repair and request for a new system. As mentioned earlier, there are already now thousands of schemes in Nepal in need of capital maintenance investment, whether it is simply for keeping up with an increasing demand due to population growth and/or higher expectations, or because of the need to replace structures that are simply getting old. These needs are not always because Water Users and Sanitation Committees (WUSCs) are not functional, not committed or reliable, not professional, or not being able to recover costs: they may be well functional and able to cover costs, but not enough for major re-investments.

This study focuses on community-managed rural water systems in Western Nepal. It explores how the urgent need to address functionality and sustainability of rural water supply in Nepal could be used as an opportunity to bring in what is titled here as 'retrospective' multiple-use of water services (MUS) thinking. These existing WUSCs have been providing services for years, sometimes decades. They may even have members who have been involved from the very beginning: these WUSCs are not starting from the scratch. At the time of writing this article, Nepal is going through historical times with major local governance restructuring in process. This could be considered as an opportunity for multiple-use of water services paradigm, given the role of MUS in local development and rural livelihoods.

OBJECTIVES AND METHODOLOGY

The main objective of this study was to explore what kind of local financing mechanism and related policy changes could allow for cross-sectoral investment in the context of water supply systems rehabilitation, reconstruction and service level improvements? This paper focuses in local financing while acknowledging that this is not the only challenge. There are several other factors, such as technical, socio-cultural, livelihoods-related, and environmental realities that may limit equitable retrospective MUS application to drinking water systems. The retrospective MUS could be studied in further detail using such as sustainable livelihoods framework, with specific attention to vulnerabilities as well as the usual livelihoods assets.

This study utilizes primary data, progress reports and other project materials from the bi-lateral water supply and sanitation projects supported by the governments of Nepal and Finland: Rural Water Supply and Sanitation Project in Western Nepal Phase II (RWSSP-WN II) and Rural Water Supply and Sanitation Support Programme (RWSSSP III) which was called Rural Water Supply and Sanitation Project in its phases I and II. The recommendations made in this paper are directly relevant for RWSSP-WN Phase II. The purpose-level indicator 2 is "*All water supply schemes supported by the project provide functional, improved and safe water supply services*". This paper contributes to RWSSP-WN II Result 2 "*Access to safe, functional and inclusive water supply services for all achieved and sustained in the project working VDCs*" and Result 3 "*Strengthened institutional capacity of government bodies to plan, coordinate, support and monitor the WUSCs and other community groups in the implementation, operation and maintenance of domestic water, sanitation and hygiene programmes in a self-sustainable manner.*"

Box 1. Definitions

Capital expenditures –hardware and software (Cap.Ex.): The capital invested in constructing or purchasing fixed assets such as concrete structures, pumps and pipes. Investments in fixed assets are occasional and 'lumpy', and include the costs of initial construction and system extension, enhancement and augmentation. Cap.Ex. 'software' includes once-off work with stakeholders prior to construction or implementation, extension, such as costs of once-off capacity building.

Operating and minor maintenance Expenditures (Op.Ex.) include labour, fuel, chemicals, and materials. Minor maintenance is routine maintenance needed to keep systems running at peak performance, but does not include major repairs.

Capital maintenance expenditure (Cap. Man.Ex.): Expenditure on asset renewal, replacement and rehabilitation costs, based upon serviceability and risk criteria. Cap.Man. Ex. covers the work that goes beyond routine maintenance to repair and replace equipment to keep systems running. (…)

Expenditure on direct support (Exp.DS.): includes expenditure on post construction support activities direct to local level stakeholders, users or user groups. The costs of ensuring that local government staff have the capacities and resources to help communities when systems break down or to monitor. (…)

Source: Fonseca et.al, 2011

CONCEPTUAL POINTS OF ENTRY

This study takes the Service Delivery Approach (SDA) as the conceptual approach to the provision of rural water supply services. SDA acknowledges that at the beginning, there is a capital-intensive period which is followed by the service delivery itself. The latter aspect is often ignored in the sectoral debates where most of the attention, and with it, also funding, goes for the new water supply schemes. Both the national and donor governments are more eager to report new beneficiaries. Consequently, 'serving the unserved' guides many rural water supply projects and programmes. While this target is highly appreciated, there should be equal attention to those who are already served: if the functionality aspect does not get the attention it needs, there will be even more unserved people when the existing services degrade beyond repair.

The service delivery aspect has to enter the policy discussion, drawing attention to such activities such as operations and maintenance (O&M) and administration aiming at the continued delivery of a service over time. This can include physical interventions to update, expand and eventually replace physical assets (above ground structures, storage tanks, transmission pipes and pumps), as well as extending the services to households initially un-served, or by a major upgrade of the service, e.g. adding another water source (Lockwood and Smits, 2011). SDA emphasises "*the entire life-cycle of a service, consisting of both the hardware (engineering or construction elements) and software required to provide a certain level of access to water*." SDA calls for continued investments to both capital maintenance and operational costs. (Lockwood & Smits, 2011).

For MUS, this article utilizes the definitions provided by van Koppen et.al (2006). These authors in their much-cited definition describe MUS as "*a participatory, integrated and poverty-reduction focused approach in poor rural and peri-urban areas, which takes people's multiple water needs as a starting point for providing integrated services, moving beyond the conventional sectoral barriers of the domestic and productive sectors*" (Van Koppen et al., 2006; in van Koppen et.al 2009). In this definition, the last 'S' stands for Services and is here linked to above mentioned SDA. The authors define 'water service' as "*the sustainable provision of water of a given quality and quantity at a given place with predictability and reliability*" (van Koppen et.al 2009).

They further acknowledge that "services have hardware and software components. Hardware components of water services concern infrastructure or technology – and include issues such as technology availability, spare-parts, engineering skills, or water resources assessments. Software refers to all the non-hardware related issues, such as support for institution building (leadership, rule setting and enforcement), water allocation and conflict resolution. Linkages to other services that enhance the benefits of water use, such as hygiene education or marketing support, are other important components." The authors further see services as something that is continuous and caters for post-construction technical and institutional support. The authors note that in principle; MUS should reach the poor and marginalised. (Van Koppen et.al, 2009:28). Inclusiveness and equity add another layer of intrigue also for this paper: is it MUS for all, or MUS for some?

The following chapter utilizes the definitions as given by Fonseca et.al (2011), and as summarized in Box 1.

FINDINGS – COST ITEM BY COST ITEM

This chapter reflects the findings by using the key components of SDA and related life-cycle costing as sub-headings as defined in the Box 1, then reflecting what kind of financing mechanism caters for these.

Capital Expenditures (Cap.Ex.) includes both hardware and software. The traditional support for infrastructure has focused on directing public funding to Cap.Ex. or other inputs used by public (or private) providers, with payments and instalments to WUSCs based largely on costs incurred. In the Nepal local government system the proposed schemes go through the local government planning cycle on annual basis, the availability of funds (at the central level) influencing what gets eventually funded and what does not. The planning process takes over a year. At the same time, there are numerous off-budget programmes and projects which may or may not go through the local government planning process. Quite often small NGO project simply do not have time to go thorough it. Shrestha and Wicken (2008) noted how most drinking water and sanitation-related expenditure in their study district was outside of the local government budget, and that the off-budget investment by the Department of Water Supply and Sanitation (DWSS) office represented 45% of total expenditure and expenditure by local NGOs. In contrary to many others, the Finnish supported bilateral water projects have channelled their funding through the local governments and on-budget since 1999. The focus being heavily on Cap.Ex. and new beneficiaries. The bi-lateral water project in Nepal have been using the local government-level 'District Development Funds' for funding the Cap.Ex. to WUSCs since 1999.

Expenditure on Direct Support (Exp.DS.): As described in Box 1, Exp.DS includes such as expenditure on post construction support activities, both to WUSCs and local governments. In the bi-lateral water projects, the post-construction support was often funded under the Cap.Ex. heading, but over the past three years, there has been a separate sub-budget heading for the capacity building taking place through the local government funds. At the same time, the local government staff and government official level trainings have been funded through the donor and its Technical Assistance budget capacity building and governance headings. Some of these have been joint ventures with the relevant government authorities, such as training for the local government accountants in using the new accounting software while addressing the programme specific fund flow issues. Overall, Exp.DS. has been fragmented, and somehow piece-meal and perhaps not as results-oriented as it could have been. There has been national WASH sector efforts to address programmatic and sector-wide capacity building needs, but these have not influenced the local government level units as yet. In the future, the expenditure related to the post-construction support needs to get more harmonized, aligned and results-oriented than what it is now, in addition to having a Exp.DS. budget of its own right.

Operating and minor maintenance Expenditures (Op.Ex.) include such as village maintenance worker (VMW), electricity, spare parts and other materials needed to keep the system running. Minor maintenance is routine maintenance needed to keep systems running at peak performance, but does not include major repairs. (Fonseca et.al, 2011). WUSCs need to be able to collect some cash and this cash needs to keep its value, stay safe and be available when it is needed. RWSSP-WN has realized that the "normal" banks where WUSCs have opened their accounts for the initial investment funds are not the long-term solutions. Firstly, these banks are often located in the district headquarters, far from the villages. Consequently, these accounts tend to remain idle, eventually losing the interest that may have been minimal in the first place, and eventually the entire value due to inflation. Secondly, many of these banks do not offer any interest at all but on the contrary, may even charge an administration fee. In these cases, the value decreases even quicker. Some WUSCs mobilize their O&M fund as an informal saving-and-credit fund in the community, but this is not necessarily safe and sustainable option either, a formal cooperative would appear as more safe and having better financial discipline. In short, WUSCs are very rarely if ever able to accumulate up-front funds for any Cap.Man.Ex given that they are already struggling with Op.Ex. Yet, Op.Ex. would be the fund directly associated with MUS and livelihoods. The livelihoods context could make people both willing and able to pay water tariffs, as well as get them interested in revolving funds or services provided by a local cooperative in developing their businesses. As a WASH sector, we need to stop encouraging WUSCs to collect idle capital that looses its value in a bank.

Capital Maintenance Expenditure (Cap.Man.Ex.) includes expenditure on asset renewal, replacement and rehabilitation costs, based upon serviceability and risk criteria. Cap. Man.Ex. covers the work that goes beyond routine maintenance to repair and replace equipment to keep systems running (Fonseca et.al, 2011). In case of Nepal, a lot of the investment under 'needs major repair', 'needs rehabilitation' and even some cases of the 'needs reconstruction' fall under this item. However, funding is not available for WUSCs. In the bi-lateral cooperation a lot of this is funded under post-construction support for the project affiliated schemes. This is possible for a long-term project such as RWSSP-WN, but it is still not institutionalized in the local structures as something that could be described as 'regular service to any WUSC'.

LEARNING FROM THE PAST - LOCAL FUND-FLOW MECHANISM

The Nepal-Finland bi-lateral water project have since RWSSP II (1996) been operating through the District Development Funds (DDFs) until now. At the time of writing the article, the role of the District <u>Development</u> Committees (DDCs) is radically changing into District <u>Coordination</u> Committees, shifting also the fiscal responsibilities into the newly established Gaunpalikas (Rural municipality, hereafter referred to as GP) and Nagarpalikas (Urban municipality, hereafter referred to as NP). This article considers that it is the time and the opportunity to bring the different life cycle cost elements as discussed in the previous chapter, together, and to explore how the different life-cycle costs could be financed at the local level. This could provide context-specific support for WUSC to introduce retrospective MUS.

RWSSSP Phase III ('Lumbini project') had two financing modalities, the '50:50 Fund' which was planned through the usual Government of Nepal process through central treasury, and the 'Self-Reliant' fund where the DDC contribution was matched with the Government of Finland contribution (Figure 1). '50:50' schemes received funds from the Governments of Nepal and Finland through the central treasury and related authorization process even if in practice the Government of Finland funds were directly deposited into DDFs. This is the current practice in the bi-lateral water projects at present. 'Self-Reliant' schemes, in turn, received funds from DDC and Finland only, again through the same DDF. At the time this was called 'District Water Supply and Sanitation Development Fund'. 'Self-Reliant' schemes did not go through the heavy planning process that is better suited to large investment schemes rather than large number of small schemes and training. Towards the end of RWSSSP Phase III, about half of the schemes were 'Self-Reliant' schemes, these including numerous rainwater harvesting, point-source improvement, and sanitation schemes, see Box 2.

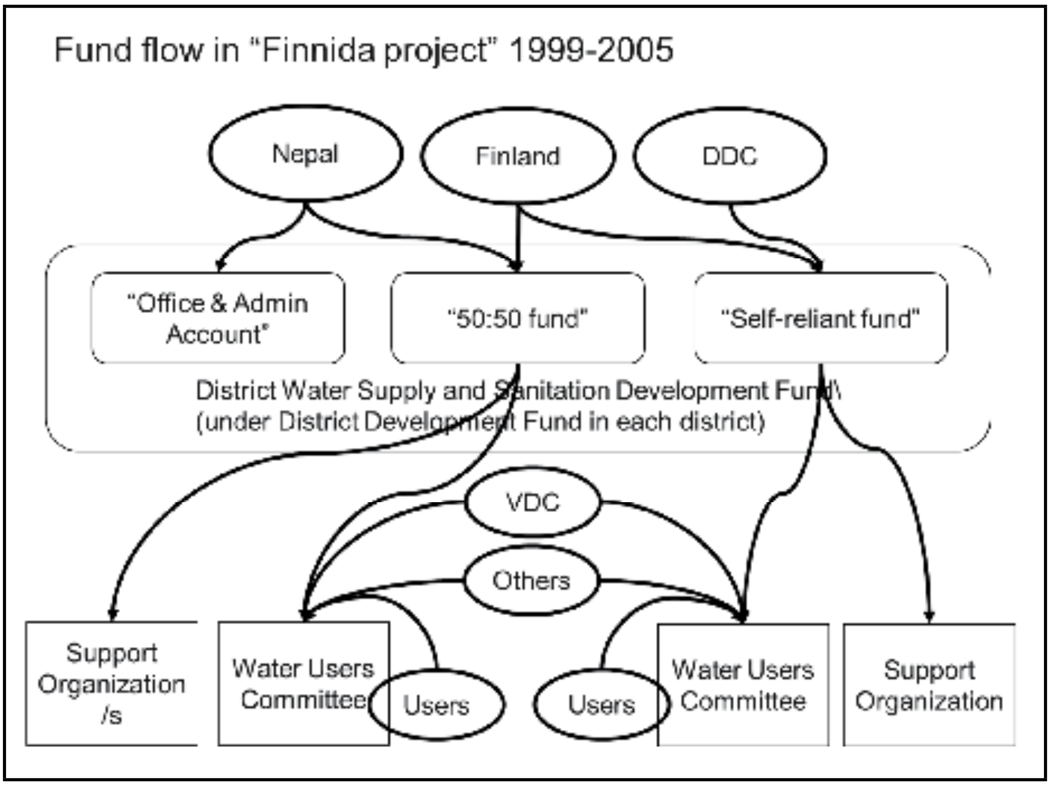

Figure 1. Fund-flow for Cap.Ex. in RWSSSP III in 1999-2005

In the RWSSSP Phase III the total of NPR 48 million (equivalent of 4 million Finnish Marks) were allocated as a lump sum for the entire Phase III for the self–reliant activities. For the first fiscal year of Phase III, an amount of NPR 1 million was budgeted for each district, and the DDCs were expected to match this, hence having a total NPR 2 million self-reliant fund at their disposal during the first year. Thereafter the total amount of the fund depended upon the volume of activities and implementation capacity of a district, and of course, the district's willingness to allocate matching fund: "*Each participating DDC in the Programme area had to contribute its share to this account on a mandatory basis. A DDC classified as "Focus District" should allocate at least 20 per cent of its annual total net internal revenue to this account and at least 8 per cent by other DDCs. In this manner, a total of NER 18 million is estimated from the participating districts. Financing from this account demands contributions from other actors too*" (RWSSSP III, 2001). The Finnish contribution to the Self-Reliant account could range from 0 to 40% of the total cost of an individual scheme. In practice, the local contributions were even more, indicating the strong commitment especially from the users themselves to contribute especially in kind. The RWSSSP III (2001) also noted that "*the Finnish share should be retained at 25 per cent only on the average of the total cost at the district level. The wide range of 0-40 percent contribution from this account is to allow the flexibility to extend more support to the poor and disadvantaged communities. Existing financial rules and regulations pertaining to the Local Self-Governance Act, 1998 will apply while administering this account*" and "*DDC and Finnish side put their respective shares in the Self–reliant account on instalment basis. The Self-reliant activities should be endorsed by the District Council. DDC rules and regulations should be followed in funding of the activities*" (RWSSSP III, 2001).

RWSSSP III and Self-Reliant Fund in 2004 – Captions from the Executive Summary and recommendations

RWSSSP was a joint endeavour from His Majesty's Government of Nepal and the Government of Finland to serve the rural poor in providing safe and adequate water supply and sanitation facilities in all six districts of Lumbini Zone since 1989 and extended to Parbat and Tanahun, in 2001. MLD/DoLIDAR, DDCs, VDCs, SOs and Users' are the major stakeholders of the Programme. The Programme follows two types of funding models: 50:50 and Self-Reliant. The second type of funding model was introduced in phase III of the Programme in order to mobilize additional local resources for the establishment and operation and maintenance of facilities so that the gradual withdrawal of external support is possible to achieve self-reliance, to enable cross-subsidization among the communities with unequal economic base so as to establish social equity and to provide technical back-up to the local governments to exercise more power on decentralization in terms of water supply and sanitation activities. A total of NER 66 million was planned to mobilize through this funding modality excluding contributions from VDCs and Users. This report is the result of a desk study commissioned by RWSSSP to measure the applicability of the approach. Funds were allocated to the districts on a demand-led system in consultation with DPMT considering the absorbing capacity of the districts and were released on instalment basis upon the request of DDC after the later has deposited the committed fund in Self-Reliant Account. (…) Coverage of completed Self-Reliant Schemes at present share 51% of the total population coverage by the Programme which will be stand at 54% after the completion of all ongoing activities. Variation in per capita cost of two modality confirms that Self-Reliant Model is cost effective, economical and efficient in comparison to 50:50. (…) Flexibility in terms of planning and implementation is the greatest strength of the Modality. The modality strongly supports to the process of decentralization and is amicable to mobilize additional resources from local level. Indicative results signify that the model has been instrumental to internalize the concept from local governments due to increased responsiveness towards local people exerted from the modality. The modality provides enough room to address the issue of poverty. (…) *Source*: Aryal, B.B. 2004.

Box 2. RWSSSP III and Self-Reliant Fund

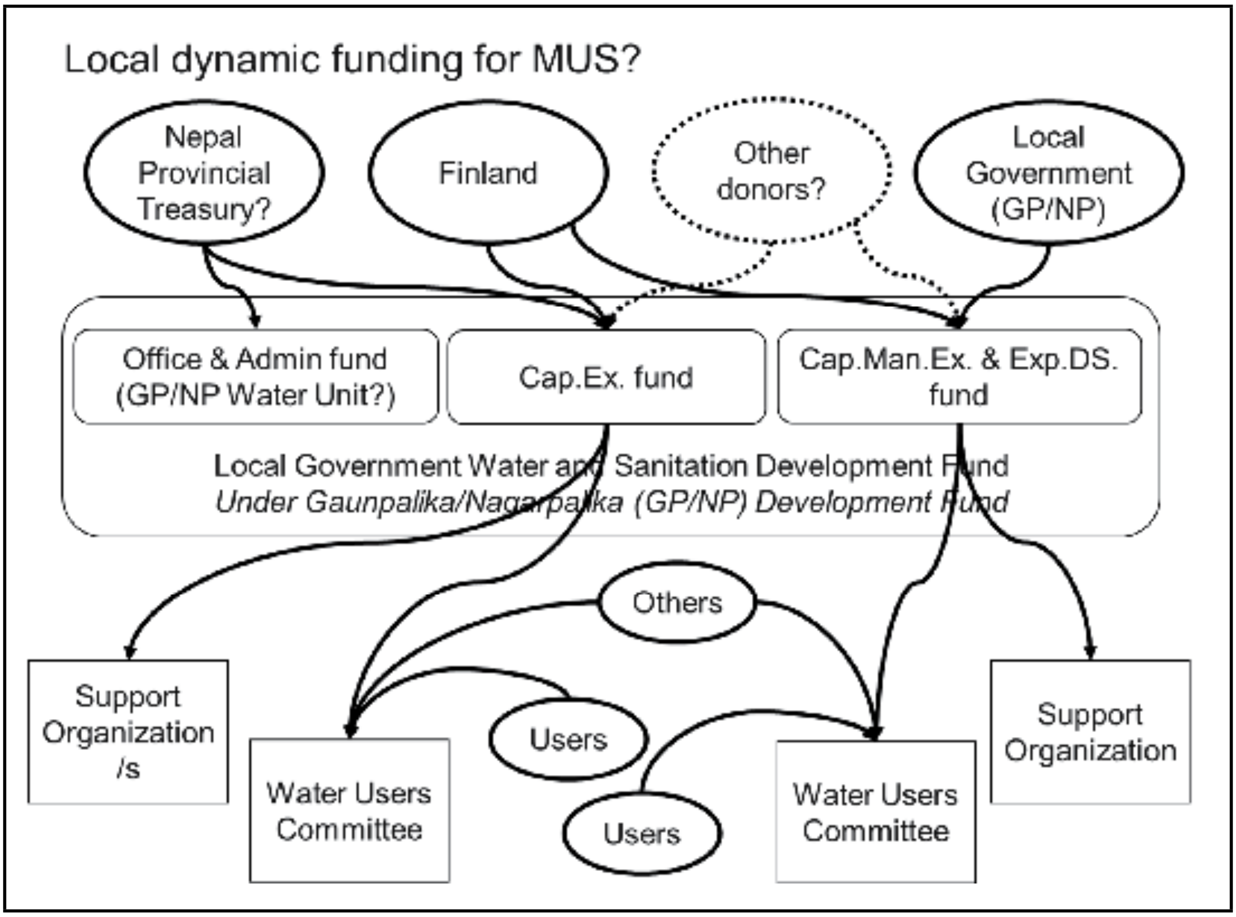

Figure 2: Proposed Fund-flow for Cap.Ex., Cap.Man.Ex. and Exp.DS

Figure 2 translates the Figure 1 into the proposed fund flow that could make MUS available at local level while addressing various functionality and service delivery issues. In Figure 2, Cap.Ex. goes through the treasury for large capital investments representing the earlier '50:50' fund, and Cap.Man.Ex. together with Exp.DS. being raised largely from local resources representing the 'Self-Reliant' fund. In Figure 2, the Support Organizations are an option where the GP/NP Water Unit cannot recruit or even should not recruit specific type of staff. Retrospective MUS may call for very specific technical or other skills, such as value chain development. These may be scheme-specific service, or completely off-water sector, for instance agriculture or business oriented services that serve one or more users groups. Therefore, it cannot be expected that there would be regular staff in GP/NP Water Unit that can provide such services. This is an option, perhaps selected depending on the context, scheme by scheme. Figures 3 and 4 give details on what could be funded under the main headings.

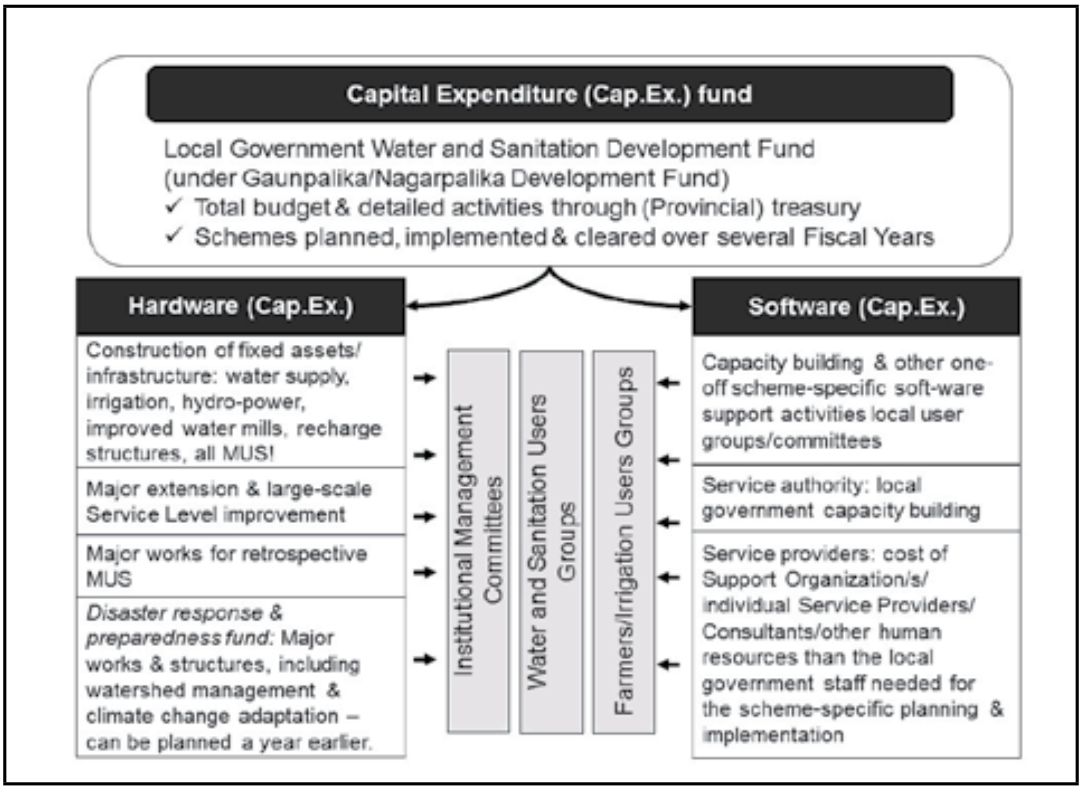

Figure 3. Closer look at Cap.Ex. in the proposed model

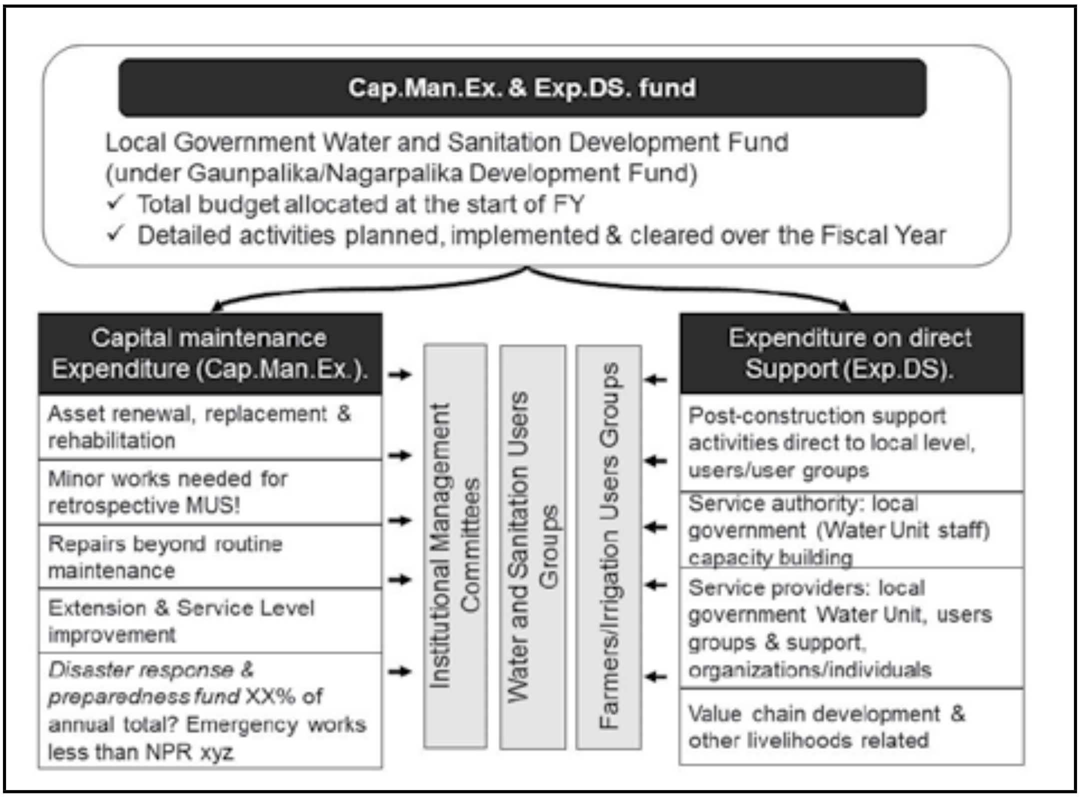

Figure 4. Closer look at Cap.Man.Ex. and Exp.DS. in the proposed model

CONCLUSIONS AND RECOMMENDATIONS

Rural water systems, whether for drinking water supply, irrigation, hydro-power or milling, face a number of long-term financing challenges both for Op.Ex. and Cap.Man. Ex. Most WUSCs struggle to cover even their basic operating costs, in too many cases at break-even point. Too many services are degrading, eventually providing only a fraction of the services or no service at all, continuously depending on the external funding for keeping them running or rather, constructing them again as new schemes simply because Cap.Man.Ex. funding is not available. The smaller the need, the less likely it is that a WUSC will get support for it. At the same time, the full cost recovery principle is unrealistic, given that in many developing economies, including Nepal, the inflation rate alone undermines the savings. The contribution pattern and related cross-subsidization need to stay flexible to allow for the situations where those who CAN contribute, contribute; and those who CANNOT contribute, get more subsidy or other support. The criteria should be very clear in this regard. For instance, if the proposed scheme is about adding private connections to an existing water supply scheme, the users should contribute more than if the scheme serves a disadvantaged small group of households who have never benefited from water supply. In case of MUS, it may be possible that not all benefit the same way and hence, should not contribute the same way either.

The proposed strategy here is described in Figure 5. This adds a local financing institution, whether a local cooperative or a development bank, into the earlier Figure 4. In this system, the payment for the functionality and MUS are partly based on soft-loan, only part of it qualifying as a grant (subsidy). In this strategy, the service providers (WUSCs) are paid partly through grants and partly through soft-loan (revolving fund with 0% interest rate) only after they have initiated the process by themselves and delivered technically sound plan which specifies the outputs. Those who can act immediately, and get funds from the local financing institution to act immediately, eventually being rewarded with an out-put based grant or similar from the local government managed Cap.Man.Ex. fund. Since the cases are not fixed in advance but remains responsive throughout the year, the service providers' incentives for efficiency and innovation are strengthened: they do not need to wait passively and helplessly over a year to find out whether or not their needs are responded to.

The scheme contribution pattern is tailored in each case, acknowledging that not all may benefit the same way. There may be for instance one specific group who will benefit from the additional irrigation facility, but not all, both in terms of one-time payment for Cap.Ex. and in terms of paying back the soft loan through the water tariffs as part of the operating expenditure (Op.Ex). The extent to which payments are subsidies or to what extent they are soft loan to be paid back, is determined case by case. Making the subsidies (grant) and the loan (revolving fund) amounts explicit, context specific and output driven, would give room for case and context specific targeting: those who can pay more, should pay more. Those who can pay back quicker, pay back quicker

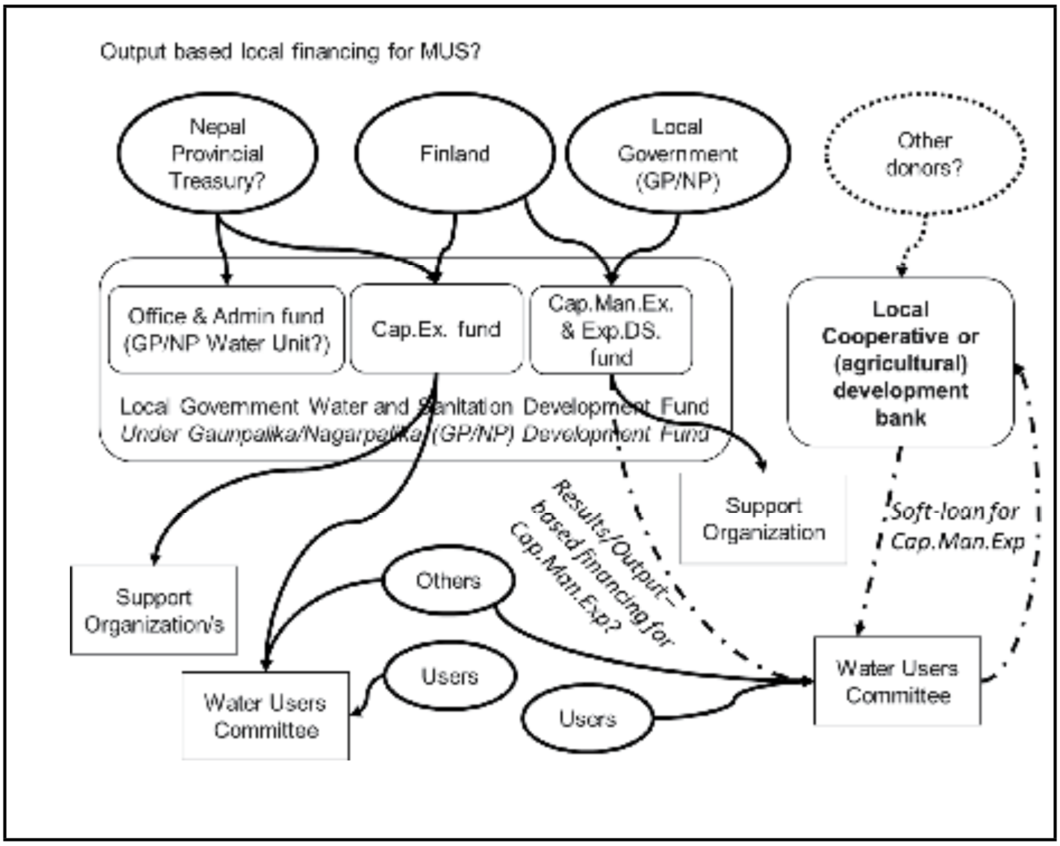

Figure 5. Adding results-based thinking and local financing institutions

Needs for local financing of Cap.Ex. and Cap.Man.Ex. raise within a dynamic environment. The types of needs are likely varied in between the years and over the year, especially if the fund is supposed to respond also to such as emergency repairs after natural disasters. For example, if the local governance area experience one major flood over one specific year, it is likely that several water schemes, water supply and irrigation alike, are affected, resulting all the related WUSCs to apply for the emergency repair funds during the same year. On the other hand, works related to extensions and service level improvements are more predictable and can be planned over several years, prioritizing schemes with some local criteria. Understanding the factors which influence these local needs is important, and best planned at the local level where the both explicit and tacit knowledge should be the best. Appreciating the complexity and dynamic nature of the rural water sector, this article recommends to integrate and scale up MUS while making the systems functional, sustainable, resilient and adaptive by making local funding mechanism available through the local government structures. This study calls for close collaboration in between the stakeholders working with the farmer-managed irrigation and community-managed water supply systems, also at the policy level. Access to finance should be made easier for committed WUSCs that truly want to improve their services, whether as a service level improvement, coverage extension or both.

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4. CLIMATE CHANGE AND METHODS OF ADAPTATION AND APPROACHES FOR INCREASING RESILIENCE

4.1 GUIDELINES FOR WATER MANAGEMENT OF HIGHLAND AGRICULTURE IN MAE SA NOI VILLAGE, PONGYANG SUB-DISTRICT, MAERIM DISTRICT, CHIANG MAI PROVINCE

NATHITAKARN PINTHUKAS[1]

PREFACE

Water is the essential natural resources to life and becomes more essential in the future due to the increasing number of people while the quantity and quality of water are limited. In the past, Thailand possessed the fertile water resources so the people used water recklessly. Resulting from that, water was inefficient like in the past and lack of water occurs and causes the following problems such as argument among farmers or among water users from different agricultural departments (agricultural part or industrial part). It is important to improve the water management system with the most effective way. Under the sustainable developments, all, governments and normal people seriously participate in water resource management (Pramote, 1997). Human use water in daily life to wash , to cook, and for the agricultural and industrial purposes. Furthermore, water is also used to produce electricity, to be a part of transportation, relaxation, fisheries, food resources for aqua life and plants, and to maintain the natural balance (temperature, rain quantity, gas in the air).

The result from ineffective water management caused conflict among water users when it comes to the crisis. Conflict happens in many groups such as conflict within agricultural department,

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conflict between agricultural and industrial group, and conflict resulting from pumping underground water for agriculture. This study was associated with water conflict in agricultural department which was unequal water allocation between farmers that lived the nearest and the furthest from the water station. This problem was often found in summer or during crisis, resulting in inadequate water to the need of the farmers living the furthest from the water station.

Mae Sa Noi is a Hmong village (Hmong is one of tribes in the northern part of Thailand and the countries nearby, and is in the Thai-Hill tribe group), located at the 1,200 meters above sea level in Maerim District, in the northern part of Chiang Mai since 1967. After moving from the old Mae Sa village due to drought in 1981, DoiPui National Park had announced that Mae Sa Noi is a village within the National Park Area with 717 people, 120 families, and is also the biggest Hmong community in the northern part of Thailand. Due to being situated in the National Park, Mae SaNoi villagers are allowed to do the planting in the limited area which they had been cultivating before the announcement (easily-found situation). In the past, villagers grew opium but in 1970, all kinds of addictive were purged so they gave up growing it. At present, villagers grow lychee, corn, lettuce, and carrot instead of opium. Compared to the opium, this kind of agriculture takes more area to grow so villagers trespass the forest and lack of water becomes a next problem both in the village above and the village down. Moreover, landslide, and decreasing numbers of wildlife also occur.

Resulting from those reasons, the researcher is interested to study in this issue related to the participation of farmers' group in water management. It is considered as important matter to the farmers' cultivation, adaptation to the changing climates, co-operation in adequate water allocation for growing, and also provides the guidelines to use water ultimately and effectively, and prevent the argument about water. The researcher hopes that this research would benefit the farmers and the organization related to and would be the water management guidelines for the farmers to achieve their objectives.

DOCUMENTS CHECK

To study the guideline of water management in Highland of Mae Sa Noi, Pongyang Sub-District, Maerim District, Chiang Mai Province, researcher had summarized the relevant idea, theories, literature review, and the studies etc:

1. The idea of the strong communities
2. The idea of river management; people, communities, and river
3. The idea of water and drought management
4. The idea of public policies' implementations

PROJECT'S OBJECTIVE

1. To study the participation in water management for agriculture in Mae Sa Noi, Pongyang Sub-District, Maerim District, Chiang Mai Province
2. To analyze the problems and obstacles of water management for agriculture in Mae Sa Noi, Pongyang Sub-District, Maerim District, Chiang Mai Province
3. To provide the guidelines of water management for agriculture in Mae Sa Noi, Pongyang Sub-District, Maerim District, Chiang Mai Province

TOOLS AND METHOD

The tools in this research were divided into 3 parts:

1. The meeting with the people concerned by analyzing the farmers who use water and to understand their role, obligations, and the main purpose related to water management
2. Use of the semi-structure questionnaire and in-depth interview with the farmers, who use water. The main informants were: the president of people who use water, the board, and farmers who use water. The questionnaires are separated into three parts including: (1) the questionnaire related to the farmers' participation in water management, (2) the questionnaire asking about adaptation and solving the problem of lack of water, and (3) the questionnaire asking about the problems and obstacles in farmers' management.
3. Holding the small forum with people concerned with using water and to exchange the idea together: again informants were the president of people who use water, the board, and farmers who use water to.

DATA COLLECTION

Focused interview is used in this research by researcher and co-researchers. 50 families were interviewed as the sample group:

1. Researchers exchanged the idea with the president of users, the board, and farmers who use water in order to inform them the main purpose of doing the survey about their opinion towards the participation in water management for agriculture.
2. Data collection by interviewing 20 minutes per person from each family in January 2016.
3. The semi-constructed questionnaire was brought to be examined and analyzed.

DATA ANALYSIS

The researchers examined and encrypted the semi-constructed questionnaire to analyze the information through the processing program:

1. Analyze the semi-constructed questionnaire of each person through frequency, percent and free variable.
2. Analyze the problems and obstacle in water management for agriculture and provide the guidelines of water management for agriculture.

RESULTS

It was found that more than half of people from the sample group in this study, water management for agriculture in highlandin Mae Sa Noi, Pongyang Sub-District, Maerim District, Chiang Mai Province, lacked water for agriculture due to water resources shortage (52.0%), and climate change (48.0%) (1^{st} Table)

Table 1: Reasons of Water Shortage

N=50

Reasons of Water Shortage	Total Number (person)	Percentage
Deforestation	**0**	**0**
Climate change	**24**	**48.0**
Lack of water resources	**26**	**52.0**
No water management from community andpublic agency	**0**	**0**
Increasing numbers of agricultural area	**0**	**0**
Increasing number of population	**0**	**0**
Developing projects of public agency for economiccrops	**0**	**0**
Total	**50**	**100.0**

Table 2: Problems from Using Water for Agriculture

N=50

Problems Condition	**Level of Severity**					**Level of Opinion**		
	5	**4**	**3**	**2**	**1**	**Mean**	**S.D.**	**Meaning**
Public agencies do not cultivate the conscience for caring the water resources to in farmers.	0	0	26 (52.0)	11 (22.0)	13 (26.0)	2.26	0.853	5 = The most severe 4 = The average severe

Lack of cooperation from related agencies	0	0	18 (36.0)	26 (52.0)	6 (12.0)	2.24	0.657	3 = Medium severe
Public agencies do not have plans e.g. digging a pool, building the reservoir for resolving the lack of water and for agricultural water or have plans but not responsive enough to the problems and the farmers' need.	0	5 (10.0)	23 (46.0)	20 (40.0)	2 (4.0)	2.62	0.725	2 = Less severe 1 = The least severe

AGRICULTURAL WATER MANAGEMENT IN THE PRESENT

It was found that more than half of people from the sample group in this study (water management for agriculture in highland in Mae Sa Noi, Pongyang Sub-District, Maerim District, Chiang Mai Province), built the dam in the agriculture area (58.0%), dredge the pound, canal, and marsh (20%), built the reservoir (12.0%), and built the dam (10.0%).

Table 3 Water Management for Agriculture at the Present

N=50

Water Management	Number (person)	Percentage
Building the reservoir	6	12.0
Building the dam to save the water	5	10.0
Building the pool in the farm	0	0
Building the check dam	29	58.0
Building the irrigation system	0	0
Digging for ground water	0	0
Pumping water projects	0	0
Making artificial rain	0	0
Dredging the pond, canal, and marsh	10	20.0
Raise awarenessfor conserving and using water	0	0
Total	**50**	**100.0**

DISCUSSION

From the research, the guidelines of water management in highland of Mae Sa Noi, Pongyang Sub-District, Maerim District, Chiang Mai Province, it can be inferred as following:

Reasons of Water Shortage for Agriculture in Mae SaNoi Area

Woranart(2012) studied the guidelines of water management for agricultures in Lam Huay Mae Sai, Dong Mahawan Sub-District, WiangChiang Rung District, ChiangRai Province. It was found that the opinion of farmers and official authorities towards the reasons of water shortage in Mae Sai stream were the deforestation and lack of water resources in the communities. The physical biography of Mae Sai stream has no forest area to save the water. The agricultural policy led to the monoculture extension, and the causes of argument related to the public land possessed by the investors. Because of the investor, there was not enough area to build the big reservoir. Farmers thought that it caused from the climate change and lack of water management from the communities and state agencies. Official authorities thought that it was because of the sandy loam which cannot save the water and the forest concession in the past.

Guidelines for Solving the Water Shortage for Agriculture in Mae SaNoi Area

Woranart(2012) studied the guidelines of water management for agricultures in Lam Huay Mae Sai, Dong Mahawan Sub-District, Wiang Chiang Rung District, Chiang Rai Province. It was found that there were 5 state organizations which were responsible for solving the water shortage in Huay Mae Saiarea.The 1st organization was 35th Mobile Development Unit which dredged the water resources and small pounds in the farm. The 2nd organization was Land Development Department which dug the pool in the farms. The 3rd organization was Dong Mahawan Sub-district Administrative Organization which dredged the canal and built the dam and the check dam, digging project in the farmers' land, ridge development project to prevent the landslide, Reforestation Project in communities to raise awareness about other people living the nearest to the water station. The 4th organization was Department of Disaster Prevention and Mitigation who helped to build the check dam and dredge the canal. The 5th organization was Department of Water Resources which helped to build the check dam to support the ecosystem, to establish the group of people who use water in order to manage the water in the communities together and provide how to maintain the water resources. In addition, Thitinan (2012) also studied the water management of the group of water users in the irrigation system and water maintenance in Mateang, Chiang Mai Province. It was found that the guidelines in water management were divided into 2 parts. The first part was the operation of water user which was supposed to be partly improved within the group for more effective ways in term of information, group meeting, rules within the group, activities, outputs, and irrigation system. The second part was the Department of Water Resources which was supposed to improve the authorities in the department for better cooperation with water users in the aspects of irrigation information, authority of the staffs and activities.

Summary

To solve the argument related to the water and unequal irrigation system is to charge the fee for using water which raises awareness and the feeling of the ownership by all water users. If there is unequal water irrigation, the complaints and the solution among water users themselves would follow since water users have their own rights to use water equally. This might lead to set the rules and reduce the conflict for using water. Water fee might be charged from the unit or from quantity used. Water Charge based on the unit is probably easier and more convenient without installing the additional equipment. As farmers who live the nearest to the water station tend use water recklessly, charging on the unit base is more appropriate and more equal because the farmers pay according to how much they use. In this way, other problems might occur such as installation, measuring the water used, and recording the water use of each family. The possible solution for this problem is to charge the water fee in a group or main water pipe by measuring the water passing through the pipe to the farm area. The farmers of each main water pipe are responsible for the quantity used by each farmer in their own main water pipe.

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4.2 WATER SCANTINESS IN ANDHIKHOLA RIVER BASIN: FARMERS' ADAPTATION STRATEGIES

SHUBHECHCHHA SHARMA[1]

INTRODUCTION

Farmers in Nepal embark to perpetual adjustments to their livelihood capitals to become accustomed to uncertainties; predominantly germane for farming communities of Andhikhola River basin in Syangja district. These farmers experienced erratic and unfavorable weather conditions, along with larger social changes **(AEPC, 2016).**The immediate effects of these changes are prominent on water resources that implicates agricultural system and food security; especially true for Nepal, a least developed country with higher agriculture dependent livelihood **(Bartlett, Bharati, Pant, Hosterman, & McCornick, 2010)**. Climate change is likely to result in extreme drought and lower rainfalls **(Bartlett, Bharati, Pant, Hosterman, & McCornick, 2010**). Given the climate change impacts are extreme and number of adaptation strategies undertaken by the irrigators (**AEPC, 2016**), this river basin offers distinctive prospect to scrutinize irrigator's planned strategies to cope against the change. With the time gone by, deliberating the impact of these planned activities on addressing the climate challenges would help frame future initiatives. However, not all of the planned activities are likely to be implemented due to diverse constraining factors (**Wheeler et al, 2013**), it would be useful to identify those constraining factors for Nepalese resource managers to come up with diverse ideas to rally farming community's capacity to adjust to climate changes and water scarcity.

Mitigating to water scarcity is difficult that necessitates huge

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investment. Farmer's approach on adoption of technologies and irrigation management systems are studied in diverse literatures: **Pereira et al., 2002; Mertz et al., 2009; Gebrehiwot and van der Veen, 2013**. Mainstream adaptation literatures are focused on general climate change variability and perceptions (**Tessema et al., 2013 andDeressa et al., 2009**) and bio-ecological models on the impact (**challinor et al, 2009; Lobell, 2010**). Studies specifically focusing on adaptation to drought and water scarcity are scarce. Many of the climate adaptation initiatives are "Africanized" with similar agro-ecological, socio-economic and climatic conditions**(Alam, 2015**). No single adaptation solution fits globally. Studies conducted in Bagladesh (**Rashid et al, 2013**) and Nepal **(Bartlett, Bharati, Pant, Hosterman, & McCornick, 2010)** showed that climate variability impacted assorted climatic zones diversely, which warranted for the need for more location-focused adaptation strategies corresponding to uniqueness in socio-ecological arena. However, as per these studies, farmer's responses are crucial to understand and economically estimate the adaptation process and climate change impacts respectively; vital for policy courses. Despite of much studies conducted and myriad of literatures available, still knowledge gap on how irrigator's experiences and socio-economic criterion affected their actions, adaptation decision and best practices at local level. In reality, farmer through-out the globe make adjustments as the pressure on water resources is extremely high. A better understanding of their adaptation choices is vital to government and policy makers as food security and agricultural growth is to be sustained in changing global climate phenomenon. Using a survey of 105 samples, this study ascertains diverse influenceson farmer's adaptation actions.

BACKGROUND

Andhikhola River located at 400-650 meters above sea level (**CERD, 2007**), is a snow-fed perennial river at western development region of Nepal (**Sharma et.al, 2015**). Andhikola originates from Karkineta and drains at Kali Gandaki River, which is one of the largest country's hydropower dam. According to **Jha(2006)**, the river is approximately 96 km long with general basin area of 195km2.

Table 1: Irrigation Facts

	Nepal (command area in ha)	Andhikhola river basin (command area in ha)
Scheme wise Irrigated Area		
Surface Water	960,237	4011
Ground Water	278,158	0
Non-Conventional Projects	13,011	45 (sprinkler, rower) *ADB/N upto 1996
Present Status with CCA (Culturally Command Area) for Surface Irrigation		
DOI Project	314,521	0

Agency Assisted FMIS Project, New	38,169	22
Agency Assisted FMIS Project, Rehabilitation	295,258	3989
Non Assisted FMIS	312,289	Not documented
Source: CERD, 2007		

Small streams and rivers that drains to Andhikhola is the major source of irrigation for upland agriculture. Water is scarcest in the spring months from February to April and very high during monsoon season from July to September (**Sharma et al, 2015**). Perhaps, this can be linked with the snow melting season: increasing trend in the runoff during months of April to May. The precipitation records from 1948 to 1994 and monthly flow trend shows huge variations in both annual and decadal precipitation (2011). Approximately 4011 ha command area is under irrigation mostly through Farmer Managed Irrigation Systems (FMIS) (Table 1). During field visit it was observed that there are numerous FMIS working over myriad of command areas which is yet not documented. Variability of precipitation is likely to increase in water availability with simultaneous declination in winter while increases in summer. It is very possible that future fluctuations will affect future allocations and adaptations deemed necessary.

World-wide studies are conducted on understanding people' opinion on climate change; approximately 61% of farmers and natural resource dependent communities in Nepal believe that climate change is happening while less than 23% understand human activity as a major contributor (**Sharma, 2014**). While, facts are not clear whether there exists a connection between existing knowledge and adaptation mechanisms undertaken. It also becomes crucial to understand what influenced farmers to undertake such adjustments? With this paper, I tend to answer the following questions: (1) were there any differences between the irrigator's planned activities versus the real adjustments? (2) What factors may have influenced irrigators to make such adjustments to the erraticism?

LITERATURE REVIEW

This section concisely lists assorted literatures on impact of climate change on agriculture and details on how a particular farmer adjusts his practices to climate irregularities, together with factors influencing adaptation at grassroots' level to deal with extreme events. In context to adaptation in agriculture, it is "the adjustments of farming mechanisms to deal with actual or awaited climatic stimuli to avoid or assuage risks to produce impending opportunities" (**IPCC, 2001; Smit et al, 2000; Alam, 2015**). Sustainable innovative adaptation strategies in water scant farms are required to endure the production aptitude, which may occur at both local and national level. Farming mechanisms are changing through adoption of stress tolerant high yielding varieties, farm mechanization, capacity building, water trade and insurance are generally included in adaptation practices (**Allen, 2006; Marshall, 2010**).

Adaptation is primarily focused on "African developing economies and to some degree in developed countries" (**Wheeler et al, 2013**). Climate change is likely to have both positive and negative consequence in rich countries, while the consequence is likely to be negative in poor countries; poor will be further marginalized and displaced. (**IPCC, 2014**). For instance, agriculture in United States of America and Europe are predicted to be affected both positively and negatively, despite of regional differences; however, Africa is likely to be affected negatively (**Reilly et al, 2003; Bryan et al, 2009; Bindi and Olsen, 2011**). Farmers throughout the world are vastly malleable to extremities, but climate erraticism stood unforeseen risk for impending farm managers. There are mostly two major components for adaptation: "perception and adoption" (**Maddison, 2007**). First the local farming community is required to distinguish a variation in climate and then undertake set of plans to target them. However, the actual adaptation varies according to socio-ecological arrangements. Planned strategies mostly requires state's intervention, while few pivotal organization may autonomously adapt to them.

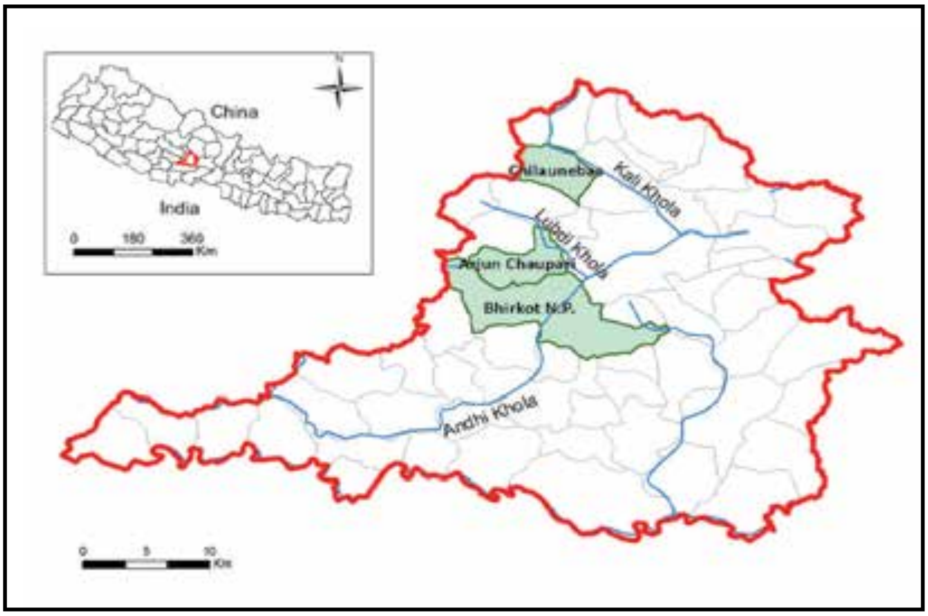

Figure 1: Map of the Study Area

There are reasonably less literatures focused on developing a model on adopting climate change adaptation strategies, especially in agriculture. Among the few such studies conducted, **Alam (2015)** found farming experience, education, tenure rights, access to resources and climate change awareness associated with adoption of adaptation strategies. **Below et al. (2012)** found availability of four capitals (social, financial, natural and physical), education and production factors to be significantly related with adoption of adaptation strategy. Very few empirical analysis on how the planned strategy actually differs from the actual implementation exist. Even though a farmer perceives a change and then plans a strategy, it is likely that diverse factors may constrain the real implementation. Age, sex, farm size, tenure arrangement, climate information influenced adaption in Ethiopian highlands (**Gebrehiwot and Van Der Veen, 2013**). In a historical irrigator survey conducted by **Wheeler et al (2013)**, in Australia's Murray Darling basin found climate change beliefs were crucial influence in climate change adaptation strategies adaptation. Similarly, **Nepal (2011)** also suggested that knowledge on climate change had a positive correlation with the management of food security in the onset of climate change. This article puts an attempt to examine the dissimilarities amongst planned and actual adaptation actions by means of survey of irrigators inAndhikhola river basin. Many researchers have used livelihood framework for conducting similar studies, this article attempts to combine the five capitals enlisted within the livelihood framework. Irrigator's climate adaptation strategies are grouped into two broad clusters: extensive and intensive. Extensive adaptation strategy include increasing areas under irrigation, while intensive adaptation strategy refers to reducing areas under irrigation. There may be other adjustment strategy, whereby, an irrigator may undergo certain management changes: choosing drought resistant variety, water harvesting etc. For a particular adjustment, there are assorted factorsinfluencingadoption activities, which in turn are related to plannedaction further interconnected to irrigator's attitude and number of factors to restraint the action.

IRRIGATOR'S ACTUAL AND PLANNED ADAPTATION ACTION

This article compares farmer's actual and planned adaptation action over 7 years using a questionnaire survey. The information were collected from two micro-watersheds within broader Andhikhola River Basin: Kalikhola and Lubdikhola. The irrigators were randomly sampled from members of local organizations representing those two areas, currently based in Kathmandu, Pokhara andChitwan. A total of 105 irrigators were surveyed across the watershed. Few of the chosen irrigators were surveyed in Bayarghari and Pokhara as most of the respondents had migrated to newest towns over the period of seven years. The survey collected data on irrigator's socioeconomic and demographic characteristics, climate change beliefs and plans. Irrigators were asked to recall their plans during 2009/2010 which were then compared with actual actions undertaken till date. This provides evenness between irrigator's intensions and their actual implementation.

During 2009/10, approximately 29.5% of the irrigators planned intercropping rice with other crops. The plan was to grow mungbean, cowpea, soyabean and chickpea with the rice. Seven years later, approximately 19% of the irrigators had in-fact intercropped rice with legumes. During group discussions, irrigators revealed that legumes acted as coverage against failure of rice due to reduced water. Typically, the land equivalent ratio (LER) is believed to be greater than pure rice cropping (**Agriinfo, 2015**). This difference between the planned and actual activity are significant. Likewise, 16% of the irrigators planned to reduce area under irrigation: reduce area under rice plantation. Astonishingly, more than 34% of the farmers reduced their farming area. Farmers argued that prevalence of severe drought considerably reduced the seasonal water allocation, while lack of field labor and heightening of labor prices, along with poor irrigation infrastructure may have also influenced farmers to reduce the rice growing area. Similarly, much many farmers significantly sold their farming entitlements than earlier planned. This could probably be the last option when water is severely constrained. However, this could also be associated with family/farming debt added over the years due to unproductive farming due to rapidly increasing drought. There is another important dimension to selling of existing farming entitlements: migration. Irrigators contended that many families and groups are migrating to peri-urban and urban areas for economic reasons, as agriculture offered no worthwhile options for keeping them out of poverty. Remittance has significantly overturned the family economic structure as many people are migrating to gulf countries. As such, agricultural sector becomes comparatively narrower and exodus of people within and across countries becomes unavoidable (**FAO, 2016**). One of the pervious farmer returned from Saudi Arabia revealed that he yearned to stay within the village and commercially produce off-seasonal vegetables. But with the steep geography, fetching water from the source was very expensive as it required huge motors to pump the water 400 meters up to vegetable fields.

In 2009/10, greatly of 69% of irrigators sort to undertake physical and managerial improvements within next seven years. Concomitantly, more than 86% of them made infrastructural improvements. These improvements included removal of algae and other vegetation in the canals, managing seepage and drainage systems. The difference between the planned and actual activity is significant at $p<0.05$. Changing basic farming location was among the diverse planned activity among the irrigators. Nevertheless, only two households have altered their farming locations. Irrigators said that regardless of their interest on moving their plantations in areas with accessible to water, the transaction cost of commuting to fields on daily basis was quite high.

Table 2: Irrigator's planned vs Actual Activity at Andhikhola River Basin

	Planned activity 2009/2010		**Actual activity 2016/17**		**Significance**
	N=105	**%**	**N=105**	**%**	
Intercropping	31	29.52	20	19.05	*
Adjustment of Plantation Time	56	53.33	47	44.76	
Altering Plantation Location	10	9.52	2	1.90	**
Improving irrigation infrastructure	73	69.52	91	86.67	***
Increase farming area	11	10.48	9	8.57	
Reduce farming area	17	16.19	36	34.29	*
Purchase more farming area	16	15.24	20	19.05	
Sell farming areas	7	6.67	15	14.29	*
p<0.1* p<0.05 ** p<0.01***					

Rationally, it can be assumed that irrigator's planned and actual actions match in conditions with moderate to high water availability. Especially in agriculture, lack of water further aggravated by other limiting factor pose consequence for implementing previously planned actions. The area is believed to have no single project implemented by the government. Disconnection from government's extension services and support may also have aggravated the gap between planned intensions and actual implementation.

DEPENDENT AND INDEPENDENT VARIABLES:

Irrigators of Andhikhola river basin were asked to recall their plans back in 2009/10 regarding water management in ongoing scarce situation. Their plans involved intercropping, adjusting of plantation time, altering of plantation location, improving irrigation infrastructure, increase in general farming area, reducing farming area, purchasing more farming area and selling of farming area. Table 3, demonstrates irrigator's plan classified as extensive and Intensive. Higher proportion of irrigators had planned for intensive plans than extensive with most plans targeted at better management of irrigation infrastructures. The least likely was selling of farming areas that could be temporary renting to permanent selling. Upon further step within intensive plans, the most planned activities are basically making adjustments to basic farming systems.

Table 3: Andhikhola River Basin irrigator's planned activities.

Irrigators' plan			Proportion%
Intensive	Adjusting	Intercropping	29.52
		Adjustment of Plantation Time	53.33
		Altering Plantation Location	9.52
		Improving irrigation infrastructure	69.52
	Reducing Farming areas		16.19
	Selling of Farming areas (Temporary rent, Permanent)		6.67
Extensive		Increase farming area	10.48
		Purchasing of more farm area	15.24

In order to quantify planned actions, an index is used which represents capacity of adaption. The values are provided either 1 or -1; for a particular planned action, "1" is assigned if the actions that are extensive and adjusting, while a value of "-1" to assigned to other intensive actions **(Wheeler et al, 20013).** The sum of all these actions is adaptive index. The results so obtained are modelled through least square regression. Each actions are also modelled with probit regression. We do not use the weightings as in most of the cases, they are inherently biased. Depending of socio-ecological factors all the planned actions could be equally important.

Many literatures have focused on five livelihood capitals to model irrigator's future adaptation actions **(Below et al, 2012, Wheeler et al, 2013 and Nelson et al, 2005).** Human factors are mostly erratic and considered to be an important one as it impacts the decision-making process. Irrigator's actions against the change are governed by his values and approaches, not restricted by considerations for profit maximization. **Wheeler et al, (2013)** used five attitudinal factors as independent variables for regression analysis. During our field visit, we excluded two of the five factors: "the environment" and "technology availability"; as negligible irrigators emphasized on environment and technology. Family tradition, economy and climate change beliefs are considered as independent variables in our study. Approximately 46.67% of irrigators believed that climate irregularities posed a risk and 39.04% were considering the knowledge while making future plans. This acceptance of climate variations was significantly related experience in agriculture ($p<0.05$), education ($p<0.05$) and had received scarce water ($p<0.01$). Similarly, an actual implementation index was created alongside, while used above mentioned three independent variables in adaptation index. For human capital, the variables grouped are experience on the field and education. In terms of social capital, membership and networking along with access to information effects irrigator's decision (**Sharma, 2014**). Type of the farm, its location, size, composition and amount of water received can be considered as physical capital. Likewise, variables under financial capital embraces production, farm revenues, farm debt and off-farm work. Table 4, summarizes the basic list of variables.

Table 4: Summary Statistics

Summary Statistics	Mean	S. D.	Min	Max
Adaptation index: planned	1.67	1.3	-2	6
Adaptation index: implemented	1.5	1.6	-2	6
Intercropping (1=undertaken in 7 years;0= else)	0.29	0.4	0	1
Adjustment of Plantation Time (1=undertaken in 7 years;0= else)	0.533	0.5	0	1
Altering Plantation Location (1=undertaken in 7 years;0= else)	0.09	0.4	0	1
Improved irrigation Infrastructure (1=undertaken in 7 years;0= else)	0.69	0.4	0	1
Reductions in farming areas (1=undertaken in 7 years;0= else)	0.16	0.3	0	1
Selling of farming areas (temporary rent, permanent) (1=undertaken in 7 years;0= else)	0.066	0.5	0	1
Increase of farming area (1=undertaken in 7 years;0= else)	0.1	0.5	0	1
Purchasing of more farm area (1=undertaken in 7 years;0= else)	0.15	0.4	0	1

Irrigator's age	47	9.9	23	77
Experience in farming (years)	34	11.3	7	65
Climate change Beliefs (1= climate change happening; 0= else)	0.4	0.3	0	1
Family value score	0	1	-2.5	2.2
Economy Score	0	1	-2.5	2.7
Size (ropani)	10	3.16	2	21
Frequency of water received in a month (days)	2	0.2	0	4
How long the water is available? (days)	2.1	0.4	1	3
vegetable grown areas (ropani)	3.1	0.9	0.2	
rice grown areas (ropani)	5.3	3.17	0.5	18
% income from the farm (in 2016/2017)	17.52	11.89	2.1	39.23
[redacted]				
% income from off-farm (in 2016/2017)	79.32	13.45	52.47	96.13
Productivity changes in seven years (5: strongly increasing; 1-strongly decreasing)	2.1	1.4	1	5

RESULTS AND DISCUSSIONS

Table 5 shows the outcomes of the model, while the results of individual strategies are shown in Table 6. The results show that belief that “climate change is happening” is significant to overall adaptation index. Nevertheless, table 6 shows that with knowledge of climate change and their impacts are adversely linked with purchasing of new piece of land. Irrigators knowing that lack of water is likely to be affected by them are definitely not increasing their land entitlement and are likely to reduce their areas under agriculture. As, one of the adaptive strategies they are willing to adjust their practices more towards intercropping and generally maintaining the irrigation systems. Nonetheless, belief that climate change is really happening will prepare individuals against the extremities. Similarly, irrigators’ past experience with overall adaptation activity is likely to have the largest influence on their future planning and implementation. The activities undertaken during 2009/10 have significant positive impact on our model. Those activities that the particular irrigator undertook in past is likely to be repeated.

Table 5: Regression of adaptation index in 2016/17

	Adaptation Index	
	Coefficient	**Standard Error**
Planned Adaptation Index	-0.129**	0.8160
Believes that Climate Change is Happening	-0.270**	0.0638

Family values score	-0.205**	0.2199
Economic Score	-0.088**	0.0868
Age	-0.010**	0.0415
Experience in Farming (years)	-0.075***	0.0056
Frequency of water availability (days)	1.366***	0.0121
Duration of water availability in a particular frequency	0.564***	0.0936
Proportion of Income from off-farm activities	0.087***	0.1425
Agricultural Productivity	-0.350***	0.0081
Observations	102	
Adjusted R2	0.771	
*p<0.1 **p<0.05 ***p<0.01		

Irrigator's future plans are more likely to be supported both by younger irrigators and those with more experience on farming. Specifically young irrigators are likely to increase their farming areas, undergo intercropping and better manage irrigation infrastructures. Similarly, they are somewhat supported by experienced farmers who are likely to undertake intercropping, adjust planting time, alter location and manage irrigation infrastructure. Irrigators with family oriented values and tradition are not likely to undertake more of adjustment interventions rather than expansive adaptations. Irrigators that are associated with number of social groups are also positively linked with better adaptability. During field visit few irrigator's group revealed that networking within the group has given them access to information through mutual sharing. Networking through social groups has also increased the level of trust and reciprocity.

Irrigators with large amount of irrigated farm areas are likely to be determined to reducing the area, while irrigators with smaller amount of areas are determined to increase the farming area. One of the variables that indicate climate influence on future activity comprises of frequency of water received and duration of water received within the particular frequency. If the farmers receive more water, they are likely to plan on reducing land and managing irrigation infrastructure. Farm productivity also influences adaptation: irrigators who have experienced more farm production are likely to increase land holdings and not prefer intercropping or mix cropping. Correspondingly, irrigators who receive more income from off-farm activities are possibly not to purchase new piece of land or change their current farming practices.

Table 6: Anticipated Effects of logistic regression model for future strategies

	Intercropping	Adjustment of Planting timing	Altering plantation location	Improving infrastructure	Reducing farming areas	Selling of farming areas	Increase farming area	Purchasing of more farm area
Believes that Climate Change is Happening	0.16	0.12	0.29	0.16**	0.15	-0.12		-0.11***
Family values score	0.03	0.12	0.31	0.19	-0.006***	-0.004***		
Economic Score					0.01	0.05***		-0.04
Age	0.023***	0.23	0.21	-0.00032			-0.01***	-0.02***
Experience in Farming	0.004***	0.003***	0.001***	-0.002	0.0023**	0.0032***		
Frequency of water availability	0.05**	-0.3	-0.21	0.16**	-0.13		0.08	-0.9*
Proportion of Income from off-farm activities	-0.001				-0.0001			-0.0023*
Agricultural Productivity	-0.03*				-0.64***			0.05**
Size of the farm					0.14***		-0.29***	
Members of social group					0.04			0.09**
Intercropping	0.23							
Planting time adjustment		0.29						
Planting location alteration			0.16					
Infrastructure improvement before				0.28				
Farming areas reduction					0.14			
Farming areas sold before						0.36		
Increased farming area							0.17	
Farms purchased								0.22
Pseudo R2	0.07	0.25	0.148	0.26	0.14	0.26	0.27	0.21
Chi square	135***	289***	224**	314***	235***	275***	164***	148***
Correct %	69	78	78	73	77	75	76	79
*p<0.1 **p<0.05 ***p<0.01								

CONCLUSION

Adaptation to climate change is inevitable, as frequency of drought, erratic precipitation and lower water allocation is expected to rise. Irrigators of Kalikhola and Lubdikhola micro-watershed within broader Andhikhola river basin would need to adapt to the changes irrespective of their understandings on climate change. With this article, I have examined probable influences on adaptation planning. Broadly, the adaptation were classified into two categories: extensive and intensive. Within intensive group, small adjustments made to adapt to climate changes are incorporated. Comparing the difference between the past planned activities with current actually implemented activities, a model is developed to possibly identify major factors that influence irrigators' decision. The irrigator's aptitude to adjust to climate change is influenced which determines irrigator's capability to deal with water irregularities and hence remain robust and viable. Most importantly, irrigators with a knowledge that climate change is happening is likely to be planning and implementing more adjustment strategies.The study has also proved that once the irrigators implement any of the intensive and extensive activities, this is likely to continue to influence future planned activities. Policy makers and planners may use this information to their benefit to formulate plans depending upon farmer's influences. Policy actors should consider developing climate change adaptation strategies together with development of farming strategies where necessary.

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4.3 INTEGRATING RESILIENCE CONCEPT IN THE FACE OF CHANGING CLIMATE: LEARNING FROM SOME NRM PROJECTS IN NEPAL

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BACKGROUND

While the world has experienced increasing challenges from climate change on the ambition of sustainable development, collective actions to devise and implement appropriate strategies to respond the challenges at local level is far from adequate. Literature showed that the climate change has multi-dimensional impacts on various sectors including natural resources management and people's livelihoods. According to Folke et al (2006), managing natural resources is a complex interactive process between human and ecosystems, and ecosystems responses to human actions under complex systems are mostly non-linear. The climate change has further aggravated the complexities in the systems. In this context, the strategy to resist with climate change impacts is not only denial of future uncertainty associated with climate change but it will also be an ineffective and expensive venture in long run. According to Millar et al., (2007), creating resistance to directional change is akin to ''paddling upstream'' under changing climate. Hence, in the constantly changing climate, socio-ecoomic and environmental drivers, the other viable strategy would be to adopt resilience thinking in managing socio-ecological systems. According to Folke (2016), resilience can be a better strategy 'to cultivate the capacity to manage change and sustain development in the face of expected and surprising change and diverse pathways of development'.

Nepal, as a party of UN climate change convention and

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a signatory of the Sustainable Development Goals (SDGs), has expressed its firm commitments to fight against climate change by strengthening resilience and its adaptive capacity to climate related hazards and natural disasters (NPC, 2015). Similarly, Nepal's National Determined Contributions (NDC - 2016) and the 14th Development Plan have emphasized for sustainable forests management through promotion of adaptation and mitigation strategies. But, these national commitments are yet to be translated into local actions and evaluating them considering the challenges induced by climate change.

Integrating resilience thinking in planning and management and their proper assessment are critical in the changing context. For assessing resilience in NRM sector requires a set of robust indicators to continuously monitor the capacity to socio-ecological systems to cope, adapt and transform. The existing process of identification of performance indicators are purely technocratic and focused at national level application only. The basic premise of the process comes from a modernist paradigm of policy making which assumed that policies can be designed to produce predictable outcomes. This approach however does not work in NRM where various actors and diverse ecosystems interact simultaneously at multiple levels. Hence, the conventional approach of identification of indicators in NRM sector to assess resilience is inadequate. In this backdrop, this review aimed to identify appropriate indicators by considering climate resilience approach in NRM sector in Nepal.

RESILIENCE THINKING IN NRM SECTOR

A common approach and framework for understanding and measuring resilience are not available in the literature. Due to multi-dimensional nature of resilience, it is being defined and understood in various ways. Literature review revealed the resilience thinking has also been evolving over time. The roots of the resilience thinking are found in various displicines including ecology, engineering, systems theory and human development. In the early stage, resilience was mainly considered as ability of return to equilibrium or as bouncing back after a disturbance. The literature related to ecology in early 1960s showed that how forests can survive after disrupstion such as fire, drought, diseases and may over time 'return' to a functioning ecosystems similar to previous stage or transform to a new state (Folke, 2006). In the next stage, the resilience thinking was perceived more from system thinking by brining social and ecological systems together taking into account of the complex realities of socio-ecological interactions (Folke 2016). Lately, the resilience thinking has been linked with the recent development theories such as human development (i.e. human agency) and livelihoods approach. These new development approach focus on human development helps to reshape the existing socio-ecological orders to create new norms and relationships in the natural resources management (Cote & Nightingale, 2012; Khanal, 2014; Tanner et al, 2015) that may assist to integrate risks, adapt, rejuvenate and transform by developing the socio-ecological systems more robust against unprecendented changes.

The human agency approach in community forests management can bring purposeful interventions that draw on disparate human capacities to imagine, anticipate and motivate individual and collective action to manage change. The approach can be therefore useful to increase resilience of forests ecosystems by promoting collective action and social learning that can be used to ensure better coping, adaptation and transformation to moderate change and uncertainty induced by climate change.

STUDY METHODOLOGY

The study reviewed the existing NRM projects supported by CDKN in Nepal and other initiatives. CDKN supported projects aiming to address climate change issues and to increase resilience. Those projects include climate smart agriculture, resilient irrigation and adaptation to climate change in hydropower.

The review emphasizes the theoretical aspects of resilience used in the project ad methodological approach applied in identification of climate resilience indicators. Besides, some experts from NRM sector and climate change were consulted to triangulate the output of the review.

MAJOR FINDINGS

Major challenges towards promoting resilience in forests ecosystems

Climate change has both direct and indirect impacts on growth and productivity of natural resources and these impacts are mainly attributed to temperature rise and changes in rainfall patterns (too much water and too little water). Climate change has increased frequency and intensity of forest disturbances. Some of the changes in the forests eco-systems over time are: shift of vegetation line toward higher altitude, phenological changes of plants, change in plant and animal habitats, increase of invasive species, increased numbers of forest fire and changes in forests and agro biodiversity, among others. All these changes influence the structure, functions and process of ecosystems and impact on releasing ecosystems services such as grass, medicines, water and edible products. These changes in the characteristics of ecosystems and release of ecosystems services have serious implications on ensuring resilience and sustainable resources management.

Major elements and interventions areas for climate resilient indicators

The study noted various elements that are important for developing climate resilient indicators in NRM sector. The resilience of ecosystems is mainly determined by the nature of ecosystems, level of biodiversity and watershed conditions, among others. The role of organizations to manage natural resources is important as they are responsible for conservation and sustainable management of natural resources by developing operation plans, implementation, resources sharing mechanisms among the users and other sustainable Natural Resources Management approach. In these governance processes, human behavior and their attitudes are equally critical in preparing a ground for and promoting resilience. In this context, the role of human agency to challenge the old order and reshape new norms and relationships is quite important. This can be achieved through individual and collective actions, and social networks. In addition, policies and institutions at national level and local development planning process at sub-national level determine the nature of resources management which have direct influence in resilient forests management.

With the rapid change induced by climate on socio-ecological systems, there is a need to intervene to enhance the fitness through increasing adaptive plasticity in the systems. The study identified seven interventions areas which can strengthen the capacity of socio-ecological systems to promote resilience and they include: enabling policy framework / institutions for integrating climate risk management; climate smart technologies and practices; knowledge and skill to understand and address climate change risks; biodiversity /ecosystems services to minimize shocks and stresses; climate resilient Infrastructure; equity (e.g. gender and social inclusion) based benefits sharing; and ensuring economic returns (figure 1). These elements together are expected to improve absorptive, adaptive and transformative capacity of forests ecosystems as well as users groups.

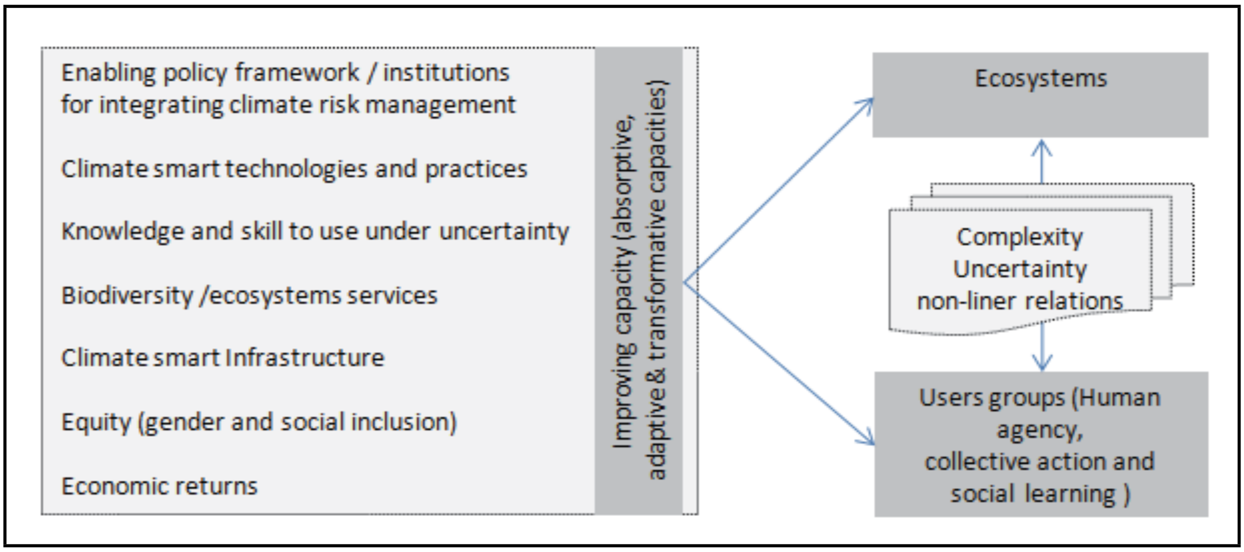


Figure 1: Framework for improving resilience in community managed forests

DIMENSIONS OF CLIMATE RESILIENCE INDICATORS

Resilience is considered as an ability of the socio-ecological systems generated through a combination of capacities to anticipate, avoid, cope with, recover from, plan for and adapt to (climate related) shocks and stresses by individuals, households, communities, institutions and systems. Considering these basic principles, the study reviewed the approaches being used to identify indicators from the selected projects. These indicators were validated with NRM experts. Finally, a list of indicators was identified based on the relevancy at local level, appropriateness to climate resilience and ease of use.

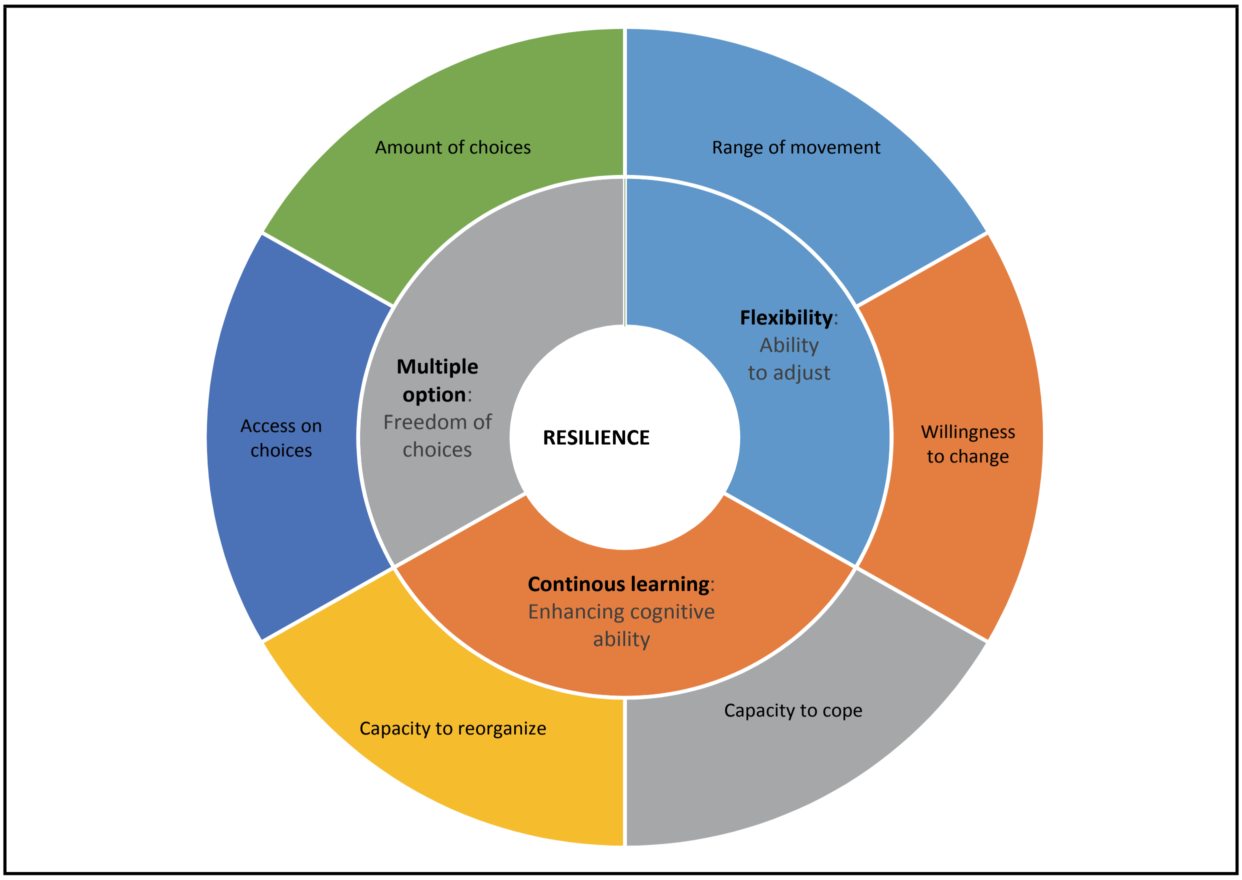
The analysis noted that resilience has multidimensional facets and individual indicators alone cannot provide a comprehensive picture of resilience in the forests ecosystems. But, for the practical application purposes, too many indicators may also become a financial and human resources burden to generate baseline data and measure them. Hence, minimum number of indicators need to be selected to the extent possible that can still fulfil the purpose of assessing the resilience in the chaning context. One option is to grouping indicators based on their mutual association that can represent and reflect the multidimensional nature of resilience.

Schipper and Langston (2015) examined 25 sets of indicators from different frameworks for monitoring and evaluating resilience. From the review, they identified three dimensions i.e. learning, options and flexibility that cover key constructs of resilience recur in the literature. Based on this finding, the study used these three dimensions to analyze the alignment of the selected indicators. It is also showed that each of these three dimensions can be further divided into two sub-dimensions that help to analyse and integrate the important aspects of resilience while making comprehensive set of indicators (figure 2). The following sections provide a brief analysis of these dimensions and sub-dimensions.

Learning:

According to O'Neill et al. (2006), learning is the acquisition of new information that leads to changes in our assessment of uncertainty. So, learning is a process of acquiring new information, synthesizing in the form of knowledge, reflecting based on the context and modifying in human behavior to meet specific needs. In case of climate change context, learning is crucial for people to be able to take action in order to reduce their exposure and sensitivity to climate change and natural hazards (Rodin, 2013). By this process, people enhance their cognitive ability to manage climate induced shocks and stresses immediately (capacity to cope) and to devise mechanisms for the long term change (capacity to reorganize).

The analysis of indicators showed that about one third of the indicators is aligned with enhancing 'learning'. Some of the indicators in this category are 'action plans based on past learning for immediate coping from climate change shocks and stresses', and 'level of use of learning from climate change risk in existing forests operational plans'. These learning related indicators help to assess the ability of NR users to acquire appropriate information for NRM practices; take appropriate decision for immediate actions; integrate climate change vulnerability and risk factors in their annual plans; and incorporate lesson from monitoring of activities in overall planning process. Hence these indicators collectively are useful to enhance cognitive ability of forests users' in order to build 'capacity to cope' during extreme climate event and 'capacity to reorganize' for future after immediate climate risks are over.



Source: Author's analysis

Figure 2: Various constructs of resilience for developing climate resilient indicators

Option:

'Option' provides a freedom of choices to select from various alternatives. So, a diversity of options helps to ensure that people will cope and do well when an event occurs (Rodin, 2013). In the context of uncertainty and complexity induced by climate change, keeping some redundant options can serve as insurance and reduce the chance to be highly vulnerable during climate shocks and stresses. In addition, multiple alternative options and diversity enable overall systems to recover, heal and improve even if one sub-system is compromised due to climate change. So, the diversity of options helps to increase ability of a system to survive and thrive from external shocks and stresses induced by climate change.

From the prioritized indicators, about forty percent of the indicators are found to be associated with this dimension. 'Status of native vs improved species', 'types of mechanisms available for responding the risks from climate change in NRM operational plans' and 'trends of release of ecosystems services (water, NTFPs, timber, forage and others) from forests ecosystems' are some of the representative indicators in this category. It is important to have this dimension so that users can choose one of the best available options in case climate induced shocks and stresses affect the normal systems. Within this dimension, it is noted that 'amount of choices' in the form of number of options available within the systems, and level of 'access on the options' to users through socially accepted process and/or legal mechanisms are very vital to ensure resilient. These aspects are therefore crucial to adopt while developing climate resilient indicators.

Flexibility:

The third dimension of the resilience is flexibility. Flexibility can be described as a quality of adjustment of a system or sub-systems with change to adapt, supplement with other interventions and extend according to the need. Flexibility is one of the important aspects of resilience to make the socio-ecological systems adjustable with continuous change process (Nelson et al., 2007). The resilience approach acknowledges that the natural state of a system is changing continuously and flexibility within the systems is required to absorb and buffer the change process such as perturbation and rapid change of the forests systems.

About one fourth of the prioritized indicators from the study are related to 'flexibility' dimension. Some of the indicators under this dimension include – 'mechanisms in places for regular review and improvement in planning and management process'; 'frameworks for intervention strategy is in place to address various types of shocks and stresses considering climate change'; and 'inclusive of representations in the users committee among users and other stakeholders'. The analysis of indicators revealed that flexibility could be two groups i.e. 'range of movement' - the quality of mechanisms available to adapt and supplement and 'willingness to compromise' by stakeholders to maintain the self-regulating ability within the systems.

PROCESS FOR IDENTIFYING CLIMATE RESILIENT INDICATORS

To manage the socio-ecological systems in a resilient and sustainable way, the NRM systems require a move from a traditional way of forest management to a systems thinking. It requires actors to learn new knowledge and support innovative approaches in order to address the complex nature of NRM and these have to be well reflected in identification of indicators as

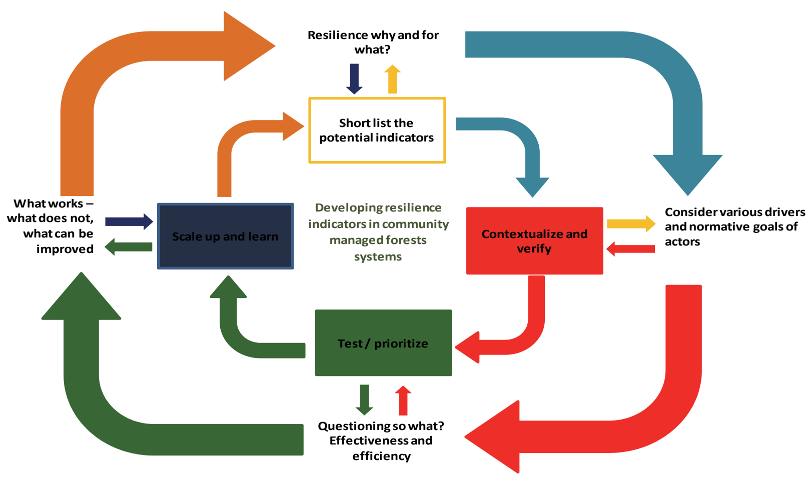


Figure 3: an iterative process for selection of climate resilient indicators

well. According to Tschakert and Dietrich (2010), an iterative process allows developing and testing theories through action, and facilitates learning in complex situations. So, in this context, the iterative learning and reflection process can provide a good basis for identification of climate resilient indicators. The study adopted this process to identify the specific processes. It includes four steps. They are 'shortlisting of indicators' by taking into accout the main purpose of having resilience and what elements to be covered; 'contextualize and verify indicators' reflecting various drivers of change and expected objectives of actors considering local situations; 'test and verify the indicators' in real world situations by asking 'so what' questions, their effectiveness and efficiency among the actors; and finally use of indicators by scale up and learn what works and what can be improved for future use (figure 3).

CONCLUSION

The study aimed to contribute on the debate regarding the understanding and measurement of resilience, and improve current approaches for assessing resilience in NRM sector. Dealing with resilience issue in NRM sector is complex. Hence, developing indicators in the complex system during the changing climate demands an innovative approach by considering various elements that can affect resilience. Besides, the indicators need to be contextual considering local needs, capabilities of actors and ease of use. Due to multi-dimensional nature of the resilience, individual indicators can not fully represent the multiple aspects of resilience so categorizing indicators based on various dimensions of resilience is required. The prioritized indicators in this study showed that three dimensions and six sub-dimensions are useful to cover the multi-dimensional nature of the resilience in the forests systems. As many issues and knowledge are emerging in this discourse, iterative process of identification of climate resilient indicators is required.

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4.4 BARRIERS AFFECTING HUMAN LIVING UNDER CONSEQUENCE OF CLIMATE CHANGE IN CHIANG MAI, NORTHERN THAILAND

SJUTHATHIP CHALERMPHOL, NATHITAKARN PINTHUKAS, RUJ SIRISUNYALUCK[1]

INTRODUCTION

Thailand is the one country of Asia, where the majority of rural people's occupation is agriculture, accounting for 17.6 million people are working in the agriculture sector (Wisartsakul, 2012). In the year of 2014, Thailand was the one leading exporter of agricultural products from the top 10th countries in the world, with valued at 40 billion dollars per year (World Trade Organization, 2015). Agriculture sector is main earning of Thailand, but the average income of farmers is nearly nine times lower than industry employees and most part of farmers coming from the rural sites (Sakondhavat, 2012). However, agriculture has been generally accepted as the most economically important and made significant contributions in the country (Somsak, 2011). In addition to this, agriculture in the Northern Thailand remains as an important industrial sector and the labor force of Northern region is around 6.8 million people, 47% of whom work in the agriculture sector (Bank of Thailand, 2014). Moreover, Chiang Mai is the one province, which emphasizes agriculture sector as the supporter of the country's economy, with a totally 21,441 million Thai Baht per year. Conversely, Chiang Mai's agriculture has various problems, particularly, one negative factor that causes the contraction of agriculture sector is the variability of weather conditions. This problem causes the decline and delaying rainfall during rainy season as well as affecting the level of water in the reservoirs leading to an inadequate water for applying to the

1 Faculty Members at Chaing Mai, University, Chaing Mai, Thai land.

agriculture sector (Office of Agricultural Economics, 2015). Besides the small farms also provide the majority of country's agriculture products and a large proportion of these rely on irrigation system. Small-scale irrigation is playing a main role in adapting to climate change, achieving food security, and improving household incomes (Won-Ho Nam, Jin-Yong Choi and Eun-Mi Hong, 2015). Furthermore, agriculture is extremely exposed to climate change, as farming activities directly rely on climatic conditions.

Similarly, farming activities relying on climatic conditions directly affect the farmers' adaption. Suta, Khempet, &Jongkaewwattana (2014) founded that Farmers in upland of Chiang Mai province have known about the variability of climate conditions such as the reduction of animal and insect species, high temperature, late rain, drought and flood. A case study of Maewin community in Chiang Mai province from Earth net foundation (n.d.) revealed that climate change affects the lives and livelihood of the people in the community. People face heavy rain and flooding in the rainy season as well as extremely high-low temperature in winter season that result in the reduction of winter fruits and the number of animals' death. On the other side, during summer People face water shortages, forest fires, and lack of water for consumption.

Frequently unknown climate change increases the risk of agriculture. More attention has been paid to agricultural system itself in the research field, but few have been attached to the perspective of social dimension. Based on the research on Yangtze River Basin of China, the paper has adopted vulnerability theory including the exposure of agricultural ecosystem, farmers' sensitivity to exposure and adaptive capacity to climate risk, to explain farmer's adaptation to climate risk. It concludes that climate change has increased climate risk in agriculture and the uncertainty of agricultural production. Confronting climate risk in agriculture, different farming bodies have shown different farm and off-farm/non-farm adaptations in pre-risk, during risk and post-risk, which has reduced their short-term vulnerability. Household life cycle, pressure, institution, available resources and technologies are the key influential factors. From the adaptation in long term, it still requires external support and more investment including agricultural insurance system, village-level information and technology dissemination mechanism (Li, Ting, &Rasaily, 2010).

Climate change influences several environmental aspects, including fluvial flooding, storm surges, saline intrusion, costal land loss, salt water intrusion of groundwater aquifers, sea level, marine ecosystems, extreme temperatures, forest fires, drought, health, water availability, the reduction of rice-growing and maize cultivation, specifically related to agricultural water resources (Met Office Hadley Centre. (n.d.). In different areas, changes in rainfall and hydrologic patterns due to climate change can increase the occurrences of reservoir water shortages and affect the future availability of agricultural water resources differently. Considering the impact of climate change on reservoirs in relation to the passage of time is an important component of water resource management and the maintenance of a stable water supply (Won-Ho Nam, Jin-Yong Choi and Eun-Mi Hong, 2015). More efficient and sustainable use of water is more and more becoming urgency. In particular, water supply is expected to become more uncertain because of climate change (Francisco Alcon et al., 2014). Study on impact of climate change on farmers of small scale irrigation systems have been an essential process for preparing farmer adaptation.

RESEARCH OBJECTIVES

In this research we will look on the small scale irrigation system maintain and various aspects related to the impact of climate change on farmers of small scale irrigation systems in northern Thailand. The proposed research will try to investigate barriers affecting human living under consequence of climate change in Chiang Mai, Northern Thailand.

RESEARCH PLAN AND METHODS

This study focused on farmers of small scale irrigation systems in Chiang Mai, northern Thailand. It is based on 30 irrigation systems that were divided into two types of research site: adjoining district to the Chiang Mai city and high land area.The methodology was designed as per standard of qualitative and quantitative research. In terms of climate change impact, the data were gathered from interview and analyzed using multiple regression to investigate barriers affecting human living under consequence of climate change.

RESULTS

The major source of water used for all 30 irrigation systems is surface water. This referred to both the head works of the systems and other sources from which water is made available for irrigation. When surface water is the primary source, most type of surface water is river. There were 2 irrigation systems that had the dam for other storage facilities at irrigation system level that can control the flow of units in the production, distribution and appropriation resources for the benefit of all users.

Selected farmers had the land at upstream, midstream and downstream. The analysis of multiple regression by taking variables into the equation then calculated as the normal methodology (Enter) appear that F = 2.526 Sig. = 0.000, apparently at least one independent variable that is statistically significant in explaining with the dependent variable. (Barriers affecting human living). The coefficient of determination; R2 = .30 from the estimation means that all independent variables can explain 30.0% of the variability of the dependent variable. Meanwhile, among 7 independent variables, those found to have effect on the dependent variable at the 0.05 level of statistical significance were (1) risk-climate (2) risk-price as detailed in Table 1 The estimated regression equation is as in the following:

$Y_1 = 2.220 - .014X_1 + .147X_2 -.779X_3 + .025X_4 - .073X_5 -.157X_6 +.179 X_7$

Tabl 1: Barriers affecting human living under consequence of climate change in Chiang Mai, Northern Thailand

Variables	Unstandardized Coefficients			
Barriers affecting Human Living (Y_1)	**b**	**Std. Error**	**t**	**Sig.**
Risk-Climate	-.059	.024	-2.470	.014
Risk-Government	.040	.028	1.452	.147
Risk-Input	-.007	.025	-.281	.779
Risk-Prices	.054	.024	2.242	.025
Risk-Migration	-.042	.023	-1.794	.073
Risk-Irrigation	-.030	.022	-1.417	.157
Risk-flood	.031	.023	1.345	.179
Constant=2.220R = 0.172 R^2 = 0.30SE_{est}= 0.708 F = 2.526 Sig of F = 0.014				

Y - Barriers affecting Human Living

X_1 - Risk-Climate

X_2- Risk-Government

X_3 - Risk-Input

X_4 - Risk-Prices

X_5 - Risk-Migration

X_6 - Risk-Irrigation

X_7- RISK-Flood

CONCLUSIONS

The barriers affecting human living under consequence of climate change in Chiang Mai, Northern Thailand are 1) risk of climate change meant that the first major health impact of climate change is the rise in rates of mortality and diseases caused by extreme weather events. These include floods, droughts, and other disasters that threaten human health and safety. Climate affects human health on many levels such as heat waves and flood that can seriously impact health. These changes can also produce harmful water and limit a region's food supply. Floods can contaminate crops and water, increasing the likelihood of foodborne and water-borne illnesses. 2) Risk-uncertainty with yield price meant agriculture is affected by climate change. Crops need suitable soil, water, sunlight, and heat to grow. These changes are expected to continue in many regions. In general, in northern Thai agricultural productivity might increase due to rainy season. Raining and longer growing seasons might also allow new crops to be cultivated. Crop yields are also expected to vary increasingly from year to year due to extreme weather events and other factors such as pests and diseases. Changes in temperatures and growing seasons might also affect the proliferation and the spreading of some species, such as insects, weeds, or diseases, all of which might in turn affect crop yields and price. Fluctuation price affect to human living that farmers cannot expect their income under climate situation. A part of the potential yield losses can be solved by farming practices, such as rotating crops to match water availability, adjusting sowing dates to temperature and rainfall patterns, and using crop varieties better suited to new conditions (e.g. heat- and drought-resilient crops).

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5. WATER- ENERGY BENEFIT SHARING

5.1 CLIMATE RESILIENCE AND PERFORMANCE OF CHAPAKOT TAR IRRIGATION SYSTEM

KHEM RAJ SHARMA AND MANJU ADHIKARI[1]

ABSTRACT

Chapakot Tar Irrigation System is in Syangja District, Western Nepal. The system gets water from Jyagdi Khola through its main canal of over 25 km of which 14.5 km is the idle length. Also at the chainage of 6.06 Km there is a feeder canal from Bhumdi Khola and there are several control structures along the alignment. The system has a command area of around 885 ha and serves about 12,000 farmers living in 2,000 households. The system is managed jointly by Department of Irrigation and the local farmer community. For the study, monthly rainfall and temperature data at the DHM station in Syangja Bazar of the past 12 years were collected and analyzed. Farmers' perceptions about climate change over the years and the coping mechanism for increasing their resilience were assessed after field survey. The system performance with regard to irrigation water supply, cropping pattern and yields, system management activities was assessed through focus group discussion and field observation.

From the analysis, it is observed that flow of water at the source during winter and spring seasons is drastically low as compared to the monsoon flow. Several spring water sources are drying up adding the drudgery of the local inhabitants especially women in fetching drinking water in the locality and prompting the farmers to avail support in constructing a lift water supply system from Chite khola. Pest and disease infestation as well as lack of markets have been a major problem in vegetable farming in recent years. Equitable water distribution between head and tail ends is a big challenge. Unreliable water supply

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and uncertain climatic pattern along with the labor shortage have resulted into reduced interest among the farmers in agriculture. Due to reduced water flow in the canal and migration of local youth for employment elsewhere, cropped area during dry seasons is considerably low as compared to the wet season. So far, the Water User Association has not introduced the provision of collecting irrigation service fee from the beneficiaries resulting into backlog of system maintenance. Farmers living in uphills have a tendency to settle into the downhill on the plain Chapakot tar thus gradually converting the agriculture areas into settlements. The landslide near the system headwork's and along the canal alignment due to 2015 major earthquake and the floods affected the functional status of the system. Silt deposition in the canal intake has been a perennial problem. Farmers perceive that it is getting warmer in recent times, but whether it is climate change is not well perceived by the farmers. The cropping pattern is still traditional with rice – wheat/potato – maize/pulses domination in monsoon, winter and spring season respectively. With the construction of a gravel road from Galyang to Chapakot, things are changing lately. As a coping mechanism farmers now apply high doses of pesticides, insecticides and fungicides, especially in vegetables. Use of chemical fertilizer is in the increasing trend for a better harvest. The system is currently under rehabilitation process with support from DOI through the Asian Development Bank funding.

BACKGROUND

Nearly a billion people live in hunger around the world out of which half of them are small holder farmers. About a third of population or an estimated 4.2 million people are under the poverty line where the majority of people earn their living through agriculture. It is recorded that, in Nepal agriculture contributes one third of its GDP with more than 50 % of its export depending on agriculture (Karki, 2015). Also agriculture is main source of food, income and employment for majority people. The total rainfall varies between 1,000 to 4,000 mm with an annual average of 1,814 mm and more than 75% rainfall occurs during four months of the monsoon period (June - September) (ICID, 2015). So, most of the agriculture farming is monsoon dependent. Only 18% year round irrigation is recorded in Nepal (Prasain, 2016).

Climate change a burning issue is also impacting agriculture by lowering its productivity as it contributes erratic weather pattern. Because of urbanization, fertile agricultural areas are getting converted into settlements reducing fertile agricultural area. Mean time performance of infrastructures along with its sustainability has been an outstanding issue from years. To address this issue, role of irrigation is crucial. But poor operation and maintenance with head to tail equity problem has threatened the sustainability of irrigation system. Small-scale irrigation systems managed by farmers are facing multiple challenges including competing water demand, climatic variability and change, and socioeconomic transformation. Though the relevant institutions for irrigation management and the farmers have developed some coping and adaptation mechanisms, the intensity and frequency of the changes have weakened their institutional adaptive capacity (Thapa et al., 2016).

Climate change has had an adverse effect of lowering the soil moisture content in Mwingi which has been compounded by the already low precipitation levels. In addition, sudden down pours in the area have caused soil erosion, preventing soil absorption and retention (Mangoti. et al., 2010). South Asia will face negative impacts on agriculture due to climate change and food scarcity will increase if adaptation measures are not considered (Lobell et al., 2008). Over the past 20 years, East and Southern Africa have been hard hit by the impacts of changing weather patterns. In many areas in Asia, low crop yields have increasingly become the norm as a result of erratic rainfall whilst in other areas; longer periods of drought have resulted in repeated crop failure. It's predicted the severity and impact of extreme weather events will worsen with time due to anticipated decreases in precipitation and increased variability (Nombewu, 2016). Sustaining a reliable water supply can help improve the ability of communities to survive in a changing climate. For it, a sustained irrigation infrastructure which provides regular water supply is needed. Furthermore, for a system to be sustained it needs to be well-designed and properly maintained at the local level.

STUDY AREA

The Chapakot Tar irrigation system (CTIS) is a hill irrigation project located on Chapakot and Ratnapur VDC of the Syangja District. The System was initiated by Department of Irrigation (DOI) from its own funding resources. The first engineering survey work was carried out in fiscal Year 2022/023 (1965) followed by the construction of Headwork in 2028(1971 A.D). The project was quite huge so construction works was completed by continuing budget from Department of Irrigation. Final completion of the project was made in 1995(2051 B.S). In 1981, the project was considered in the first Hill Irrigation Project to be constructed under ADB financing. The system is currently under rehabilitation process with support from DOI through the Asian Development Bank funding. The study area receives annual average rainfall of 2735 mm. Almost populations are farmers in this study area besides the member who went elsewhere for employment. Main occupation of this area is farming. The farmer of this area is not much motivated in commercial farming. They grow for fulfillment of daily need. Generally, this area is in practice of traditional farming with paddy – wheat/potato – maize/pulses domination in monsoon, winter and spring season respectively. Market area is extended in slow rate. Galyang and Mirdi are the nearest market head from the Chapakot. Brahmin is predominant caste living in the study area. About 36 % of total population is Brahmin here (NPHC, 2011). Beside it, the study area is inhabited by Chettri,

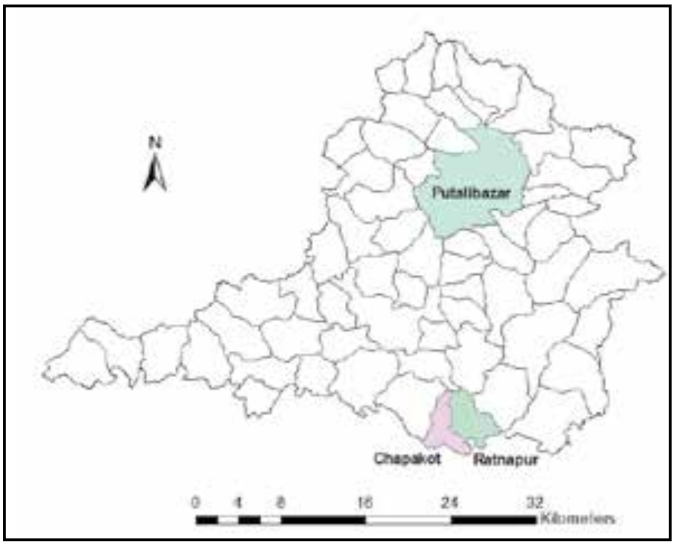

Figure.1: *Location Map of Study Area*

Magar, Tharu, Newar, Dalit, Thakuri, Gharti, Kumal, Gurung, Bote and Musalman. Chapakot Tar irrigation system posses mix ethnicity in a coordinated way. There are altogether 2000 beneficiaries' households with 12000 populations (DOI, 2014). The location map of the study area is shown in figure-1.

CHAPAKOT TAR IRRIGATION SYSTEM LAYOUT

The main source of Chapakot Irrigation System is Jyagdi Khola which is perennial and minor augmentation of water has been made from Bhumdi Khola. Both of these sources are perennial in nature. Headwork structure of this system is located in Darsing (Malyangkot VDC) with the rock cliff at left bank and canal off-take at right side. The discharge of Jyagdi Khola is 1902 lps (measured in Jan 15, 2017). The system irrigates command area of 885 ha (NCA) land through its main canal of over 25 km of which 14.5 km is the idle length. The command area has elevated river terraces of the mountain range along the left bank of Kali Gandaki River characterized by flat to gently sloping south facing terrain at an altitude ranging from 325 meter to 450 meter above sea level. The Kali Gandaki divides Chapakot from Palpa District to the south, and to the north is Keware Bhanjyang. The study area is shown in Figure 2.1 (DOI, 2014). Small and marginal farmers having less than 5 Ropani are average land holders of the study area. The majority of disadvantaged group including Dalits have also good control over the irrigated land. Chapakot Tar irrigation system is gender bias society with patrimonial behavior. Despite women's large contribution in household chores, agriculture and other economic activities their role in decision making process is limited especially in irrigation activities of WUA (DOI, 2014).

The command area is the river terrace of Kali Gandaki River, which lies in the south part of the Syangja district of the Western Region. The topographic map showing command area is shown in **figure 2.**

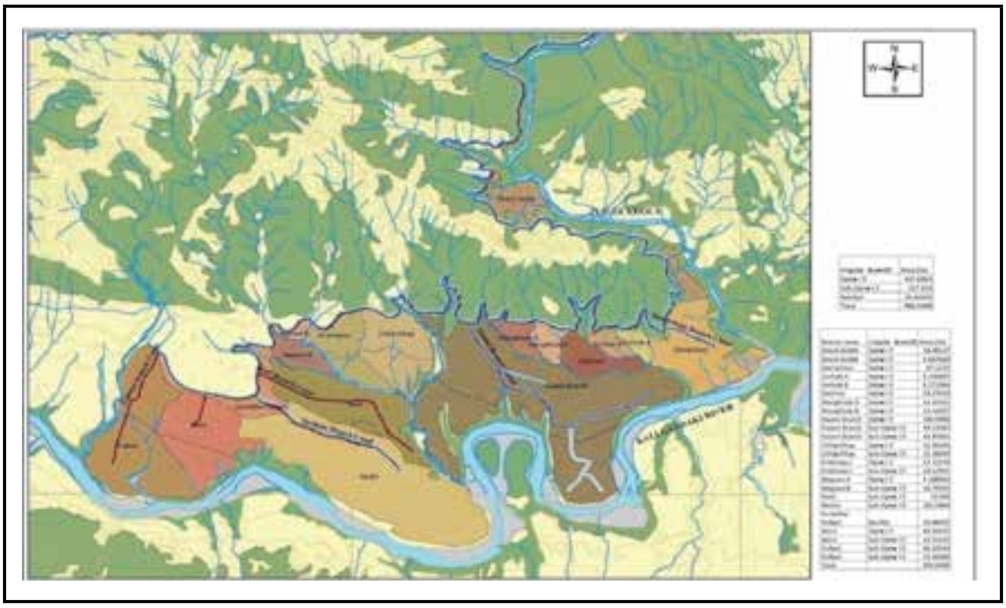

Figure 2: Topographic map of command area of Chapakot tar irrigation system

DETAIL OF CHAPAKOT TAR IRRIGATION SYSTEM

The detail of canal system, its outlet with the area irrigated by the outlet or branch canal is presented in figure 3.

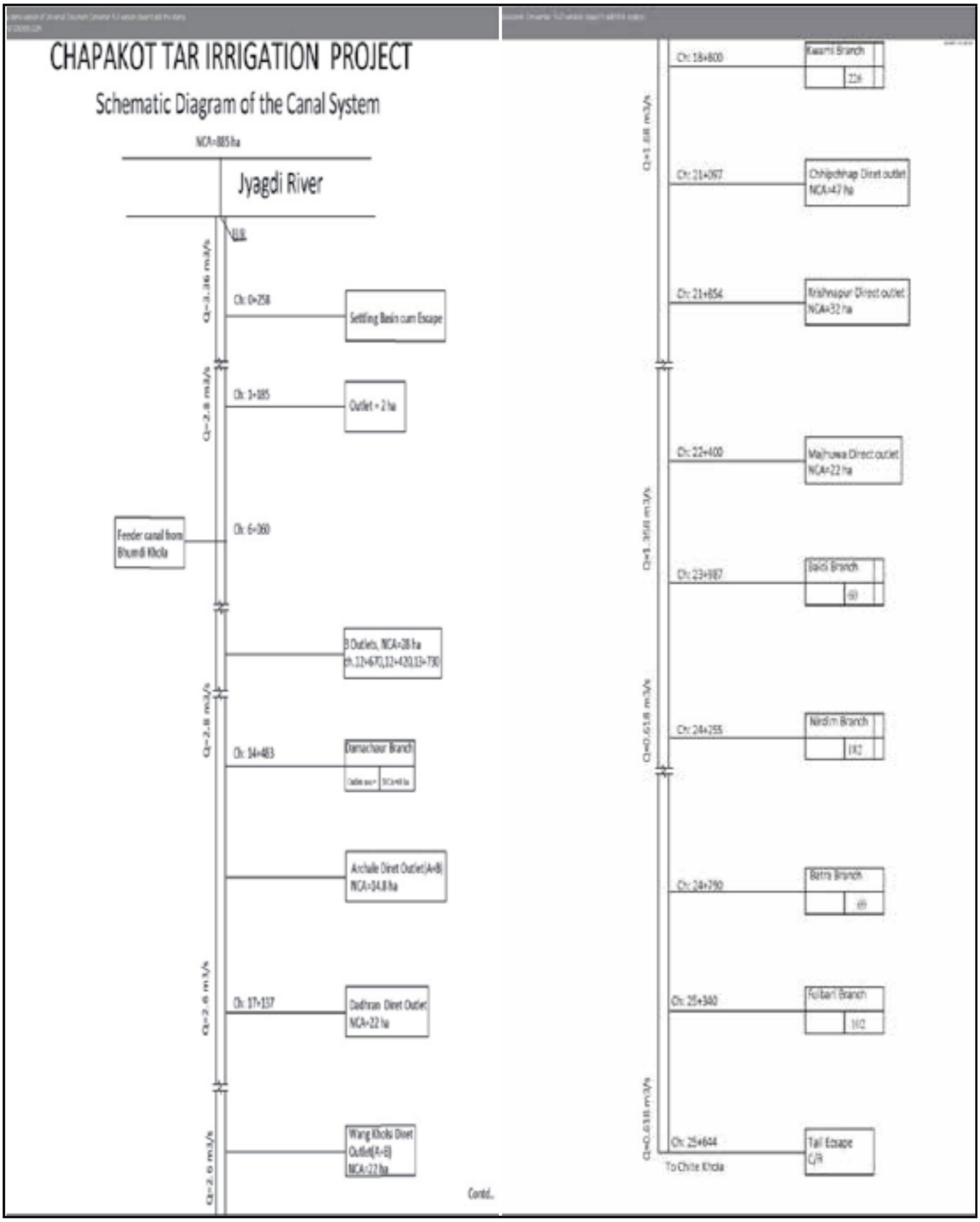

Figure 1: Schematic diagram of Chapakot Tar Irrigation System

RESEARCH METHODOLOGY

A research was conducted in CTIS adopting case study approach which included multiple spectrums of participatory tools. The research study followed both quantitative and qualitative methods which comprised a set of questionnaires to collect the quantitative and qualitative data and also comprised set of checklists for individual level as well as group level interviews.

Field Observation and system walk through, key informant interviews with the president of WUA main committee, representative of irrigation district division (IDD), Syangja, representative of district agricultural development office (DADO), Syangja and Deputy Director General (DDG) of Department of Irrigation (DOI), Kathmandu and focus group discussion with water user's group of main canal, branch canal (6 branches) and other beneficiaries were the primary data collection tools. The secondary data needed for the study was reviewed from journals, reports, documents from website and past case study report of irrigation. The literatures both published and unpublished including the documents regarding the irrigation system available in the IDD, DOI was reviewed as well.

RESULTS AND DISCUSSION

Analysis of Rainfall Pattern in the catchment area

Rainfall data of 12 years (from 2004 to 2015) of station Putali bazar is collected from DHM and is analyzed. It is concluded that annual average rainfall of study area is in decreasing trend. From this result we can trace out the decreasing water flow in the river as well. This might be the impact of climate change. The trend of annual average rainfall of the nearby station of system is shown in the graph below (Figure 4).

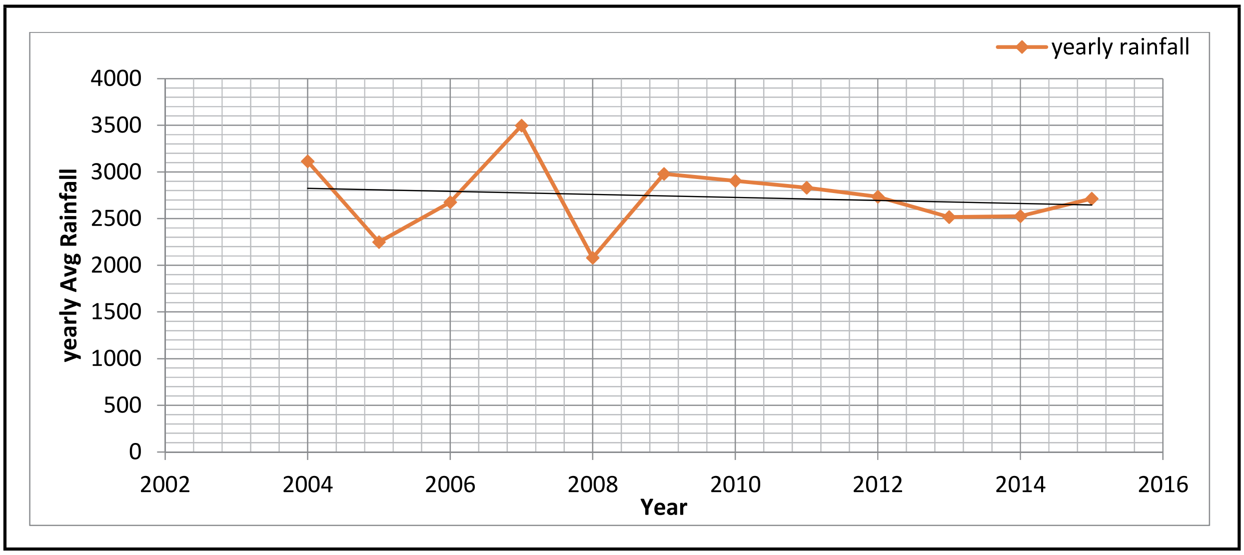

Figure 2: Trend of annual average rainfall of the irrigation system.

Similarly, monsoon precipitation gradually increased since year 2004.Whereas in dry season like March and April, precipitation seems to be decreasing over the years. In the graph below (Figure 5) green line shows the rainfall of monsoon which is increasing linearly while red and blue line is a plot of precipitation received in dry season which is decreasing linearly.

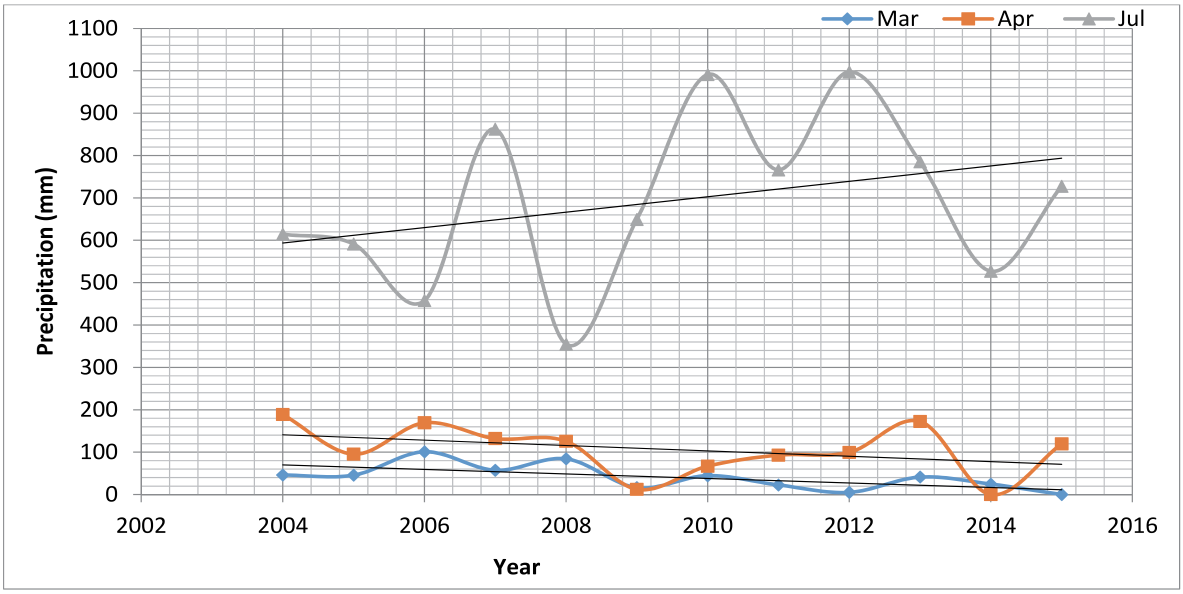

Figure 3: Precipitation received by study area in monsoon and dry season

Catchment characteristics:

The characteristics of the catchment area are;

Catchment Area	:	148 sq. km
Climate	:	Temperate
Hydrological Region	:	5
Average Precipitation	:	2735 mm
Mean Monthly Max. Temperature	:	32 ^{0}C
Name of source	:	Jyagdi Khola & Bhumdi Khola (supplementary source)

Water Availability at Source

It was evident that water availability at the source is decreasing. Discharge at Jyagdi Khola headworks measured in Jan 15, 2017 was 1902 lit/s. While comparing present discharge with the flow measured in March 4, 2014 (2820 lit/s), present discharge in the river has decreased. Also water in the irrigation canal is augmented from Bhumdi Khola, a tributary of Jyagdi khola. The discharge at the source of Bhumdi khola is 116.7 lit/s measured in

Jan15, 2017. In dry season this additional source supports the system.

Water availability assessment with mean monthly flow and 80% reliable flow (calculated by using non-dimensional Regional Hydrograph) is done. Flow Estimation was carried out by MIP method. From water availability assessment water is not sufficient for the cropping pattern the farmers are practicing at present.

Temperature Trend Analysis

Temperature is increased because of which many spring sources are getting dry. Drinking water is getting scarce in winter and spring seasons. Because of dried source, drinking water demand is fulfilled by lifting water from nearby Cite khola and water carried by tanker from nearby khola as well. Trend of temperature of the Putali Bazar station in Syangja is shown in figure 6.

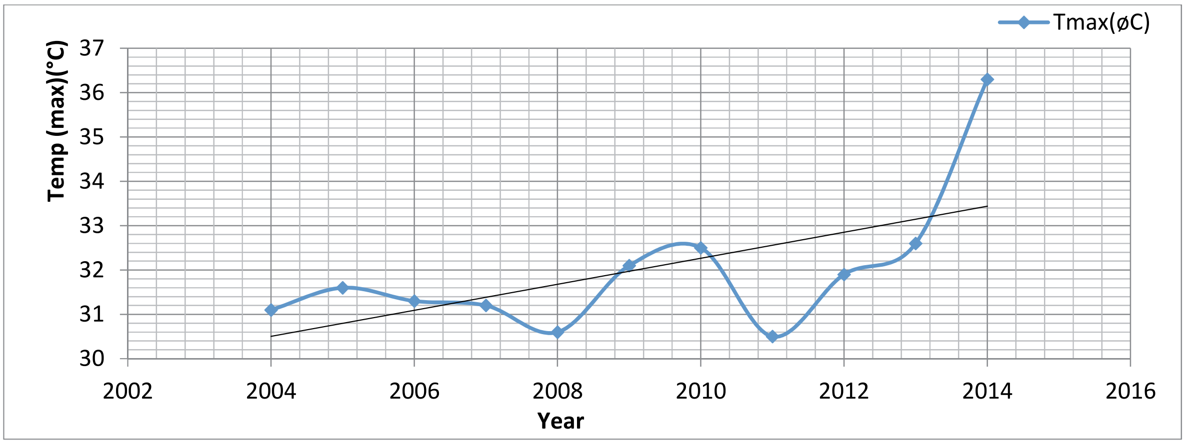

Figure 4: Trend of maximum temperature variation over the years

Temperature in a decade is increasing gradually up to 36.3°C in 2014 A.D. which is quite high in the context of mid hills in Nepal.

Cropping Pattern and yield

The cropping pattern is still traditional with paddy – wheat/potato – maize/pulses domination in monsoon, winter and spring seasons respectively. Paddy, wheat and maize are the most dominant crop combination in the area but crops like sugarcane, pulses, oilseeds, potato and vegetables are commonly grown. Due to diversity in topography, culture and climatic conditions, different cropping sequences are practiced. Farmers follow rice and wheat in the irrigated lands and maize/millet or maize/ local beans in the rain fed lands.

Cropping intensity of Chapakot Tar irrigation system as per SSPR (Sub project preparatory Report, 2014) was recorded remarkably high at 240.9% without any water stress. But according to present practice of farming, cropping intensity was found to be 213% with water stress in farm from February to June, which is still high as compared to many other hilly areas. But during winter and spring seasons, crops are grown under deficit irrigation conditions. This ultimately results in lesser yields. In 10% land at the head end spring paddy is grown. But due to insufficient water, yield is not achieved to its potential. Planting spring paddy is not recommended in this area as water flow is not adequate for the year-round irrigation. It is better to plant vegetables; enhance maize cultivation, winter potato, winter pulses to avoid water stress in the command area. For water balance and equity, cropping intensity should be minimized to 184%. In this condition, there is deficit of water in the second half of the June and March. During land preparation for monsoon rice, there is high demand for irrigation water and hence all the area is not prepared at a time. So, this deficit can be recovered by supplying water in rotational basis and that is practiced to some extent during lean period. March second half is the time of harvesting other winter crops like potato, pulses, vegetables and oilseed. During harvest time water is not required. Water for only wheat is assumed to be enough for this case. By this way irrigation water supply can be managed on year-round basis. Figure 7 shows the cropping pattern and cropping intensity of Chapakot Tar Irrigation Scheme.

Cropping Pattern for balance water condition

Season	Crops	Coverage (%)	Cropped Area (ha)
Monsoon	Paddy	85.00	752.25
	Maize	9.00	79.65
	Pulse	1.00	8.85
	Vegetable	5.00	44.25
		Sub Total	885.00
Winter	Wheat	8.00	70.80
	Potato	20.00	177.00
	Pulses	9.00	79.65
	Vegetables	20.00	177.00
	Oilseed	0.50	4.43
		Sub Total	508.88
Spring	Maize	24.00	212.40
	Vegetables	2.50	22.13
		Sub total	234.53
Net Command Area (ha)			885.00
Total Cropped Area (ha)			1620.40
Cropping Intensity (%)			184.00

Figure 5: Cropping pattern and cropping intensity for water balance condition

Due to reduced water flow in the canal and migration of local youth for employment elsewhere, cropped area during dry seasons is considerably low as compared to the wet season.

Agricultural Input Use and Yield

From the field survey, it is observed that in order to compensate the crop yield loss due to deficit irrigation, farmers have a trend of applying chemical fertilizers. Agriculture input like improved seeds of food crops, vegetables, potato, subsidized seed of paddy are seldom provided in time by DADO office while seeds of vegetables and related chemicals through agro vets are usually available in the area. There is one agro vet centre licensed by DADO Syangja in Chapakot Tar. Also, there is a collection centre made by DADO to collect and sell agricultural production to the market. But due to the lack of market availability or difficult access to nearest market, that collection centre is not brought in use so far. This too has discouraged the farmers for adopting commercial farming.

For the plant protection, application of pesticides spray in wheat, potato, vegetables, paddy, maize and oilseed is huge these days. No pesticide application was recorded in pulses. Farmer cooperatives one each in the VDCs is active in supplying chemical fertilizers in the command area. Farmers especially women mobilized in groups dealing with saving-credits are active for getting agricultural inputs and services. Loans for agricultural inputs are available at the command area through groups, cooperatives and banks. Interest rate for taking loan is 11 to 12 %. Loan can be payable at maximum 5 years in installment. But, peoples are not taking much of this loan as the system lacks commercial farming.

Farmers' perception and adaptive mechanism applied

The people of the study area perceive that quicker growths of the crops in the field but producing lesser yield could be the outcome of climate change. Equitable water distribution between head and tail ends is a big challenge. Unreliable water supply and uncertain climatic pattern along with the labor shortage have resulted into reduced interest among the farmers in agriculture. Farmers wish to have year-round irrigation for achieving the crop yield potentials. But due to shortage of water in the canal head reach areas like Damachhaur, Qwami and Baidi Branch are getting water supply throughout the year for the three cropping seasons. Shortage is also caused by maximum loss of water from earthen main canal sometimes by seepage and sometimes by crab holes. Also, water theft not considering rotational system is another reason of shortage of water in the tail reach.

Yearly deposition of silt in the canal intake has been a perennial problem. Farmers perceive that it is getting warmer in recent times, but whether it is climate change is not well perceived by the farmers. Farmers living in uphill have a tendency to settle into the downhill on the plain Chapakot tar thus gradually converting the agriculture areas into settlements.

The landslide near the system headwork and along the canal alignment due to 2015 major earthquake and the frequent floods in rainy season have affected the functional status of the system. Seepage of water from field (khet) to drains is also a problem. This phenomenon results into washing out the organic manure and fertilizer applied in the field in Chhipchhap area. Similarly, in the same area there is no drain which leads spilling of water from field to the nearby road making it inconvenient to use.

System Management activities of WUA

Water user association (WUA) is a functional organization in Chapakot Tar Irrigation System. The WUA got elected by voting system held once in four years. But due to delayed implementation of its bylaws, this interval was extended by one year this time. Election was held very recently on March 16, 2017. Main committee of 17 members has been elected on the chairmanship of Krishna Prasad Subedi. WUA is especially active in emergency maintenance of the system as emergency fund is not allocated by DOI. Fund from users is collected only to meet the emergency needs, otherwise the WUA has not introduced the provision of collecting irrigation service fee from the beneficiaries resulting into backlog of system maintenance. For Operation and Maintenance (O/M), annual budget around 12 to 15 lakhs is usually allocated from division office of DOI regularly.

Water allocation and distribution practice is done as per the decision of WUA. Operation of gate is performed by WUA selected personnel. There are two paid staffs for gate operation and distribution of water. Water is allocated as per the outlet size designed in the system.

Irrigation infrastructure is damaged in many places due to earthquake 2015. Rehabilitation is ongoing by DOI with financial support by ADB under the program CMAISP-AF this year. Under this maintenance of headwork in d/s of weir, maintenance of canal in different landslide zones has been carried out. Similarly, a cascade drop structure at tail end is under construction. To address the problem of siltation settling basin with silt excluder is also going to be provided.

CONCLUSION

Water flow in the source of CTIS, especially during lean season, is in decreasing trend. Decreasing agricultural land due to urbanization together with the increased population and reduced discharge at the source is a typical mismatch. In addition, issues of climate change have made the situation more complicated. Issues of inequity in head - tail reach of the canal are more pronounced. Drying up of the spring sources in the recent past has added the drudgery of the local inhabitants especially women in fetching drinking water in the locality and prompting the farmers to avail support in constructing a lift water supply system from Chite khola.

Agricultural practice is still traditional. Market is another constraint in the Chapakot area (now a municipality). Because of lack of year-round irrigation, market facilities and reduced farm labor, commercial farming is hardly practiced in the study area. Due to reduced water flow in the canal and migration of local youth for employment elsewhere, cropped area during dry seasons is considerably low as compared to the wet season. Application of chemical fertilizer has been increased to compensate crop yield loss due to deficit irrigation. Planting non – irrigated crops during lean seasons has contributed in maintaining relatively high cropping intensity in the command area.

Loss of water from the main canal due to long idle length (14.5 KM) is another reason for creating water deficit especially in the tail reach. To minimize water losses (seepage, evaporation) minimizing about 11 KM main canal by constructing tunnel through "Neupane Daanda"from Dhrukotbesi is considered as an option for Chapakot Tar Irrigation System. Or, providing cover along the main can be considered as a viable option for reducing the conveyance loss of irrigation water.

Yearly deposition of silt in the canal intake might be reduced with the provision of a functional silt excluder. Canal lining in the earthen portions can also be instrumental reducing conveyance losses.

Water User Association has not introduced the provision of collecting irrigation service fee from the beneficiaries at the cost of system maintenance. Whereas in emergency cases they used to collect fund from beneficiaries as there is no provision of making available of emergency fund from division office of DOI. With the construction of a gravel/black topped road from Galyang to Chapakot, commercial agricultural farming is expected to take pace with time.

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5.2 INTEGRATING IRRIGATION PRACTICES IN IMPROVED WATERMILL AREAS FOR SUSTAINABLE LIVELIHOOD

MAHENDRA PRASAD CHUDAL[1]

INTRODUCTION

Figure 1: Traditional Watermill Runner

Nepal is a hilly and mountainous country where about 83% of land is covered by hills and mountains. The country has many challenges in development due to diverse landscapes. About 65.7% of total people are still engaged in agriculture as a main business. (*Karki, Yogendra Kumar, 2015*). Agriculture is still dependent on monsoon. Besides monsoon season, there is no other provision of irrigation. The entire land does not have irrigation facility. The agriculture system is dependent on traditional techniques and no modern techniques were adopted. Although the country is rich in water resources, it is not being utilized in efficient manner and majority of farmlands have no irrigation facility. The farmers could not get financial return from their agriculture due to lack of proper irrigation system.

Watermill is an indigenous technology and is in operation in rural areas of Nepal since time immemorial. The watermill is

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directly associated with the livelihood of rural people by providing agro-processing services through generation of mechanical energy from water. In the areas of watermills, it was found that the canals for watermills were being utilized for irrigation purposes also. The water from the same canal is used for different purposes at different time. For electrification purpose the water is used in night time, for grinding and other agro-processing services, it is used during day time and for irrigation purpose, the use of water is seasonal. The usage of water from same canal is found efficient and productive utilization of canal and water.

Figure 7 Improved Watermill Runner

WATERMILL TECHNOLOGY

Watermill technology is based on the conversion of potential energy into kinetic energy through a rotating wheel by dropping water jet from a certain height. In traditional watermill (TWM), a wooden paddle is used as runner device which generates rotating energy and a grinding stone coupled at the top of rotating shaft, is used for grain grinding like maize, millet, wheat etc. The TWM has low efficiency and it needs huge volume of water (at least 25 lps) and it rotates slowly. Its efficiency is about 20- 25 percent only. From the study conducted by Alternative Energy Promotion Centre (AEPC) and Centre for Rural Technology, Nepal (CRT/N) it is estimated that the existence of traditional watermills is about 25000 throughout the country (*CRT/N, 2008*).

The improvised version of traditional watermill, replacement of wooden paddle and plank by a metallic runner shaft is known as improved watermill (IWM). The metallic runner has some sort of engineering design based upon the available water head and discharge. The IWM has better efficiency about 40 -50 percent even in case of low discharge of water. This means the IWM can grind more grains at shorter duration than TWM. The IWM can generate mechanical power from 1kW to 5 kW while TWM can generate the same up to 1 kW only. Out of 25000, only 10036 were improved and majority of them were short shaft (*AEPC, 2016*). IWMs also contribute in improvement of climate change by reduction of greenhouse gas emissions by replacement of existing diesel mills and by stopping the penetration of new diesel mills.

END USE APPLICATIONS

The efficiency of IWM is more than that of TWM and it can generate power in the range from 1 kW to 5 kW. Traditional watermills are improved in two ways i.e. short shaft and long shaft. The IWM having short shaft has improved efficiency and its capacity is limited to 2 kW and it is used for grinding purpose only. While the long shaft IWM has additional capacity that ranges between 3 – 5 kW. The long shaft IWM can be operated for diversified applications like grain grinding, paddy hulling, oil expelling, saw milling, spice grinding, rice beating and electricity generation with the addition of mechanical coupling devices depending upon the availability of power. The IWM plays a vital role in a rural area by providing for rural energy need and it is capable to generate economic and employment opportunity at local level.

IWM ELECTRIFICATION

The extension of electricity grid over the entire area is not possible due to technical and financial conditions. In this situation, a small off-grid system covering a rural area like a pico-hydro system developed from IWM electrification can be a good solution. The IWM electrification can be developed by the utilization of water available from local river. The cost of electricity generation from IWM becomes cheaper than other technologies and ranges from NPR 500000.00 to 700000.00 only. The electricity generated is capable to provide basic need like lighting, operation of radio, television, mobile charging etc. Besides this, the electrification provides economic opportunities at local level through establishment of small scale micro-enterprises like shops, tailoring, carpentry, poultry business etc.

With financial support from EnDev/GIZ and SNV, strategic support from Alternative Energy Promotion Centre (AEPC) and technical support from Centre for Rural Technology, Nepal (CRT/N), Gramin Urja Tatha Prabidhi Sewa Kendra Pvt. Ltd. is implementing IWM electrification programme "Rural Community Electrification with Watermill and Micro Enterprise Development in Nepal". The programme is being implemented in six districts of the country namely Kavre, Sindhuli, Makawanpur, Khotang, Nawalparasi and Dhading. The programme has the objective of installation of 20 IWM electrification systems having gross capacity of 60 kW. It provides basic electrification service to 900 rural households. Prior to this, the programme already developed 16 projects in Kavre, Sindhuli, Makawanpur and Dhading.

INTEGRATION WITH IRRIGATION SYSTEM

Prior to the integration of irrigation systems with IWM systems, the irrigation practices were carried out by individual household. The entire activity like construction, repair and maintenance was being done in individual manner. There was no formation of groups or associations responsible for management of irrigation systems. Watermills were integrated with irrigation systems into two ways either by construction of new canal and utilization for both IWM and irrigation or

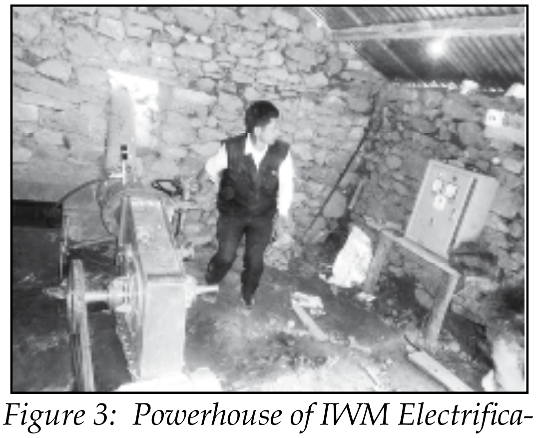

Figure 3: Powerhouse of IWM Electrification Project

utilization of existing irrigation canal for IWM application. After integrating with IWM systems, the activities were started to conduct in organized way by formulation of Users' Committee of IWM electrification system. Some cases on integration of irrigation system within watermill areas are presented below:

Case I

Figure 4: Survey for construction of canal for powerhouse

Aaldanda is located at Mahadev Danda VDC – 1, in the north-east part of Sindhuli district. The village has 32 households and the main occupation of the habitants is agriculture. However the village does not have any access to energy services like electricity and watermill etc. The people either use domestic grinder "Janto" or visit electric mill located at other village at the walking distance of more than two hour for grinding / processing of their agriculture products. Mainly, the female members are facing more drudgery for agro-processing for maintaining their daily livelihood. The electric mill is found very costly as it takes Rs. 2 per kg for processing (hauling or grinding).

When the villagers became aware of IWM Electrification Programme through, Ghatta Entrepreneurs' Association, Sindhuli, they lodged an application for installation of IWM Electrification project. After conducting detail survey of the project, it was found that a 2.0 kW Sakhukhola IWM Electrification Project can be developed and a paddy huller system can be coupled in the same powerhouse to provide access of mechanical energy for paddy hulling.

The village has an existing irrigation canal for irrigating about 20 ropanies of land. From the survey of powerhouse, it was found that the same canal can be used for electrification system in terms of technical and financial aspect. For this purpose, the Users' Committee of electrification project reached to an agreement with the owner of canal Mr. Mahabir Sunuwar for the use of canal and with Mr. Megh Bahadur Sunuwar for the use of land for construction of powerhouse. For the compensation of this contribution, the Users' Committee assured that the entire canal will be renovated as stone masonry from earthen canal. The periodic maintenance of canal will be carried out by Users' Committee itself. The necessary water will be provided to the canal owner when needed. The electrification needs water during evening and night time only. The water is further used in day time for operation of paddy huller which provides agro-processing services to local people at low cost. However the electrification system and paddy huller both are owned by Users'

Committee of the village and it has been able to provide employment opportunity to a local person as operator. The application of existing canal brought an efficient and diversified utilization of water for electrification, paddy hulling and irrigation from the same canal.

Case II

Mr. Jibalal Lamichhane, resident of Mithukaram – 4, Nawalparasi contributed his private land for construction of canal for IWM electrification project in his village. The village has 55 households with no access to electricity. Some of the households are using small scale solar home system while others are still dependent on kerosene wicked lamps.

Figure 5: Canal and Powerhouse of Nirandikhola IWME Project

When the villagers came to know about IWM electrification programme, the local partner organization Himalayan Community Development Forum, Kawasoti, Nawalparasi motivated the villagers for installation of IWM electrification project. After construction of 4.0 kW Nirandikhola IWM Electrification Project, the entire village got connection with electrification facility, paddy hulling service and irrigation facility for improvement of their rural livelihood.

The Users' Committee committed to provide irrigation facility in the village. The newly constructed canal is capable of of irrigating about 18 ropanies of cultivated land. From such newly constructed canal, the community believed that the productivity of land will increase. The establishment of paddy huller will replace the existing mill operated by diesel. This will result in the saving of cost of agro-processing and save environment by stopping pollution emitted from diesel.

Case III

Figure 6: Powerhouse of Barabise IWME Project

Barabise IWM Electrification Project having capacity of 3.5 kW is in operation in Netrakali VDC – 5, Sindhuli. The project provides electrification service to 68 households of the village. After getting electrification service, the community tapped various economic and employment opportunities through establishment of poultry business, tailoring services and shops at their locality. Besides electrification service, the community established a paddy huller machine at the premises of powerhouse in order to utilize waste water during day time. The establishment of paddy huller brought a good opportunity for income and employment generation at local level. This project also saved time and money of the local people. The community fixed a very cheap service price of paddy hulling facility and people from other village also started to visit the powerhouse for paddy hulling.

For the construction of powerhouse, a 350 m long stone masonry canal was constructed. The construction of canal became “boon” for the local people as it provided irrigation facility during the season of cultivation. The canal has been able to provide irrigation facility for about 104 ropanies of land and the people realized the improvement of productivity of irrigated land through improvement of production of maize, rice and started cultivation of garlic and onion as cash crops. Besides this, the paddy huller operator tapped an attractive income generating opportunity at local level; he committed to take entire responsibility of repair and maintenance of powerhouse and canal. In overall, the community seems very happy with development of IWM electrification project and the sharing of its diversified benefit.

CONCLUSION

The integration of IWM canals with irrigation system resulted in increase of productivity of agriculture by proper management of irrigation system. The irrigation system reduced dependency on monsoon season. The productivity of crops was increased and the people started to cultivate offseason vegetables as well. Besides this, the security of water was increased and, repair and maintenance cost of canal was entirely reduced. The establishment of agro-processing facility in their locality reduced drudgery of women and children by minimizing workload and time in remarkable manner. The integration of watermills brought a positive change in rural livelihood by ensuring food security and sustainability of rural community.

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5.3 SOLAR PUMPED DRIP IRRIGATION

ROBERT YODER

Abstract:

Gujarat farmers' comment: "... solar pumping worked great, point the panel, flip the switch, the water flows, no problem! But I already have diesel pumps and only need to run it a few hours a day. I'll keep the drip system and use our engine pumps!"

This paper describes the initial experience in developing and field-testing solar powered drip irrigation for smallholder farmers. Solar powered pumping has technically been available for many decades but only with the dramatic drop in the price of solar panels in the past six years has solar power become cost competitive for operating irrigation pumps.

Since drip irrigation is more effective in placing water into the root zone of plants than surface flooding, furrow or sprinkle application, it reduces the amount of irrigation pumping required for a given area of crops. Results of field trials in Gujarat, India are presented, illustrating that for production of high value vegetable crops in a water scarce environment, solar powered drip is effective for producing high quality produce and pays for itself in one to three growing seasons.

In groundwater-abundant Bihar, India the water extending value of drip irrigation is irrelevant and quality and yield improvements are the primary factors for considering drip irrigation. Even with the cost of solar pumps at an all-time low the initial cost for installing solar pumping is in the order of 3 to 4

times that of purchasing an engine pumpset. Unless there are additional cost breakthroughs or financing becomes available, solar pumping for irrigation remain unattractive.

BACKGROUND

Entrepreneur Paul Polak has devoted the past four decades to increasing the income of smallholder farmers. He concluded that irrigation, even more than good quality seed and fertilizer, is the key input for increasing yield and quality of smallholder production. One of Dr. Polak's earliest endeavors was to streamline the manufacturing, delivery and installation of treadle pumps in Bangladesh and India. This technology spread rapidly and in less than a decade, millions of manually operated treadle pumps were irrigating smallholder plots and providing a significant net increase in household income (Shah, et al. 2000). In 2013 Dr. Polak established Affordable Village Solar (AVS) as a USA registered non-profit company to develop, test and promote solar pumping options for irrigation in India. This paper reviews the work to date in developing an affordable solar alternative to fossil fuel based pumping.

GROUND WATER IRRIGATION IN INDIA

In the Gangetic Basin, where the water table is shallow enough for irrigation pumps using suction lift from the surface, local craftsmen can be hired to construct tubewells at very low cost. Treadle pumps have been replaced by powered pumps greatly expanding the area irrigated in the past 5 decades. Where reliable electricity is available, 2 or 3 kW electric motor driven centrifugal pumps are preferred but the vast majority of farmers rely on engine pumpsets. Many types of engine pumpsets are available in the market but most farmers use a 3 to 7 hp diesel engine to drive a centrifugal pump delivering between 5 to 15 liters/second. Water from the pump is generally delivered to the field through a layflat hose to flood level, bunded, fields or to be directed through furrows between rows of crops.

Pumping from groundwater now sustains nearly 60% of the area irrigated in India. In both Pakistan and India, pumped groundwater bridges critical gaps in water delivery from the large reservoir or river-diversion irrigation systems of the Ganges and Indus River basins. Since individual farmers control their own pumped irrigation water deliveries, the quantity and timing is flexible and reliable. Groundwater access has dramatically improved irrigation in South Asia.

A study conducted by iDE in 2008 in 26 districts of the Ganges Basin, and coastal areas of Orissa in India plus parts of the Nepal tarai, found there were 39 million operational land holdings in the study area with most households cultivating less than 2 ha. There were 6.7 million small pumpsets being used to irrigate portions of these holdings. It was estimated that this sample represented less than one-third of the total number of diesel engine pumpsets operating in India. On average, the pumpsets operate 500 hours per year consuming about 1.1 liter of fuel per hour. In the study area 3.7 billion liters (23.2 million barrels) of diesel fuel are consumed each year for pumping irrigation water. In the study area, pumping results in the addition of over 10 million tons of CO2 to the atmosphere at 1.5 ton CO2 per diesel pumpset (IMRB International, 2008).

On average small engine pumpsets have capacity to deliver about 600 liters of water per minute. To save fuel and wear, the engine pumpsets are typically operated at less than full capacity (~500 liters per minute). At that pumping rate it takes a farmer about 4 hours to irrigate a 1-hectare (2.5-acre) field. During that period, the pumpset will consume about 4.4 liters of fuel costing a total of $3.30. Typically, irrigation water is applied about 50 times during a growing season, so the operating cost, excluding repairs, is in the order of $165 per crop for a 1-hectare field. Engine pumpsets used to irrigate vegetables or other high value crops will usually pay for themselves in the first one or two crop seasons.

Engine pumpsets are globally available. In India, a 3 to 7 hp engine pump retails for between $400 and $500. They are cheaper in China and considerably more costly in Africa but in most countries can now be purchased at local hardware shops

SOLAR PUMP DEVELOPMENT—CONCEPTUAL REQUIREMENT

The objective of the ongoing AVS solar pump project is to develop a proven low-cost solar pumping system that can compete with fossil fuel engine pumpsets on the basis of cost. Since the majority of farmers in the Gangetic Basin are irrigating one hectare or less with engine pumpsets the design target for solar powered irrigation was established as capacity to irrigate one hectare.

To develop pumping requirements, it was assumed that the crop canopy would cover the entire 10,000 m^2 area and that the irrigation supply would replenish the daily evapotranspiration (ET) of the crop. The average ET over the Basin area is about 5 mm/day (1 liter/m^2) requiring a daily water supply of 50,000 liters/day if the water applied is 100% effective (58,000 l/day if application is 85% effective).

Drip irrigation was selected as the water application method for two reasons. First, it is the most effective method of applying irrigation water (> 85% of the water enters and stays in the root zone) as compared to surface flooding (< 50% effective) and sprinkler, requiring higher pressure (~70% effective). Since energy required for pumping is proportional to the product of pressure (or lift) times volume of water pumped and low-pressure drip irrigation applies the pumped water more efficiently than surface irrigation it requires less energy for pumping. Second, drip irrigation allows more precise water application resulting in higher crop yield and better product quality, increasing income.

At the latitude of much Gangetic Basin nine hours of sunlight for pumping is available most days in the winter and spring dry seasons. With a solar pump running 9 hr/day, including the loss of up to 15% of the water, a pumping system is needed that can deliver water at the rate of 1.8 l/sec or 58,000 l over a 9 hr pumping period to meet the evapotranspiration demand.

IN SEARCH OF A COST-EFFECTIVE SOLUTION

Many programs in India promoting solar pumping for irrigation install PV capacity to replicate the water delivery rate of a diesel pumpset in order to simply replace the engine pumpset. This requires 3 to 4 kW of installed PV that can then flood irrigate one hectare in half a day. Since a 4 kW PV array cannot easily be shifted to a new location it is limited to irrigating fields that can be easily reached by a layflat hose. Since landholding is severely fragmented in India a single farmer can seldom operate such a pump more than a few times per week.

The AVS project took a different approach. It searched for a pumpset with capacity to deliver the irrigation water by pumping nearly continuously when the sun is shining. For the 1 ha design size selected, that requires a pump that can delivery about 2 l/sec. This allows the PV array to be designed to provide just enough power to delivery 58,000 l/day. AVS also reviewed all components of the drive and delivery system to find the lowest cost and maintenance solution for PV pumping. In summary, the system designed for the first iteration of field testing consisted of the following:

- 4 panel PV array mounted on a post with manual tracking ability (as noted below this was updated to 800 W to accommodate the deeper groundwater in Gujarat, see photo 3)
- 36 volt PV panels connected to deliver power directly to a DC pump motor without maximum power point tracking (MPPT)
- Brush type DC motor with proven robust operating characteristics over a wide voltage range
- A direct coupled centrifugal pump with an efficiency curve that best matched the variable head and flow conditions of solar power and well drawdown
- A flexible suction pipe from the pump inlet to the well bottom included a bottom end high-flow “foot valve” for open wells and a priming hand pump arrangement for tubewells)
- A 1000-liter (tote type) tank elevated so the delivery valve was 1.5 m above the ground and the top of the tank 2.5 m. A 3 in. PVC pipe with open top end extending 1 m above the top of the tank was connected to the deliver pipe to increase the overflow pressure to 3.5 m above the ground (photo 4)
- An oversized screen filter with low head loss before the field delivery line to assure clean water for the drip system
- 2” tank valve and 2” PVC ball valve on the field side of the filter

- 3″ PVC or layflat hose to the center of the field
- An H shaped zoning connection at the center of the field so that any one of four drip irrigation zones could be operated singly or simultaneously with any or all other zones
- PVC or Layflat manifold pipe for each zone with drip line offtakes at the preferred row spacing
- 40 m to 60 m drip line runs.

FIELD TESTING

The first season of testing, 2014-15, took place in Gujarat where the local NGO Save Saline Area Vitalization Enterprise, Limited, (SAVE Ltd.) was prepared to assist in finding farmers interested in trying a solar pumped drip system and to manage the field activities for the testing. Nine farmers were selected near the town of Bhatiya in Western Gujarat who agreed to try growing vegetable crops for local markets at the end of the rainy season in November of 2014 through the spring dry season of 2015. This is an area where they use large diameter hand or excavator dug wells that are as much as 9 to 10 m deep. The water table in the rainy season is about 3-4 m below the surface but drops to 8-10 m within 2-3 months. With their engine pumps, they only grow fodder near the well in the winter season since there is not enough water to grow other crops. This is a very water deficit area for winter and spring crops a period when there is no dependable rainfall. The farmers were clear that they did not think there was enough water for more than 1 acre (4000 m^2) for post rainy season irrigation.

So instead of 1 ha, the initial testing area was 4000 m^2 near wells on 9 different farms. The agreement was that the project would install both the pumping and drip irrigation system after the farmer prepared a 4000 m^2 area for planting. The farmers were free to select one or more crops of their choice to grow and sell in the local market. The farmers were responsible to use their own land and well and provide all the labor for land preparation, planting, irrigating and cultivating, harvest and marketing the produce. Most used only family labor but some also hired labor to help with planting and harvest.

Further, the agreement was that each farmer would keep a daily record, with assistance from the local NGO, of all their input costs that were not family labor, i.e., hired equipment and labor for things like tilling, fertilizer application, harvesting and marketing, etc., as well as seed, fertilizer and any other cash input costs related to production, harvesting, processing and marketing of their crop. The agreement with AVS was that at the end of the season the farmers would be able to purchase the solar pumping and drip system at cost, i.e., without subsidy or AVS overhead or profit.

The center pipe in photo 5 is the main line from the pump. It connects to a distribution manifold that connects four zone valves and submain lines. Each of the four by 1000 m^2 zones can be operated independently depending upon the pumping rate and/or water required by individual zones.


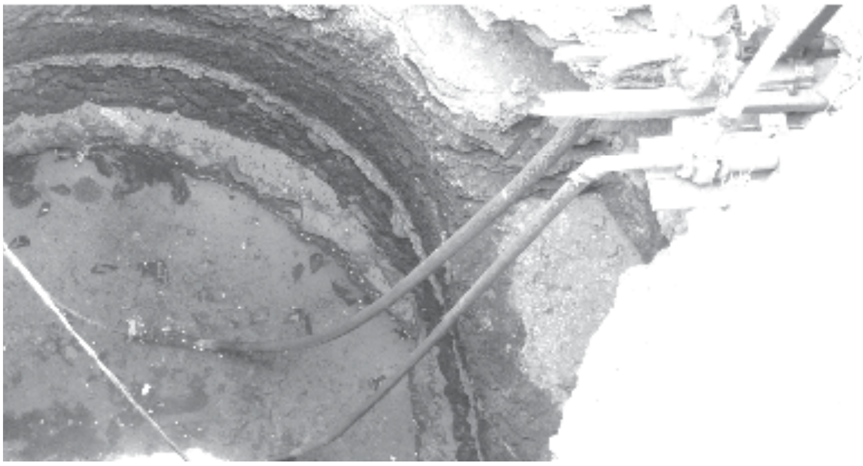

Photo 1 and 2. Typical wells in Bhatiya, Gujarat. "Left photo" with only engine pump fitted and "right photo" with DC pumpset installed. Note: because of the excessive well depth the pumps needed to be placed "down the well" in order to not exceed the maximum suction lift.

Photo 3. Two 400 W solar arrays each with manual tracking mounts.

Photo 4. Pump, tank and pipe arrangement

The extra 400 W of power was required because of the depth of the wells.

Photo 5 & 6. Main delivery line and submain zone lines with drip line offtakes.

SYSTEM COST

All of the solar pumped irrigation system components were purchased from manufacturers or hardware shops in India with the exception of the high-flow foot valves which we could not find locally. The component costs are listed in Table 1. These are invoice costs that include local taxes but no overhead or business development cost.

AVS SOLAR PUMPED DRIP IRRIGATION COST OF MATERIAL/FITTINGS				
Name Of Item	**Amount (IRs.)**	**Amount (NRs.)**	**Amount ($)**	**($/m^2)**
PV Module 100w(Shivam Solar) x 8 = 800W	36,120	57,792	578	
PV Stand GI and fittings	9,411	15,058	151	
Suction pipe and fitings	3,027	4,843	48	
Surface Motor & Pump 600w (Rotomag)	28,500	45,600	456	
Tank and mount, filter and piping from pump	8,829	14,126	141	
Solar Pumping System (subtotal)	85,887	137,419	1,374	0.34
Delivery pipe and fittings (filter to zone manifold)	1,196	1,914	19	
Zone manifold, valves & submain	3,499	5,599	56	
Drip line and fittings	22,739	36,383	364	
Drip Irrigaton System (subtotal)	27,435	43,895	439	0.11
4000 m^2 Solar Pumped Drip Irrigation (Total)	113,322	181,314	1,813	0.45

Table 1: Solar pumped drip irrigation system cost for 4000 m^2 installation

PRODUCTION COST AND INCOME

All nine farms, with assistance from AVS and SAVE, were successful in preparing their land, planning and planting their crops and successfully installing the pumping system and operating the drip irrigation system. One farmer planted only tomatoes and another only watermelon but most plant a mix of crops that included: chili, tomato, melon, radish, okra, cucumber, and eggplant.

Aware that their water supply was limited they took great care to only apply water when the soil moisture was depleted as evident by digging next to the plants and testing for moisture with their fingers. Under cloudy conditions they only irrigated one zone at a time but with full sunlight they could simultaneously irrigated 2 and sometimes 3 zones. Whenever the pressure pipe above the storage tank overflowed they opened the delivery valve on one additional zone. As the water supply was becoming depleted by April and May several farmers rationed their irrigation to 1 or 2 hours/day for each zone without noticeable plant stress. Only one farmer completely ran out of water before his crop was ripe.

Photo 7, 8 and 9: Drip irrigation reduces weed competition producing higher yields and better-quality product than flood or sprinkle irrigation.

Farm records and observation were used to determine cost of production. This included only out-of-pocket costs, i.e., paid labor and purchased inputs of seed, fertilizer, pesticides and costs associated with transport and marketing. This information along with the income from sales is compiled in Table 2.

	Input Cost (only hired labor & purchased inputs)		Total Revenue From Sale of Produce		Profit (returns to land, labor & water)	Seasons to pay system
Farm	Nepali Rs.	US$	Nepali Rs.	US$	US$	
1	28,943	287	103,180	1,022	735	2.5
2	21,719	215	73,181	725	510	3.6
3	32,142	318	147,905	1,464	1,146	1.6
4	15,845	157	224,852	2,226	2,069	0.9
5	27,407	271	126,346	1,251	980	1.9
6	55,639	551	252,036	2,495	1,945	0.9
7	14,770	146	54,103	536	389	4.7
8	20,830	206	178,024	1,763	1,556	1.2
9	44,036	436	120,400	1,192	756	2.4
			average of 9 farms		1,121	

Table 2. Cost and income data for farmers in Gujarat irrigating 4000 m^2 using the $1,813 solar pumped drip irrigation system.

Farmer 7 grew water melons but his well became empty just as the melons were ripening. He estimated that yield was less than 50% of what it would have been with adequate water. Farmer 4 and 6 both had prior experience with vegetable production and marketing. They understood better than the other farmers how much labor was involved in growing, harvesting and marketing vegetables and were able to arrange for hired labor to assist during peak harvest periods. Even with the extra cost of labor they earned the highest profit, enough to pay for the full cost of the pumping system in their first season. Farmer 1, who grew only tomatoes had an excellent crop but was able to harvest only a portion of his crop due to lack of labor. Others with mixed crops that ripened at different times were able to better manage the harvest and marketing with only family labor.

At end of the season interviews all nine farmers agreed that using drip irrigation made it possible for the first time in their farming experience to grow a crop in the dry season. They also expressed surprise at how much work vegetable crops took to harvest and market but all said they would continue to both use drip irrigation and grow vegetables because they could see how profitable that would be. However, they would be more careful about what crops they grew and limit the area for each to avoid labor bottlenecks.

All nine farmers agreed to purchase the drip system. However, all nine declined the opportunity to purchase their solar pumping system. The reason each gave was that they already owned their engine pump and with the limited pumping required to irrigate using drip the cost of operating the engine would be minimal.

The takeaway lessons for AVS from the Gujarat solar pumped drip testing were:

- Vegetable production and sale is a profitable business in Western Gujarat. Carefully managed solar pumped drip irrigation illustrated payback of initial investment in 1 to 3 seasons.
- Low pressure (1 to 3.5 m water head) drip worked well with drip lines of 40 m length achieving greater than 90% application uniformity.
- The 5/8" drip line with 3.8 l/hr and 4.0 l/hr emitters at 40 cm spacing worked well with no clogging suggesting that the oversized screen filter performed as planned. Testing indicated that with 1.5 m pressure drip lines of 60 m length would have acceptable uniformity.
- Drip lines from 5 different Indian manufactures were tested confirming that quality differences were minimal. Smaller manufacturers had both cheaper products and were more responsive to request than the larger internationally recognized manufacturers for the small quantity orders required by these farmers.
- The solar pumping system worked as expected with no serious malfunction. One pump was sent back to the manufacturer when the shaft would not rotate. A representative from the manufacturer visited the field and demonstrated a simple remedy. The problem was caused by rust when the pump was not operated for a few days.

- The solar pumping system, using a centrifugal pump, had wire to water efficiency of 34%. A positive displacement pump could provide 50% or greater efficiency reducing the number of solar panels required but none were found in the market with 2 l/sec delivery capacity.
- The initial (upfront) cost of a solar pumping system is about 3 times more than an engine pump and remains a barrier that must be overcome in making solar pumping attractive
- Some type of financing will be required before most farmers will consider solar pumping.

FIELD TESTING IN BIHAR 2015-2016.

With limited funding, field testing in Bihar was curtailed to several exploratory visits in the spring of 2015 and three installations were made in early 2016. As an opportunity for quick installation of drip irrigation in a standing crop the project searched for farmers with banana plantations interested in testing solar pumping. Two pumping systems similar to those used in the Gujarat test were installed in late spring. Both pumps were run continuously to test solar availability and pump capacity. Water in excess to irrigation needs was diverted to nearby ponds used for fish farming.

These tests gave opportunity to pump from tube wells usually used by engine pumpsets. The water table was 4-5 m below the soil surface. The tube wells were built with “one-way” valves about 1.5 m below the top of the casing. The purpose of the valve is to simplify pump priming. Priming, however, remained difficult when the one-way valves did not seat properly making it difficult to expel all the air from the suction pipe and pump necessary for priming. The solution was to store enough water in the tank used as a buffer for the drip system and then allow it to flow back into the pump to expel the air.

What became evident in the search for 1 ha size banana plantations was that very few 2 ha farm owners had any single field much larger than half a hectare. The land holding is severely fragmented. When engine pumpsets are used for irrigation they are moved multiple times a day almost, one plot to the next, or layflat hose is used to transfer water hundreds of meters to distant plots.

Given the small size and fragmented holdings, a smaller PV pump was procured and set up to drip irrigate three nearly contiguous plots totaling 1500 m^2. This is a pump sold by Future Pump brand named the SF1 solar pump and manufactured in Gujarat, India. At 6 m of total lift the SF1 delivers about 1600 l/hr in a 9-hr pumping day. Using drip application this would fully irrigate 2300 m^2 of full canopy crop with ET of 5 mm/day. The ex-factory cost of the pump with PV panel is about $600. This is a positive displacement pump so has considerably higher efficiency than the centrifugal pumps used in Gujarat.

LESSONS LEARNED IN THE BIHAR TESTING

Since ground water is easily accessible in much of Bihar, drip irrigation is almost unheard of in rural communities. Even those focusing primarily on high value market crops have not used or even seen drip irrigation. The primary conclusion of the 2015-2016 testing in Bihar is that it will take a multi-year, project-type demonstration to successfully demonstrate and fully test solar pumping in this environment.

Several opportunities became clear even with the abbreviated Bihar test. Perhaps most important being that fish ponds have a very high profit potential. There are locations in South Asia where fish farming is well advanced but in Bihar it has not been developed yet as a profitable enterprise. Ponds are dug if there is a government subsidy but they are only filled with rainwater which seeps away before the end of the dry season giving a much too short growing period than necessary for profitable fish raising. Smallholder fish ponds would integrate well with solar pumping for irrigation. It gives opportunity to fully utilize the solar pumps capacity even in periods when irrigation requirement is limited. A number of issues were identified that could be best addressed in a longer-term demonstration project:

- The ponds have very high seepage loss that could be reduced by either lining with a plastic membrane or soil treatment to reduce seepage.
- Groundwater is not added to the ponds during the dry season because pumping costs are too high. Determining the cost and benefit of pumping water for fish raising will be useful.
- Quality fingerlings are not being used for socking the ponds so there is no species control.
- There is little knowledge about which fish species grow well together or about their market value.
- Fish feed is not readily available nor systematically administered.
- Extension information for fisheries and training are currently not available to smallholders in the areas of Bihar that were visited and should become part of a demonstration activity.

Other lessons and observation from Bihar

- Land ownership, plot size and disperse location of plots makes it difficult to install a 1 ha system for irrigation unless the system is mobile. The SF1 pump or the anticipated SF2 pump with double the capacity of the SF1 are more appropriate as irrigation only pumps with respect to the dispersed small plots.
- Pumps suitable for 1 ha irrigation may integrate well on farms where the farmer also has a fish pond that requires supplemental water. Considerable investigation is required to determine if pond seepage can be reduced and how much supplemental water will be required.

- Iron content in the water was high in the test area and will need to be addressed if drip irrigation is used. Rice husk char is readily available in Bihar and can be used to make activated carbon filters to remove iron from the water. Alternatively, chlorine treatment can be used to control iron bacteria that cause the slime that clogs drip emitters.
- Drip irrigation is currently not widely used in Bihar. There are no equipment dealers or shops selling drip tape and fittings. While there are numerous manufacturers in Western India, shipment and sales without local stocks remain problematic given the status of India's interstate commerce.

CONCLUSION

AVS based its solar pump design on water application on drip application technology. This work started at the time when the cost of PV was $1.5 to $2.0 per Watt. A higher cost of PV put a premium on reducing the power required for pumping which was accomplished by using drip application. Drip also enables a finite quantity of water to be spread to a much larger crop area making it a cost-effective technology where water is limited. The price of PV dropped by 50% by the time testing began in Gujarat. However, the results in Gujarat were still positive because of the limited water supply.

In Bihar where water is abundant it is difficult to see a water related or financial incentive for choosing drip with its high up-front cost as compared to engine pumpset irrigation with surface application. However, the quality and yield difference of vegetable production has clearly tipped the scale to drip irrigation even in water abundant parts of the word where vegetable production is finely tuned to markets. It will be worthwhile investigating this in the Bihar setting in the future.

Table 3 presents the cost information for irrigating a one-hectare area using both an engine pumpset with surface application and for a solar pumping system also applying water by surface application and compares these with solar pumped drip irrigation. One notable difference is that the engine pump can accomplish one application of water in 4 hours while the solar pump requires the full day of operation. Without counting labor, the capital cost of solar (without drip) is roughly 43% more than an engine pumpset for the first year of use. In subsequent years the engine pump requires $288 operating expense while the solar pump require none. By the 3rd year cumulative expenditure for engine pump system exceeds that of the solar pump and for subsequent years the returns to the solar pump would be higher than that for the engine pump. Depending upon the useful life of each system and other maintenance expenses the internal rate of return remains slightly higher for the engine pumpset given the premium of the low entry cost for the engine pump.

		Irrigation cost for 10,000 m^2 (1 ha)		
		Engine pumped (6 hp)	Solar Pumped	
		Field-level application method		
		Surface	Surface	Drip
Pumping head (meters of water)	Static	5	5	5
	dynamic	2	1	1
	pressure	2	1	3
	Total lift	9	7	9
Application efficiency		50%	50%	90%
Irrigation to meet 5 mm ET (liter/day)		100,000	100,000	55,600
Pump rate (l/s)		(4 hr) 6.9	(8.5 hr) 3.3	(8.5 hr) 1.8
Pump power requires (W)		4375 @ 14% eff	659 (34% eff)	471 (34% eff)
Cost: solar panels and stand @ $0.72/W		$0.00	$474	$340
Cost: pump, tank, fittings		$600.00	$796	$796
Total cost: pump & PV		$600.00	$1,270	$1,136
Water application hardware cost		$0.00	$0	$1,098
Irrigation system Cost		$600.00	$1,270	$2,234
Operating cost (per season w/o labor)		$288	$0	$325
Annual Cost to Irrigating 1 ha		$888	$1,270	$2,559
		100%	143%	288%

Table 3. Cost comparison between engine pumpset and solar pumpset with surface and drip application.

In the Gangetic Basin where ground water is abundant, solar pumping has a serious disadvantage because of its high initial cost. For PV systems, larger than the SF1 type single panel pump, solar pumps are also less portable than engine pumps giving an additional disadvantage where an individual farmer's land is fragmented. Especially with cereal crops where surface flooding is easy and effective when a high discharge pump is used, solar pumping will continue to face difficult competition from the already proven engine pumpset technology.

For intensive agriculture of vegetable and other high value crops where precise water control can improve both product quality and yield solar pumping with drip application is already competitive with engine pumping and surface application even with the high initial and replacement cost of drip. This is especially true where water is in short supply as in Gujarat. Finding appropriate financing models remains a serious obstacle in the promotion of solar pumped drip irrigation.

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5.4 ADDRESSING LOCAL WATER CONFLICTS THROUGH MULTIPLE USE WATER SYSTEMS (MUS): A LEARNING FROM CALCNR PROGRAM AT DHIKURPOKHARI, KASKI, NEPAL

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INTRODUCTION

Community Based Adaptive Learning in Management of Conflicts and Natural Resources (CALCNR) is a four-year program supported by the Netherlands Organization for Scientific Research (NWO). CALCNR is being implemented in Nepal and Bangladesh with the objective of generating evidence-based knowledge on the gaps between community management of natural resources, local adaptation innovations, and national policy debates over climate change and conflicts related to natural resource access. The program's ultimate aim is to improve policy and promote cooperation between local and national stakeholders.

Ranked 17th on the Global Climate Risk Index in 2015[4], Nepal is acutely vulnerable to the impacts that climate change-induced events such as flooding, drought, and forest fires will have on its critical natural resources. With 80% of its population engaged in agricultural livelihoods that depend on natural resources[5],

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5 Nepal Water Partnership. Climate Change Trends and Impacts on Livelihood of People. (2009).

the population is at high risk. Further, Nepal is a resource-based economy, and failure in the agricultural sector would damage the country's economic stability. Without sufficient economic and technological capital to implement large-scale mitigation and adaptation strategies, the country will suffer from climate change. Concerns about long term availability of resources, water in particular[6], in the country have caused conflicts in some regions over resource management and access[7], making it critical for the country to better manage its resource and to enhance its climate resilience.

In response to the growing concerns of water scarcity in Nepal, iDE, through the USAID funded Initiative for Climate Change Adaptation (ICCA) program, designed a water engineering intervention known as the Multiple Use Water System (MUS). This program is recognized and utilized by the International Water Management Institute (IWMI) and the Global MUS Group to improve the water issues in Nepal.

This paper discusses the impacts of water scarcity, a result of climate change, on the rural Pariyar Tole community in the Dhikurpokhari Village Development Committee (VDC) in Nepal. The CANCLR program effectively reduced resource-related conflicts between communities in order to facilitate the implementation of a Multiple Use Water System (MUS) by the USAID-funded Initiative for Climate Change Adaptation (ICCA) to reduce physical water scarcity in the community. Further, the efficient use of water reduced the potential for future intra-community conflicts over water use and management. Thus the community has access to water for domestic and agricultural purposes, and can effectively handle resource-related conflicts as they arise in the future.

WHY MUS?

MUS is an improved water resource management approach that uses technology appropriate for the needs of isolated and marginalized populations relying on subsistence farming. Traditional irrigation systems are incompatible with the unevenly distributed farms and small land holdings common in Nepal, however the unconventional MUS water system is highly effective. This system integrates socio-economic development of community members with the conservation and efficient use of water in order to resolve conflicts and promote effective water management. MUS, therefore, has utility in reducing both water-related conflicts and scarcity in vulnerable communities.

Diagram of MUS technology and its multiple uses.

6 Government of Nepal. Water Resources of Nepal in the Context of Climate Change (2011).
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Key Benefits of MUS:

- Provides sufficient water for both domestic needs and agricultural irrigation.
- Enables farmers to cultivate high value crops that are best suited to changes in the prevailing climate.
- Saves labor, increases agricultural output, and facilitates farming during dry season.
- Reduces the workload of women and girls that carry water.
- Enhances community level climate change adaptation and can reduce conflicts.
- The benefit of MUS is that it helps to reduce two common climate change-related issues; water scarcity and water-related conflicts. These reasons make MUS a valuable tool when working in conflict-prone areas that suffer from acute water scarcity.

Research Approaches

The following research approaches were utilized *to facilitate the CALCNR project and MUS implementation.*

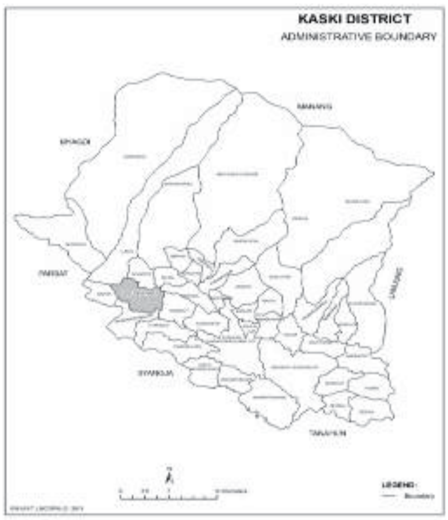
Participatory Action Research (PAR) – Research was conducted to gather information on conflicts and issues within communities. Information was regularly documented through participants' collective effort and action and from the CBO working together. The method aims to enhance CBO/participant's awareness of the situation in order to take effective action and to make progress.

Adaptive Learning Network (ALN) – Outcomes and lessons learned from the PAR approach was shared through the ALN system in order to discuss successes and problems with the research approach to improve it in the future.

Policy Stakeholders' Forum (PSF) – Lessons from PAR and ALN approaches were shared at forums with district and central policy stakeholders. These forums were targeted at the topics of advocacy and right policies.

STUDY AREA

Dhikurpokhari is a VDC in the Kaski District of the Gandaki Zone in Northern Central Nepal that experiences water shortages, leading to conflicts between communities over water resources and how to best manage them. The village of Dhikurpokhari is located 16 kilometres West of Pokhara City, spanning 23.2km² at an elevation of 1,280m. To the South of Dhikurpokhari lies the Kaskikot VDC and to the East lies the Ghandruk VDC. Dhikurpokhari has rich ethnic and cultural diversity, as it is home to people from many different



Map of the Kaski District, Nepal

castes and religions. Based on census data from 2011, the total population of this VDC is 7,318 with a male: female ratio of 3,288:4,030[8]

The majority of Dhikurpokhari VDC villagers are agriculturalists, and therefore water and other natural resources are critical to their livelihoods and survival. Dry spells and drought have made difficult to cultivate the crops. Without water, farmers will be forced to switch to other livelihoods that may disrupt the agricultural traditions of this area. With growing concerns about climate change impacting water availability, and parallel trends in conflicts between communities over resource management, this region is in a vulnerable situation.

The environment of this area is rich in natural resources and beautiful landscapes. It is a lush, richly vegetated area with stunning views of the sacred mountain Machhapuchhre (Fishtail) in the Annapurna Range. The surroundings are very peaceful, making it an ideal escape for travellers and tourists. Dhikurpokhari lies along the Pokhara-Baglung Highway and is a gateway to the Annapurna Conservation Area. This region experiences a subtropical climate, conducive to forest growth. This climate also benefits the agricultural livelihoods of most people because crops grow easily in sub-tropic temperatures. The natural beauty of the region makes it important for the country’s tourist industry, as visitors come to paraglide and trek. Climate change is threatening the environment in this region, which may impact the country’s economy as a whole.

EXHIBITED BENEFITS OF MUS IN CONFLICT RESOLUTION: DRAWING ON OUTCOMES IN THE DHIKURPOKHARI VDC, KASKI

The intercommunity and intracommunity conflicts arose in the Dhikurpokhari VDC over water resources.

Inter-community: The lower community of Pariyar Tole Ward No. 2 faced severe water scarcity. To resolve this issue, the iDE-ICCA team planned to establish a MUS in the community to relieve water stress. An iDE-ICCA engineering survey found that the only viable water source for the lower community’s MUS was 6 km away in the upper community of Maranche. During iDE-CALCNR facilitated discussions with the upper community in March 2014, upper community residents refused to grant the lower community access to their water source because they would not receive any benefit from sharing their water with the lower community.

However, once iDE-CALCNR contacted Mr. Shree Bhadra Paudel, chairman of the Maranche Youth Club, about supporting their requests, negotiations yielded positive results. Being an influential upper community resident, Mr. Paudel convinced the upper community to support the lower community, as long as the lower community provided economic compensation to the community and to the youth club. The MUS was finally constructed in November, 2014 with a delivery distance of 1,300m to support many

8 VDC data

households. The MUS reduced the lower community's water stress, and also prevented future conflicts between the communities over water access.

Intra-community: There is equal and high water demand for both domestic and agricultural purposes in the lower community. Thus future conflicts over water use and distribution within the community were likely to arise. iDE preemptively chose the MUS design in order to provide water for both purposes. The MUS designed for this community was constructed with 26 tap stands for multiple uses, limiting the potential for future intra-community conflicts.

Table-1: Actors and Interests for the use of water in the area

Stakeholder/ Community	Issue/Interest
Dalit community Lower community of Pariyar Tole, Dhikulpokhari (Ward No. 2)	Experience a severe shortage of water for domestic and agricultural purposes. Require access to water from the upper community in Maranche, Dhikurpokhari (Ward No. 7).
Elite market community Lower community of Pariyar Tole, Dhikurpokhari (Ward No.2)	Experience a severe shortage of water that negatively impacts businesses and living standards. Willing to support the lower community of Pariyar Tole if they are also granted access to water supply.
Elite community Upper community of Maranche, Dhikurpokhari (Ward No. 7)	Willing to work with the elite market community of Pariyar Tole, Dhikurpokhari (Ward No.2) to solve the water problem for both communities in the interest of their businesses and living standard.
Upper community of Maranche, Dhikurpokhari (Ward No.7)	Already have access to a natural water source, however was not interested in providing some of their water to the lower community because they saw no personal benefit from the negotiations.
Maranche Youth Club Upper community of Maranche, Dhikurpokhari (Ward No. 7)	Very influential in the upper community, and interested in getting support and funding for their club through supporting the lower community in their request for access to the upper community water source.
Government stakeholders (VDC secretary and VC4 of Dhikurpokhari VDC).	Interested in solving the water problem for the lower community so as to reduce conflict and keep VDCs stable.
ICCA, iDE, Nepal	Interested in establishing climate change adaptations such as MUS in vulnerable communities to prevent environmental challenges and to resolve environment-related conflicts.
CALCNR, iDE, Nepal.	Supports the ICCA and by mediating conflicts between the communities through negotiations that would result in the lower community having access to the upper community's water source.

PARTICIPATORY ACTION RESEARCH (PAR)

CALCNR team meeting with community members at Pariyar Tole, Dhikurpokhari

CALCNR iDE teams undertook extensive research on the conflicts and needs of the communities in Dhikurpokhari prior to becoming involved. The purpose and benefit of PAR is that the specific and unique needs of each site can be investigated and effectively addressed, using national frameworks and international intervention on a local level. The team not only met with community residents, but also completed detailed investigations of the water needs and availability in the communities before deciding that the MUS program would be most effective. The CALCNR team organized a series of meetings with community members and government stakeholders to narrow down the conflict source and to determine a plan of action for resolving conflicts. Both of these PAR methods proved successful in resolving the issues the community faced from a community-level, bottom up approach.

In March 2014, the CALCNR teams held a series of meetings with the Pariyar Tole community and stakeholders about solving the water problem in the area. Community members stated that many of the water sources available to the community were already dry, leaving the community without access to water. In response, the ICCA team developed a plan to use the MUS as a community-based climate change adaptation mechanism to promote efficient allocation of scarce water and to supply a reliable piped irrigation source to the community.

The ICCA team, with the support from the Pariyar Tole community, commenced a detailed engineering survey of the area for the purpose of establishing a safe and effective MUS in the community. After extensive surveys and consultations with community members, the team identified that the nearest water source was located 6km from the lower community in the Maranche VDC Ward No. 7. A custom MUS engineering design was developed. The MUS was designed to contain a 16 m^3 source storage tank with 26 tap stands, a 5600-transmission under gravity, and a delivery distance 1,300m. After the establishment of this design, IDE Nepal initiated projects to collect funding for the construction of the MUS.

The MUS construction would only be possible if the upper community allowed iDE to utilize their water source for the MUS. The MUS was designed to intake water from the Maranche Ward No. 7 water supply for the use of the lower community. However conflicts arose when the community of Ward No.7 decided not to grant access of their new water source to the lower community. The lower community approached the upper community for the use of their water source, however meetings were futile and the lower community was not granted access to the water because upper communities saw no self-gain from the negotiations. Without compensation, the upper community was unwilling to help.

Through PAR methods and discussions with community members, iDE-CALCNR established that to get the upper community's support, they would need to meet with upper community influential residents. Research suggested that it would be beneficial to approach the Maranche Youth Club of the upper community to ask for access to the water source because the club chairman, Mr. Shree Bhadra Paudel was well aware of the issues the lower community faced with water scarcity and would be able to convince other residents to help the lower community.

As a result of research and participation with community members, iDE assisted the lower community in working with the upper community to come to an agreement about water use. Both the Maranche Youth Club and upper community elites requested compensation and access to the MUS water supply, and these agreements were made as incentives for a final conflict resolution. Both the communities now have access to water from the MUS. As gratitude for the upper community's generosity, annual payments to the Maranche Youth Club are supplied by the lower community. The lower community has agreed that they will donate between 1% and 2% of their MUS funds to Youth Club annually. The annual amount from MUS user is estimated to be between NRs. 2,000-2,500. This payment benefits both communities, as the MUS will last for a long period of time with proper maintenance. Further, the lower community agreed to financially support the construction of a road that will enable MUS construction materials to be transported easily. The lower community supplied NRs. 7,000 for this purpose.

In consideration of the lower community's unique needs, the ICCA established the MUS as the most effective method for supplying water. Research and discussions with community residents indicated that there is an equal and high demand for both agricultural irrigation and domestic water, and therefore the multiple use system avoid conflicts over water use within the community. Further, designing of the MUS was completed using a CALCNR approach of meetings to avoid future conflict over MUS construction. The MUS piping was designed to go through a forested area in the community, and so iDE carried out further consultations with the community forest users so as to involve them in decision making. The community near the forested area granted iDE permission to install pipes in the forested area, with the agreement that no trees would be damaged or cut down.

By involving the community in the decision making through discussions and consultations, both iDE-led projects yielded positive results and gave the communities the skills to handle future conflicts and climate change issues.

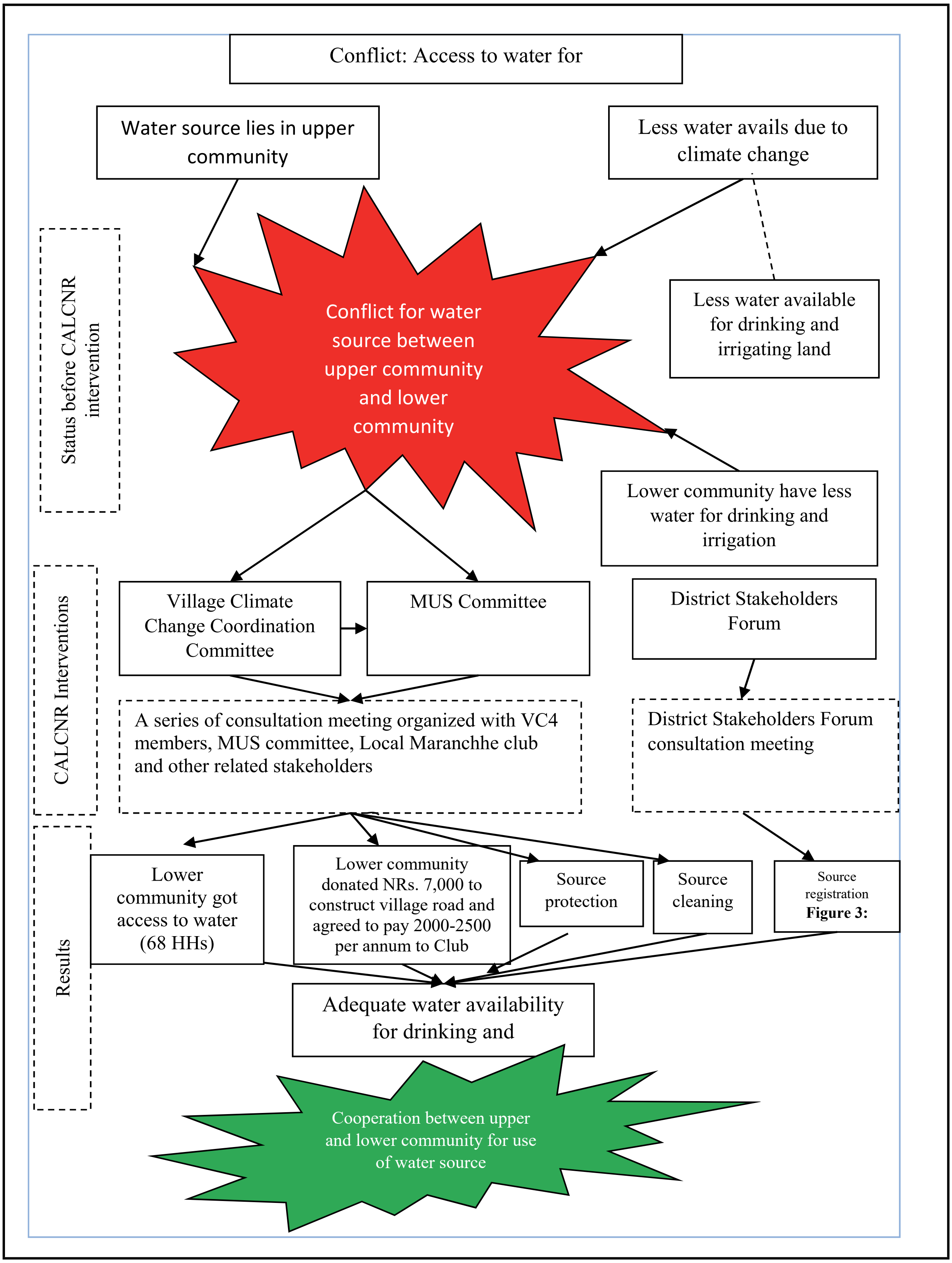
OUTCOMES AND RESULTS

Construction of the MUS was made possible once the tensions between the upper and lower community were resolved and funding was granted by the ICCA, the Mont View Church, and the Pariyar Tole community. Detailed information of the funding for the construction of MUS is provided below.

Funding Source	Amount in NRs	Amount in USD
Mont View Church	8,75,000	8,750
ICCA/iDE	80,000	800
Pitter Nidhen	35,000	350
Community Cash	1,40,000	1,400
Community Kind	6,01,745	6,017
Total Funding Received	**17,31,745**	**17,317**

A total of 340 people, 187 males and 153 females, from 68 households benefited from this MUS system as it supplies vital water for domestic and agricultural use.

Diagram 1: exhibits a map of conflict inputs and cooperation outputs at each step of the conflict resolution process



OUTCOMES:

Sarita Pariyar, Pariyar Tole community member, using drip irrigation for vegetable cultivation in a plastic tunnel.

Reduced Water Scarcity. The MUS provides water to 340 people (187 males and 153 females), from 68 households in the lower community, reducing water stress. The establishment of a MUS user committee, comprising 13 members (6 men and 7 women), facilitates maintenance of the MUS for long term use. Farmers can grow high value vegetables, and can cultivate crops during dry season for greater income generation. Community members can rely on clean water for domestic purposes, and thus MUS also reduces water-related illnesses in the community.

Prevention of Future Water Conflicts. Community members have 26 taps to draw water from, limiting conflicts over waiting lines and having to walk long distances. Water can be collected from the MUS for both domestic and agricultural needs, preventing conflicts between farmers and households over water use.

WHAT WORKS IN MUS

- Establishing MUS in areas that are prone to conflict over resource scarcity or other environmental stresses. MUS facilitates resolving current conflicts over water resources and prevents future ones over water source use and distribution.
- Communicating with members of all relevant communities will foster greater community collaboration, and is likely to limit potential conflicts between communities. Combining local resident knowledge of the region and community needs and the expertise of MUS technicians will facilitate MUS construction and support long term use of the facility as well as community ownership.
- Giving leadership and responsibility to community members such as through the establishment of MUS User Groups. This will encourage community residents to maintain the MUS themselves, and to take responsibility for it.

ADAPTIVE LEARNING NETWORK (ALN) AND POLICY STAKEHOLDERS' FORUM (PSF)

Outcoes and lessons learned from the PAR approach was shared in the ALN and Policy Stakeholders' Forum (PSF). The project findings and experiences were shared during a District Stakeholder Workshop on December 15, 2014 in Kaski, Nepal and again during the Policy Learning

Group Workshop on April 3, 2015 in Kathmandu, Nepal. The District Development Committee (DDC), The Department of Agriculture, The Department of District Livestock, The Department of Soil Conservation, and The Ministry of Environment & Population participated in these workshops.

CONCLUSION

MUS is an effective tool for both lessening water scarcity and for resolving water-related conflicts in rural communities, and greatly benefits communities trying to achieve climate resilience. The case of the Dhikurpokhari VDC water conflict exhibits the success of MUS for both of these purposes, and therefore iDE recommends that MUS be implemented with both outcomes in mind. iDE also recommends that MUS be established as a bottom-up approach to climate resilience, heavily involving communtity knowledge and participation.

fhrc Flood Hazard Research Centre

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6. PAST AND FUTURE OF IRRIGATION SYSTEMS IN THE CONTEST OF CLIMATE CHANGE

6.1 MULTI USE WATER SERVICES: ECONOMIC COST-BENEFIT ANALYSIS UNDER RURAL VILLAGE WATER RESOURCES MANAGEMENT PROJECT (RVWRMP) SCHEMES IN FAR WEST NEPAL

PALLAB RAJ NEPAL,[1] SUSHILSUBEDI,[2]

INTRODUCTION AND BACKGROUND

Efficient and optimum use of water resources and effectiveness of investment are important aspects for the investment on water resource management projects. This study focuses on the economic costs and benefits among standalone drinking water systems and multiple use water systems of the selected gravity flow technology implemented by Rural Village Water Resource Management Project (RVWRMP) in rural hills of Far West of Nepal. Through this cost-benefit analysis, it gets insight on the indicators and their economic value in monetary terms. World Health Organization, World Bank, Asian Development Bank, etc. have conducted many studies using cost-benefit analysis for standalone Water, Sanitation and Hygiene (WASH) projects, but there are rare documents that combines two types of projects (drinking water and irrigation) in a single study. So, this study combines both types of water use schemes. The Rural Village Water Resource Management Project (RVWRMP) has been working in the most remote and least developed areas of Nepal. It focuses on hill and mountain Village Development Committees (VDCs) of 10 districts (8 districts in Far-west region,

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now Province No.7-Achham, Baitadi, Bajhang, Bajura, Dadeldhura, Darchula, Doti and Kailali; and 2 districts in Mid-Western region, now Province No. 6 -Dailekh and Humla). The first phase of the project started in 2006 and continued to the second phase up to 2016. The third phase is ongoing from 2016 to 2021 as a completion phase (RVWRMP I, 2010; RVWRMP II, 2016; RVWRMP III, 2016).

The entry point of RVWRMP at the community level is the water use master plan (WUMP) of the working VDCs. This supports the planning and prioritisation of the drinking water supply, irrigation, improved water mills, micro-hydro and multi-use water system schemes. Sanitation and hygiene, livelihoods, cooperative development and improved cooking stoves, along with capacity building activities, are major components of the schemes. (White et al., 2017; RVWRMP II, 2015; Rautanen et al., 2014).

LITERATURE REVIEW

Cost-Benefit Analysis for Water Services

Water scarcity has reached, or is likely to reach, crisis proportions worldwide. Multiple uses of water are rising, increasing the draft on the limited potential. (Shah, 2005).

Cost-benefit analysis is a major tool to identify the areas for investment to optimize the resources with greater benefits. Furthermore, cost-benefit analysis can play an important role in legislative and regulatory policy debates on protecting and improving health, safety and the natural environment. The range of costs and benefits considered can vary widely. At one extreme a narrow private sector CBA (sometimes called a financial estimate) would use market prices and look only for costs supported by a small predefined group of stakeholders, usually the owners of the assets, or the project's developers, and the benefits accruing to them. On the other extreme, national, social or economic CBA would aim to assess all costs supported and benefits accruing to society at large, regardless of how they are distributed. Moreover, this economic CBA would use accounting (or shadow) prices to correct or complement market prices if they are lacking or do not reflect true economic scarcity. Moving from financial estimates to economic CBA is more easily said than done. (Gutman, 2002).

Many studies have been conducted on cost-benefit analysis on the use of water resources. However, most of them are on standalone systems.

The World Health Organisation (WHO) revealed that the cost-benefit ratio of water, sanitation and hygiene interventions is high when all benefits are included, standing at between US$ 5 and US$ 11 economic benefit per US$ 1 investment for most developing world sub-regions and for most intervention. (Hutton, 2004). For the evaluation of the Cost and Benefit of Water and Sanitation Improvements at the Global level, three dimensions have been considered; i. Direct economic benefits of avoiding diarrhoeal diseases, ii. Indirect economic benefits related health improvement, and iii. Non-health benefits related to water and sanitation improvement. The value of life has been analysed by using a human capital approach and sensitivity analysis for different discounted rates.

Another study has been conducted by IWMI in 2015. According to the study, Multiple Use Water Systems (MUS) are more resilient than single-use water supply systems in the context of Nepal: 87.5% of the MUS surveyed are still fully functional or need minor repair versus 56.8% of the single-use domestic supply systems surveyed in the NMIP and DWSS study. However, the MUS surveyed did show a high level of resilience in a context where MUS does not have yet its institutional niche and where it might be therefore more difficult for MUS water users to leverage external funds for repair, maintenance and upgrade. For the systems surveyed, the payback period is less than a year (8 months and a half) and the cost benefit ratio is 11 (excluding non-monetary benefits reported by water users such as enhanced nutrition and improved health, better sanitation and time saved). (IWMI, 2015).

Water is vital for human life, and it has multiple uses including domestic as well irrigation and other uses. Most of the systems are standalone systems, for example: drinking water supply, irrigation, hydro-power or recreational use. There are various cost-benefit analyses being undertaken of such systems. However, the approaches and methodologies of cost-benefit analysis are different among such studies. For example, in the above two studies, WHO has included health and economic benefits but IWMI has only calculated the marketable production. For this reason it is not possible to make comparisons between the economic benefits from standalone drinking water systems and multiple use water systems. Hence, this study compares and identifies the appropriate approach for investments.

Climate change has affected natural resources. In particular, depletion of fresh water resources is a global threat. Nepal is one of the high-risk countries for climate change. On the other hand, most organizations, including the Government of Nepal, have departments and projects for standalone systems (irrigation, drinking water supply, orhydro power energy). In this context, it is difficult to find strategies to cope with climate change's effects through optimizing water resources.

Opportunities for integrated water management in the Nepalese context

The Water Resources Strategy (WRS) of Nepal, 2002, aims to improve the living standard of Nepalese people in a sustainable manner. IWRM is defined as a process that promotes the coordinated development and management of water, land and related resources to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems. (National Water Plan, 2005).

Further, the Water Resource Act 1992 has segregated the priority of different uses of water in the following way:

1) Drinking water and domestic use, 2) Irrigation, 3) Agricultural use such as animal husbandry, fisheries, 4) Hydroelectricity, 5) Cottage industry (e.g. water mill or grinder), industrial enterprises and mining, 6) Navigation, 7) Recreational use, and 8) Other uses.

Furthermore, the new Constitution of Nepal (2015) has expressed the commitment of the state for the development of water resources (Article 51). It states “the state shall pursue a policy of prioritizing national investment in water resources based on people’s participation and making a multi-utility development of water resource”. However, there are many laws and related acts are yet to be developed to unfold the statements of the Constitution into practices.

Multiple –Use Water System (MUS)

A multiple-use water system (MUS) is an improved approach to water resource management, which taps and stores water and distributes it to farm households in small communities to meet both domestic and agricultural needs (iDE Nepal, 2015). It is a community-managed system that caters mainly to small landowners and marginal households in rural areas and helps to alleviate poverty and increase food security for poor and marginalized groups. The first priority is to provide drinking water and water for domestic use to the community; any excess water is used for agriculture and irrigation. (ICIMOD, 2013).

We consider here that MUS does not include the mega projects of water management. It only considers the small scale community-managed water resource schemes that are designed in such a way which can be used for two or more functions or services. In a real sense, MUS can unfold the concept of integrated water management (IWRM) at the community level.

Water Use Master Plan (WUMP) as a Participatory Planning Approach

The WUMP is a participatory and inclusive approach for integrated planning and management of water resources (described in Figure 1). Taking Integrated Water Resource Management (IWRM) as the foundation, it assesses the total water budget and its potential uses, focusing on a unit area. The WUMP encompasses capacity development of local communities and local institutions to improve the planning for equitable and efficient use of water to improve water supply and livelihoods. This is particularly important within a smaller unit of a watershed like a Village Development Committee (VDC) or one or two wards, for management at community level. (http://wumpdata.com/wumpdata/).

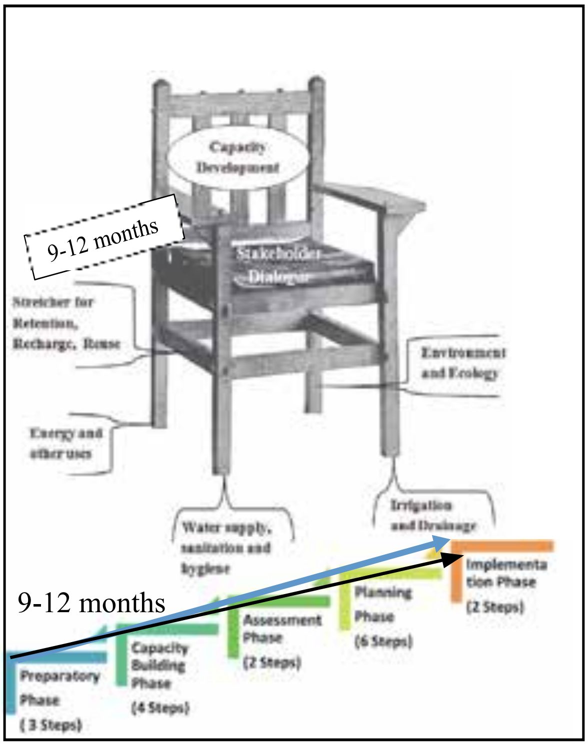


Figure 1: WUMP chair and working steps

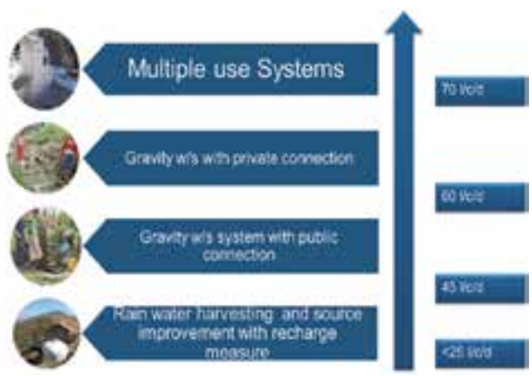
Water Resource Management Project (WARM-P) / HELVETAS (a Swiss NGO) is a pioneer of WUMP in Nepal, and WUMPs have been massively used by RVWRMP in the Far and Mid-Western Development Region of Nepal. The WUMP can be considered in two ways: as an approach and as a product. The WUMP approach gives more emphasis on the participatory process of data collection, analysis, debate, prioritization and agreement, and recording the results for public display. It incorporates many issues such as the inclusion of all stakeholders (especially women and disadvantaged or vulnerable groups); and an integrated and coordinated planning for synergy with other sectors associated with water, health and livelihoods.

WUMP as a product is a plan for optimal use of water resources considering overall water resource, hygiene and sanitation, water demands and potential uses in a holistic and integrating way for sustainable development. Building Climate Resilience of Watersheds in Mountain Eco-Regions (BCRWME) project is also developing a detailed plan for scoping water uses. Hence, in any form of water use master plan, it is important to identify the best method of water management. The WUMP preparation is a process oriented approach with 5 phases and 17 steps and needs to be closely coordinated and steered by the concerned VDC authorities to ensure commitment and ownership of the plan by the local authorities, political parties and the communities. Similarly, the district development committees endorse the final WUMP and thus must be involved in its preparation and resources mobilization. However, village and district development committees at present do not have all required human resources and professionals to prepare the WUMP by themselves. External financial and human resources are necessary to facilitate, and assist them and communities in the participatory resource inventory and planning process. Realizing the importance of WUMP, the National Water Use Master Plan (WUMP) guideline was recently developed jointly by two ministries, the Ministry of Water Supply and Sanitation and the Ministry of Federal Affairs and Local Development, to facilitate the process of water resources management.

MULTI-USE WATER SYSTEM IN WUMP

The Multi-Use Water System (MUS) has been introduced in RVWRMP as a means to maximise benefits for communities. Analysis of water source yield/supply and water demand for domestic uses to the communities is important while designing the MUS. All water sources around the micro-watershed (focus to administrative boundary of VDCs) are carefully measured and analysed, and recommendations are made regarding their best potential uses, as Figure 2, during WUMP preparation process.

Figure 2: Scheme identification according to source yield per-capita



Based on availability of water resources around the VDCs and their yield capacity, different type of MUS are explored during WUMP process (as in Figure 3) and prioritized by communities for implementation. A total of 107 VDCs have prepared a WUMP in technical and financial collaboration with RVWRMP between the years 2007-2015.

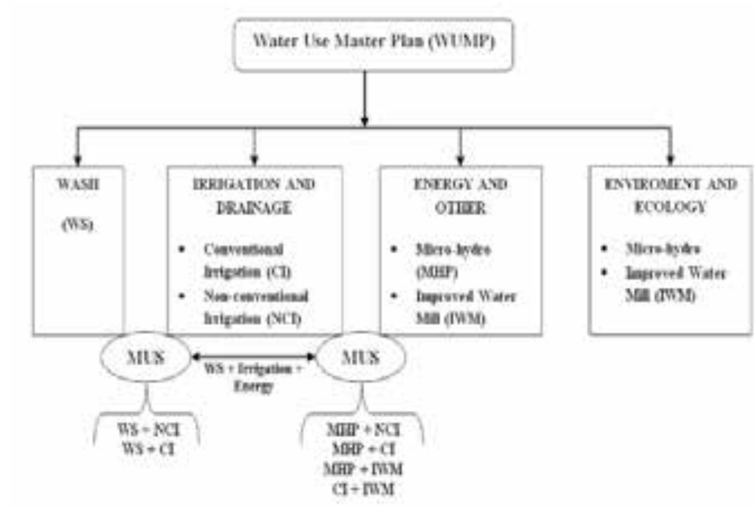


Table 1: Identified MUS by WUMP and implemented by RVWRMP

MUS Type	Identified in WUMP	Implemented by RVWRMP (2007 - 2015)
IWM + CI	223	7
IWM + MHP	14	1
IWM + MHP + CI	51	2
MHP + CI	70	6
WS + CI	8	8
WS + NCI	169	24
MHP + CI + WS	1	2
IWM + NCI	13	0
WS + CI + IWM	18	0
WS + CI + IWM + MHP	3	0
WS + IWM	1	0
WS + IWM + MHP	1	0
WS + NCI + MHP	2	0
WS + NCI + IWM	6	0
Total	580	50

580 different MUS schemes have been identified, as explained in Table 1, out of which 50 MUS schemes have been already implemented by RVWRMP from 2007 to 2015. Among RVWRMP-implemented MUS schemes, 24MUS schemes are with the combination of Drinking Water Supply (WS) + Non-Conventional Irrigation (NCI), which is the focus of this study (ref: Table 1).

OBJECTIVES OF THE STUDY

The main objective of this study is to analyse the economic costs and benefits among standalone drinking water systems and multiple use water systems of the selected gravity flow technology implemented by Rural Village Water Resource Management Project (RVWRMP) in rural hills of Far West of Nepal.

Specific objectives of the study are:

- To analyse the economic cost benefits of standalone drinking water systems and multiple use water systems, especially using micro irrigation along with drinking water.
- To identify the key issues of the schemes relating to sustainability, climate resilience and food security perspectives.

- To guide the further research on expanded sample size and future in-depth analysis at whole scheme level, after getting feedback from the audience.

LIMITATIONS OF THE STUDY

- This study covers very small number of sample households, i.e. 16 households (8 households from MUS schemes and 8 households of standalone WASH schemes). Hence, it is not appropriate to multiply by total households to get the total value of the whole schemes.

- Since, all sample schemes are selected from RVWRMP, all selected standalone WASH schemes have integration of basic livelihood activities, like intervention of home gardens, in line with project basic practices. Hence, it cannot be compared with other WASH schemes that do not have such basic livelihood interventions.

- This study has not considered the detail of sustainability indicators of the schemes. However, on a few indicators of sustainability, issues have been briefly discussed during focus group discussions.

- The authors are staff of RVWRMP therefore they have very in-depth understanding of the project area. However, there is a risk that community members are influenced. The authors have aimed to bear this in mind during analysis of the qualitative data.

METHODOLOGY

This research has utilised mixed-methods, and considered both quantitative and qualitative aspects. Quantitative aspectsof this study compare the direct cost and benefits, whereas qualitative aspects consider how community people manage the scarce water resources and how the adaptation allows them to cope with climate change's effects. This study has taken very small purposive sample of 8 schemes, i.e. 4 MUS schemes (especially with a composition of drinking water + micro irrigation technology) and 4 standalone WASH schemes. Focus group discussions among user committee members, individual household interviews and interviews with project's key staff have been conducted to access qualitative information during this study.

The area of the study has covered three VDCs of three districts in the following way (Table 2):

Table 2: Study area, sample schemes and completion year

District / VDC	MUS Schemes	Standalone WS Schemes
Darchula		
Chhapari	DandaDaha MUS (2014)	Tatopani WS (2014)
		Baba WS (2013)

Doti		
ChawaraChautara	Bunnesim MUS (2015)	Pitarmath WS (2015)
	Chhadekhola MUS(2015)	
Dadeldhura		
Rupal	Sobigada MUS (2015)	Dubid WS(2015)

The Benefit / Cost Ratio (B/C Ratio) approach has been taken into consideration with the following formula to calculate the B/C ratio of standalone drinking water supply (B/C_{ws}):

$$B/C_{WS} = \left[\frac{B_0}{(1+i)^0} + \cdots + \frac{B_T}{(1+i)^T}\right] \div \left[\frac{C_0}{(1+i)^0} + \cdots + \frac{C_T}{(1+i)^T}\right]$$

Formula to calculate B/C ratio of multiple use water system (MUS), especially micro irrigation along with drinking water supply, (B/C_{MUS}) can be expressed as following:

$$B/C_{WS} = \left[\frac{B_0}{(1+i)^0} + \cdots + \frac{B_T}{(1+i)^T}\right] \div \left[\frac{C_0}{(1+i)^0} + \cdots + \frac{C_T}{(1+i)^T}\right]$$

Here,

B/C_{ws}= B/C ratio of standalone drinking water supply; B/C_{MUS} = B/C ratio of multiple use water system (MUS); B = benefit calculated for the year "T", and i = discount rate

A 3% discount rate has been applied in this study as it seems justifiable to align with Global Burden of Disease specified by the Disability Adjusted Life Years (DALY) and the Quality Life Adjusted Years (QALY). (Hotton, G., 2015; Adhikari, N., 2012; WHO, 2010).

The cost and benefits have been calculated based on the revealed preference theory. The following table reflects the contributor indicators to benefits and costs.

Table 3: Contributor indicators on benefit and cost

Benefit contributor indicators	Cost contributor indicators
Saving on health expenditures more than before	Share of the household on the initial scheme cost (Water, sanitation, hygiene, irrigation and Poly-house)
Market value of agricultural products (increased after the scheme implementation)	Value of time spent to establish the scheme as well as to maintain it (meeting, training, mobilizing, activities on farm / livelihood production and selling / marketing, etc.)
Increased value of land due to the facilities (as compared to the nearest land that does not have such facilities)	Transportation to take production to the market.

Value of saved time that is utilized by the household	Value of depreciation of the scheme
Value of changed food menu (Lunch and Supper) due to vegetable production	Major input costs (seeds / pesticides / vitamins, manure, tools &equipment, etc.)
Value from employment opportunities at household level	Value of opportunity cost after engaging at household level livelihood activities.
How households value their regular water resources from which the schemes have been built (Existence value of water resources).	

FINDINGS AND ANALYSIS WITH AN EMPHASIS ON RESOLVABLE CHALLENGES

General Notes on Benefit-CostRatio (B/C Ratio)

There are many indicators, as mentioned in the Table 3 above, that have been converted into monetary terms. Some of the valuable indicators could not be converted into monetary terms, such as nutritional value after increased food intake, increased educational level of the children, other opportunities created after the income from vegetable sales, value ofwater optimization and climate resilience, etc. However, after the monetary value gained from the measured indicators, the B/C Ratio at the sample household level of standalone WASH scheme was found to be 4.12, and at the household level, the B/CRation of MUS (WS + MIT) was found to be 5.07.This means one rupee investment gives 0.95 paisa more return from MUS schemes than a standalone WASH scheme with livelihood intervention.

Accountability and Ownership Issues of Water User Committees

Legal identity and institutional development of the Water User Committee (WUC) is important for long term sustainability of water systems. (White et al, 2015). It should be ensured through registration of the WUC under the Water Resources Act (2049, Nepal), and enhancing the capacity of WUC members in different aspects before implementation of schemes. RVWRMP provides technical support to institutionalize the WUCs and ensures their registration before construction initiation. The Project also provides different types of trainings as a part of institutional development and capacity building of WUC members. WUCs are the main actors responsible for regular operation & maintenance (O&M) of the schemes, to ensure the system functionality and better services, including safe and adequate water supply to communities throughout the design period. However, in general, most of WUCs are active before and during construction of the system; but become inactive after completion of construction activities. This has a negative impact on the functionality of services and soon after the benefits of water schemes diminish and water productivity decreases.

Overall, the results of the study found average impacts of WUCs ownership towards the system. All schemes studied are fully functional, a village maintenance worker (VMW) is mobilized in each scheme, the community is paying an incentive to the VMW, and the water tariff is fixed and collected. WUC members and users are aware of various water-related issues and are empowered regarding their rights to water. Most importantly sanitation and hygiene, and livelihood opportunities have improved significantly. However, still many challenges exist regarding the scheme. This includes some problems still regarding the WUCs ownership of the water system – demonstrated by indicators such as regular WUC meetings, regular water tariff collection, equitable water distribution, transparency, ensuring the water quality, market linkages development, retaining the VMW, O&M fund mobilization, etc.

Availability and Accessibility Dimension of Food Security

Food availability and accessibility are major components of food security. Even if food is physically available in a region or country, it may not be accessible if households lack purchasing power. (FAO, 2016). It has been significantly observed that, due to the basic livelihood interventions even in standalone WASH schemes, households have been producing vegetables and adding them in their lunch and supper menus, at least on a seasonal basis. In contrast, in MUS schemes, households have access to vegetables the whole year round, via off-seasonal vegetable production. Hence, in the sampled households, it has been observed the varieties of crop have increased from paddy rice, oil crops and limited seasonal vegetables; to more varieties of seasonal as well off-seasonal vegetables, along with other traditional crops.

One of the direct benefits that can be seen from MUS schemes is expansion of irrigable land through the intervention of technology. The sampled four MUS schemes have converted 19.9 hectares to irrigable land. This definitely contributes to increase the national irrigable land and the quantity of food production.

Climate Resilience Perspective

In Nepal, changes in weather patterns and increased frequency of extreme events threaten to exacerbate existing threats to food security, as agriculture yields and production decrease and water scarcity increases (Krishnamurthy et al., 2013). A study done by Rural Water Supply & Sanitation Project, Western Nepal (RWSSP-WN) in nearly 2,400 sources between the years 2004 and 2014 in Tanahun district, showed that there is 50% reduction in average yield of point sources (springs) over ten years (RWSSP-WN 2015). Such kind of study has not been done yet at the study area but while analysing the rainfall data of Department of Hydrology & Meteorology of Dadeldhura, the annual total rainfall and rainfall days of Dadeldhura (Far-western Nepal) is decreasing as shown in figure 4. Decreasing the rainfall directly affect the recharge of springs/ground water; which are verified by the communities while in interview. It shows the value of water is increasing daily to fulfil the future demands of domestic and other uses. Shifting climate patterns are likely to have negative impact across most populations with strong impacts on vulnerable populations already facing minimal livelihood options and least able to adapt to climate stressors.

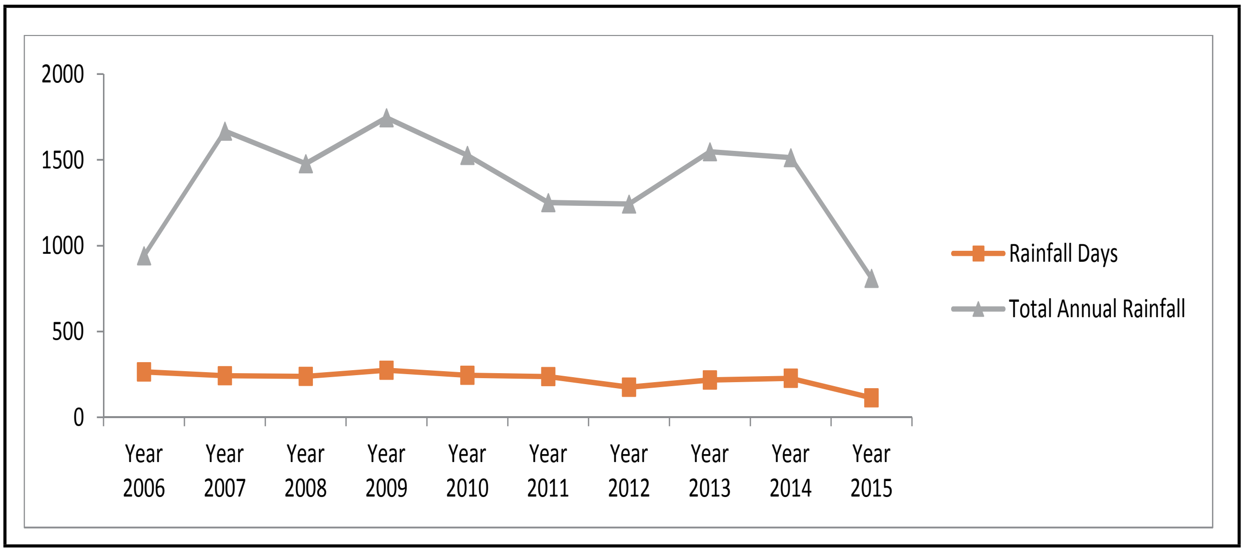


Figure 4: Annual rainfall and rainfall days of Dadeldhura

Source: Department of Hydrology and Meteorology, 2016

Overall, people interviewed in the current study were found to have limited knowledge regarding climate change effects in the study area, and they have taken very few steps towards mitigation initiatives. They report that water yields of sources are depleting, the cropping pattern changed, there is less winter rainfall, and heavy rainfall during the short monsoon period. Yet despite this, they have not developed regular source water yield monitoring mechanisms; and they also have not carried out any water source recharge initiatives yet.

With whatever water is available from the present water sources/system, communities are maximizing water productivity for domestic uses, home garden management and agriculture production for income generation. Table 4 shows the total availability of water for their productive uses. As can be seen there is considerable variation in water availability, ranging from 17,280 to 43,200 litres/day for domestic and other productive uses. Project has designed to tap maximum water from source considering the future demand and climate change effects. Excess water (more than domestic use) is used in home garden and agro-production mainly to vegetable farming and also promoting waste water for their kitchen garden management. This has consequences for the possibility to use water for productive purposes. Hence, in Dubid WS Rupal, once water is used for domestic purposes there are only 320 litres/household/day left for irrigation. On the other hand, in Danda Daha MUS in Chhapari, there are 1,550 litres/household/day available for irrigation.

Scheme Name	HH covered	Popn.	Design Yield (lps)	Total Water Availability/day	Present Household water demand (Lit/day)	Surplus water for irrigation (Day)	Water available for irrigation/HH (lit/Day)
Danda Daha MUS, Chhapari, Darchula	23	168	0.5	43,200	7,560	35,640	1,550
Tatopani WSS, Chhapari, Darchula	16	121	0.3	25,920	5,445	20,475	1,280
Bunnesim MUS, Chamara Chautara-7, Doti	18	137	0.34	29,376	6,165	23,211	1,290
Pitarmath WSS, Chamara Chautara -7, Doti	59	325	0.38	32,832	14,625	18,207	309
Chhadekhola MuS, Chamara Chautara-7, Doti	13	72	0.29	25,056	3,240	21,816	1,678
Baba WSS, Chhapari -1, Darchula	23	176	0.31	26,784	7,920	18,864	820
Dubid WSS, Rupal - 8, DDL	27	192	0.2	17,280	8,640	8,640	320
Sobigada MUS, Rupal, Dadeldhura	22	120	0.5	43,200	5,400	37,800	1,718

Table 4: Availability of Water at Sampled Schemes and Their Possible Productive Use

Standalone versus MUS Scheme Cost

The average cost per household for a standalone WASH scheme was found to be NPR 76,474 (i.e. an average figure of NPR 10,373 per person of the total cost, which includes support from government of Nepal and Government of Finland, district development committee and VDCs on average of NPR 7,568). The average cost for a MUS scheme was found to be NPR 102,509 (i.e. an average of NPR 14,200 per person of the total cost, which includes an average of NPR 10,458 of external support).

On the basis of this analysis of 8 schemes and 16 households, the MUS schemes require anaverage of 74.6% more investment than the standalone WASH schemes with basic livelihood interventions, but they achieve 0.95 more on a B/C Ratio.

However, as noted above, this is a very limited sample. The study should be repeated with a larger sample size, in order to be able to generalise.

CONCLUSIONS AND RECOMMENDATIONS

Scaling-up of Water Use Master Plan (WUMP)

As WUMP is a promising approach for planning and management of water resources (with an emphasis on MUS), scaling up such approaches is recommended - not only for easy planning, but also to ensure water resources are optimally utilized for the benefit of communities with available water resources.

More Analysis and Actions on the Schemes' Sustainability Issues

In the focus group discussions, the study does not find any differences between regular payment of operation and maintenance (O&M) fees or water tariffs between standalone WASH schemes and MUS schemes. In general, it is supposed that increase in income at household level would lead to an increase in the rate of regular O&M payments. However, with this small sample it could not be demonstrated. This assumption should be proven by a further study,or further action should be taken to review and revise the sustainability framework / activities.

MUS Schemes and Market Linkages

The most successfully operating MUS scheme among the sampled schemes was Danda Daha, which has good linkages with the nearest market. Produced crops / vegetables are directly and quickly taken down from the top of the hill to the district headquarters (Darchula) via a Gravity Goods Rope Way. In this community, almost all households are producing vegetables and selling them. However, in other MUS schemes, the market linkage is poor and very few vegetables are sold at the local market. Despite this, their vegetable consumption rate has drastically increased and their food security and nutrition has improved. However, in order to maximise the benefits, it is recommended that while designing MUS schemes, market linkages and value chain perspectives should be considered.

Food Security and Climate Resilience Perspective

Expansion of irrigable land, increased productivity, and diversification of crops accessible to the common rural people are core components for food security. These elements are observed to a large degree in the MUS scheme communities. Hence, when there is possibility of MUS schemes at the design period, food security and climate resilience perspectives should receive more consideration, rather than only cost comparison perspectives with other schemes.

Leading Institution for MUS

Although water resources have the characteristics of multiple uses, in the Nepali context, there are standalone institutions for individual use. For example, DWSS focuses on the drinking water and domestic use of water, the Department of Irrigation focuses on irrigation only, the Alternative Energy Promotion Centre focuses on renewable energy such as micro-hydropower, etc. Since, MUS schemes by definition include multiple uses of water, it is difficult to place them under one department. Hence, in the process of state restructuring of new Nepal, it is recommended that a leading institution should be selected, which leads an integrated water resource management perspective.

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6.2 MAKTUMBA FMIS RESILIENCE: THE LAST 25 YEARS AND THE NEXT

"WE NEVER HAD IT SO GOOD, BUT NOW OUR YOUTH IS LEAVING"

AREND VAN RIESSEN[1]

This article focuses on the resilience of one of twenty formerly supported and revisited FMIS in east Nepal in the context of migrating youth and the increased relevance of cash crops.

DEVELOPMENT AND COMMUNITIES

Rural Nepal's strength has been its communities and most of its development successes depend on the strength and independence of those communities. In the hills these strengths resulted mostly from the mountain habitat and its inherent isolation, and the inability of governments, projects and private sector to effectively reach or control communities or resources. Communities are used to manage their own affairs. Irrigation and forestry are two examples of development success. But while community management for forestry is a recent phenomenon, it is a very old practice in irrigation. Nepalese villages have mostly built and managed their irrigation canals themselves, and done very well. Livelihoods and society have come to depend much on whether and how irrigation is managed.

For example, in the three districts of the Mechi hills in eastern Nepal, farmers have built at least 2000 irrigation systems. These schemes were mostly very small as a 1991 X-Ray style survey of 51 VDCs showed.

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Table 1: Mechi Hills Village Irrigation Profile 1989-1991 (for 51 VDCs, 710 FMIS totalling 7964 ha)

Average system size:	11 ha
Systems with command area < 10 ha	66%
Systems with canal length < 1 km	53%
Systems with user population< 10hh	39%

External irrigation assistance programmes in that area (SNV, ADB, government, INGOs) were based on the assumption that coverage and efficiency could be improved through new construction technologies and management practices. Together they, may have added a few new schemes and improved management of maybe 50-100 existing schemes, and although the project impact for the selected villages could be considerable (see Maktumba below), the overall impact for the area must have been moderate. Maybe they added between 5% and 20% to the number of schemes, households, acreage and production.

By revisiting a number of schemes supported by Mechi Programme (SNV) between 1987-1991 and by holding more extensive interactions with one FMIS community (Maktumba), the author and his former colleagues wanted to learn how those schemes had performed, whether those old assumptions were correct and what the challenges of today are. The article discusses first the results for 20 supported and revisited schemes, and then looks in-depth in to one scheme (Maktumba). Next, the article looks at changes in agriculture, economy and population, especially at depopulation and youth leaving the villages, and tries to envisage whether and how not only these schemes, but agriculture and village societies in general can survive another 25 years or more.

TWENTY SCHEMES 1991 AND 2010[2]

WHAT THE DEVELOPMENT–WALLAHS WANTEDAND DID 25 YEARS AGO

The aim of the development project was to increase food security and wealth for the community through a newly built irrigation system that would increase food production. Irrigation (and water supply) were the entry points for slowly expanding components for agricultural development, sanitation, nutrition and gender mainstreaming. E.g. in Maktumba (450m asl), the villagers could convert from maize and millet to rice, wheat and vegetables, and maybe even grow three crops per year. To that purpose the project wanted to leave behind a well-built sturdy canal, an effective irrigation system, construction skills, management skills, links with government, an operation system, a maintenance system, a trained and functioning committee, a trained and effective maintenance worker, and a well-filled maintenance fund. Wealth and food security was thought to have additional impacts, e.g. on overall well-being, health and education. The project designed the canal, funded 75% of the construction, arranged external materials, provided capacity building and oversight through an overseer, established and trained a user committee and a

2 Part of the findings in this one chapter were also presented to INPIM in 2010

maintenance worker, and sent two users on a study tour to irrigation schemes in Palpa and Sindhupalchowk. The committee members had to frequently visit the related offices (DoI, DDC) in Ilam bazar. Few of these activities were quite new and untested at that time.

THE PREDICTION IN 1991

In 1991 we made as project team a prediction about which of the supported irrigation schemes would survive at least ten years. We were quite sure that future visitors would often not find back the user committees, maintenance workers or maintenance funds, all concepts that were not yet tested and fine-tuned for small schemes in the Mechi hills. The first lessons were learnt quite soon when in 1991 one canal treasurer ran away with the canal maintenance fund and the committee in another scheme split in warring factions after political changes in 1990 allowed multi-party democracy.

In our predictions, we did not include the bad luck that can befall any canal like unexpected landslides, inadequately skilled or negligent masons, overseers or engineers, or design mistakes, as these were too difficult to assess. So we predicted on basis of known factors like user committee strength, maintenance skills, slope stability, overall irrigation benefit and the maintenance cost-benefit ratio. In total we estimated that 10 of the 20 assessed schemes would not run anymore by the year 2000 and two only at 50% capacity. Besides landslides, the maintenance cost was an important criteria and we estimated that cost to be relatively higher for higher altitude schemes where the added food crop benefit would be less due to lower cropping intensities. As for the Maktumba canal, we knew that the cliff-hanger style canal would require expensive maintenance which might be too expensive for the small number of beneficiaries (12 households only) and weak committee. This was the basis for our prediction that the canal would not function if we would come back after 10 years, i.e. in 2000 AD.

THE RESULTS IN 2010

The 2010 scheme condition. When SarojYakami, Janwillem Liebrand and me revisited the 20 schemes in 2010 (not 10 but 20 years after the prediction), not the predicted 55% but 75% of the schemes still functioned, more than we predicted in 1991, but not always the same schemes as we predicted. WE reported about that in an INPIM session. The command area of all the five non-working schemes still got some water from alternative sources. Of the 15 working schemes, the highland systems benefited greatly from conversion to cash crops. Cash crops like cardamom, tea and broom grass not only earn cash, but also need less water and also have a slope stabilising effect for canals. Not highland but lowland communities now have more difficulty to maintain their scheme, as they still only grow rice wheat and maybe some vegetables. Low altitude canals also face more damage by crabs. The total irrigated area and number of irrigating households through the 15 functional schemes was nearly double that of the 20 original schemes, mainly due to the conversion to cash crops which need less water than wheat and rice.

Table 5: **20 Irrigation Schemes 1991 to 2010**

Aspect	**1991 (not all completed yet)**	**1991 Prediction for 2000**	**Situation 2010**
Working Schemes	20	11.5	15
Irrigated area	1349	800	2150
Irrigating households	2008	/	4000
Maintenance worker	20	/	3
Active WUA	20	/	12
Maintenance Fund	20	/	8

The 2010 O&M system situation. So, only 15 schemes still worked. Of these working schemes 80% still had a user committee (now a days named WUA/Water User Association), the rest worked through leaders. 20% still had a maintenance worker, while the rest assigned repair duties on a rotation basis among users. 50% still had a maintenance fund, but these were in practice often not used because people preferred to collect money on basis of and the time of immediate needs rather than for unknown future needs. User committees were much more mature than in 1991, although young members were often lacking due to outmigration of youth. Villagers said they benefited most as committee from the long on-site presence of overseers and interactions with project officials. They considered the training and study tour to FMIS in Palpa and Sindhupalchowk as very useful, not so much for skill development, but for widening their horizon and understanding what is possible. The new skills, exposure and relations helped them overcome crises like landslides and discord and deal more confidently with government agencies and projects. Of all the 20 schemes, 12 obtained again external assistance at some time later on, although mostly very small sums.

Maktumba, The Last 25 Years

The village of Maktumba lies in Siddhithumka VDC of lower Ilam district. It is a micro-version of hilly Nepal and what happened and might happen to it feels very similar to what we see in the rest of Nepal's hills.

Our understanding of what happened in Maktumba is based on project visits from 1988 to 1992, a functionality assessment by SarojYakami in 2010, a learning visit by Wil Verschoor, Jan Kroon and the author in 2015 and a stay of three days in April 2016 by the author during the start of the canal repair work that was partly supported by ex-Mechi Programme staff. Since 2015 there also has been regular contact with villagers and village youth by telephone, SMS and facebook.

The village of Maktumba is a very small Rai-Limbu village along the lower Maai river that was very isolated and poor when it was selected for irrigation support by Mechi Programme in 1988. For an external aid project it was also a very small village and scheme, and most other programmes would have excluded it due to its small size (12-14hh, 16ha), but it was actually close to and even above average for farmer-managed irrigation systems in the Mechi Hills (see table above), although it's canal was quite long (3km). Construction of the new canal was completed by 1993.

The 1991-prediction about its functionality by 2000 was "Not Probable", because the committee was considered weak, because they were poor, illiterate, unaware and unconnected and because the canal ran along a tricky cliff. The project investment was US$513 per extra hectare irrigated land, which was high and seen as an indicator that future annual maintenance cost would also be high. Construction quality was considered as average and not impacting sustainability negatively or positively. The main factor positively impacting sustainability was that the canal brought considerable change to a very poor and cohesive community that would be motivated to keep the canal running, even at high cost.

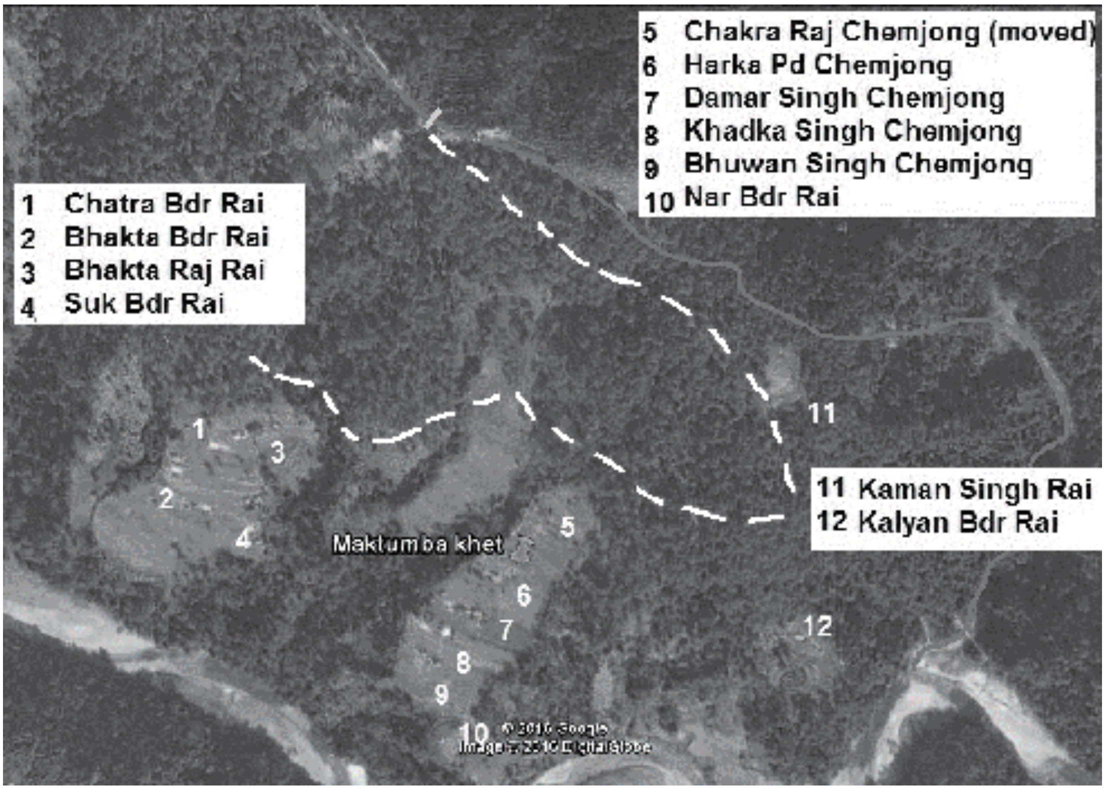


Figure 1: Maktumba, The Village and The Canal

And in 2010 it was indeed assessed as out of order since 2009. However when visited again for further learning in 2015 by three former staff, it was found functioning again at about 65% of potential. Many of the old committee members were still there. For them the project intervention had been a very important time, the only ever notable project intervention coming their way. Being Ilam's poorest and most isolated scheme, with a new canal constructed along a cliff, the project staff also always had had a soft spot for this village. When it was clear that the village invested a lot of effort to keep the canal running, and it was also found that both the expatriate engineer and the committee's chairman had both deceased about 10 years ago, we decided to privately support the canal repair in their memory. We provided NRs 150,000 that could be spent on materials and skilled labour. This was not enough for rehabilitating the canal, so they invested themselves, too, and left some work out. We suggested to hire an expert mason to lead the effort, and suggested that they discuss all the choices only with him (not with us), e.g cement quality and locations. We only asked them to invite a VDC official to visit afterwards and observe (not approve) the results, and send us some pictures.

For us it was only about the memory and the lessons. The lessons were many, as Maktumba appeared to be a micro-version of mid-hill village Nepal, illustrating what had changed over the last 25 years and what might happen next.

MAKTUMBA IN 1991

Around 1991, children of Maktumba had just started to go to school (2-3hr away), people did not have enough food, and did not have interactions with government or traders. No project ever reached that village before. The nearest road was 2 hours walk uphill, but they never used that road and normally walked a full day if they had to go to Ilam bazar or to Sukrabare bazaar in lower Danawari. In 1991 there was no electricity, telephones (the first were installed in Ilam bazaar in 1991). People cultivated maize and millet during the summer and collected food and firewood from the forests. They were unknown to working with cement, steel, paper, committees, financial calculations, government agencies, and banks, and unknown to the world beyond Ilam and Sukrabare bazars.

Figure 2: Bhuwan Singh Chemjong (2nd from left) has been active for the irrigation system since 25 years

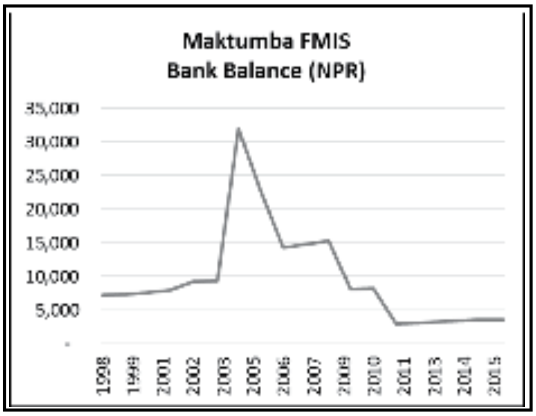
MAKTUMBA IN 2010 AND 2016

We came back in 2010 when the canal was temporarily out of function and again in 2015 to understand why it was dysfunctional. But in 2015-16 the canal was running again after a major labour and financial effort by the users. Now 12 households were irrigating 16 ha of rice, wheat and lentils. Still the canal did not run each and every monsoon month as the aging cement masonry was often leaking and damaged by falling rocks, landslides, and especially crabs.

System Detail	1991	2010/2016
Beneficiary households	13	12
Caste/ ethnicity (households)	7 Rai & 6 Limbu	7 Rai &5 Limbu
Village Maintenance Worker	1	-
User Committee member	6	6
Canal length	3	3
Q per ha (year round water availability)	Just Adequate	Just Adequate
Irrigated Area in winter (ha)	0	16
Irrigated Area in Summer (ha)	0	16
Crops in command area	Rainfed maize, millet	Irrigated rice, mustard, lentils, maize

The System. Looking back, the things that Mechi Programme had promoted had an interesting mix of results. The User Committee still existed and was actually quite strong. It really had made an effort to follow and adjust the promoted maintenance system. In general the canal, the committee, the skills, and the systems were much as could be hoped for, back in 1991. Our guess is that they had more seriously followed the promoted systems because they were a small illiterate community with very few own ideas back then. Adjustments came later with experience. Their system now included daily rotation of maintenance duty among families, penalties for defaulters, cash contributions by families unable to provide labour, fund raising for materials and skilled labour, annual user meetings, annual cleaning and repair days, and replacement of committee functionaries in which the balance between the two tars and between Limbu and Rai was maintained. They also had tried to make use of the promoted maintenance workers for three years and kept using the maintenance fund till 2009. But they found that maintenance duty rotation among families and on-the-spot cash mobilisation were cheaper and more effective than paid maintenance workers and a maintenance fund in a far-away bank account. The bank account in Ilam bazaar is still there with only 3000 Rupees in it, and it was actively used up to 2009. It still can be used for receipt of external aid, they say, but working with a bank account in faraway Ilam bazaar is cumbersome; now they raise cash when it is needed.

A FEW OBSERVATIONS ON MAKTUMBA FMIS O&M



The Committee: they retained the user committee and some members have been in it for 25 years now. When the first chairman (Limbu of Tar 1) died, he was replaced by Chatra Bahadur Rai of Tar 2. So even for such a small community, where people see each other very often, they found a committee useful. The committee calls the pre-monsoon meeting, mobilises resources for repair if needed, and looks after conflicts and other issues. They also found it natural that after a Limbu of Tar 1 a Rai of Tar 2 should be chairman.

Bank account: The bank account in Ilam was typically useful for the project to transfer funds and not so much for the villagers during repair. But still it helped people to think about importance of money and money management, and they have gradually withdrawn the money over the years, and added once a substantial amount. By 2015 the bank account was basically empty and they preferred to collect cash when needed and directly pay the shop or the mason.

Annual cleaning or repairis done by all together On such days, the no-show families (those with only older members left) pay NRs300 per day.

Daily Maintenance: During the irrigation season, they rotate the daily canal watch (2 families/day).

Water Use for Repairs: As seen when new local canals are dug, Maktumba also uses the canal water for cleaning and repair. The flowing water transports the leaves and litter, it exposes the leaks and weaknesses and is used to clean stones and structures to better see their condition. In March 2016, the 3km canal, although completely filled by leaves and dirt, was cleaned in two days by ten people, who also cleaned and inspected each structure, and if needed, dismantled them before reconstruction.

Repair Priorities (where cement/money is invested): They invest most in work that is farthest from the village, where visiting during monsoon is most difficult.

Labour: Normally villagers do all things themselves, also masonry. The older guys were most active and knew what to do, while the younger educated guys were not used to such work anymore. Youth felt embarrassed making gravel and carrying stones.

Investment and quality: Their user meetings tend to go for cheap and easy, they said, as they are not convinced that they can really build high quality structures anyhow. Expensive materials and expert masons would then be a waste.

Higher quality if needed: They were easily convinced to hire an expert mason. They found Purna Rai of neighbouring Danawari VDC (10 years' experience in Saudi Arabia and 10 in Pokhara). He did masonry in critical parts for NRs 1000/day. They were then easily convinced by him that less works (drops, lining) of higher strength would in the long run be better than more works of lower quality. They bought cement of higher quality (NRs 850-900/bag at site) and brought local materials from farther away than normal.

Post-construction check: We asked them to invite a neutral person to observe (not to approve) the results, and share some photos. After consulting NFIWUAN-Ilam chairperson Bishnu Dahal, I suggested them to ask a NFIWUAN member from upper Siddhithumka. He again mobilised a VDC technician who came down (1 hour walk from VDC) and reported very positively with photos back to us.

Figure 3: Drop structure: during dismantling(April'16) & after reconstruction (May'16)

Few Lessons for old style Irrigation Programming

- If a User Committee is to maintain the system after the project exits, then the User Committee itself should do the construction; trained and, especially, coached by technical staff
- A long implementation period can be a nuisance, but also can have positive capacity building effects due to a longer period of exposure to advice, coaching and practice.
- Maintenance Funds remain a good idea, most effective if located at a nearby bank or more practrical, at a cooperative or savings group, and if the community as a whole is already coached during project implementation to mobilise, invest, manage and spend their own construction money.

Socio-economic Situation. The people consider the project intervention a success. It brought them considerable benefits. They now have more than enough food plus extra straw for livestock, vegetables and money from crop sales. Their benefits enable them to maintain the canal, invest labour and money and send children to school and, since more recently, to college.

The village is very small (10-12 households), but all villages are small and scattered in that area. The size of the village has not decreased or increased in the past 25 years, as many "surplus" sons have moved to Danawari after splitting from their brothers, while others have moved to the cities and Terai. The village is not poor anymore and certainly not so isolated as 25 years ago. In the last one year, tractors can come to the village in the dry season. They live very simply, but they have enough land, irrigated. Their non-irrigated land is mostly strongly sloping land, used for broom grass and goat grazing. They have rice and lentils for the whole year and get their cash from goats (10-25/hh) and broomgrass (few ropani/hh).

Still the system and the village's economic situation is at risk. The task of maintaining the canal becomes more and more difficult as the older generation that built the canal is getting older and most of the younger generation received good education, even up to bachelor level, and now prefers to live and work in bazaars and cities or to work abroad for remittances. The five youth that were present during canal repair were clearly not at ease with the type and level of hard work in the canal. Most of the jobs, especially the skilled jobs were done by the older generation, while youth chatted more and looked at their mobile screens in between. Skills are being lost, while committees and systems are fraying at the edge. Without youth, there is no viable economic system, and without a viable economic system there is no need for an irrigation system.

MAKTUMBA, THE NEXT 25 YEARS

Need Future, Need Youth, Need Change

Most of the youth passed high school and quite a few studied intermediate and bachelor level. Few work abroad, others live or work in the Terai or Kathmandu. Only few young men and women live in Maktumba now. If youth continues to leave the area, the viability of the farming system (including irrigation systems) and the economy will be at risk. Most young people might be more interested to stay in Maktumba if the village has more facilities (health, education, internet, transport), more job opportunities and better connections to the rest of the world. This is only possible under a thriving local economy and the only hope for such an economy lies in commercial agriculture and related market systems and services. These can bring more business and facilities to the area, which can also lead to more investment in transport, health and education. Teachers and health professionals will prefer a well-connected and prosperous area to a poor and isolated one. At present, one can best see such development (and more young people) in Ilam around commercial centres like Ilam, Phikkal and Pashupatinagar.

There are few existing trends that indicate whether the village might ever get there during the next 25 years.

Commercialised Agriculture

There has already been a shift to cash products in Maktumba. Ilam has always been a frontrunner in well-developed market systems for a variety of products. In Maktumba, broom grass and goats have expanded a lot in response to market demand. The villagers also look at ginger and bananas and these can also be cultivated in the command area. Irrigation can be an advantage. Villagers are keen to update themselves on new crop varieties and technologies and they had heard about disease-resistant ginger and low altitude cardamom races, but providers of input and advice are still located far away. Systematic strengthening of market systems and related services networks for these lowland areas can accelerate the speed of change and increase the survival chances of the FMIS.

Increased farm sizes, mechanisation and contract farming.

Trends in other countries have also included a reduction of household numbers and increase of farm size, and possibly a transition to contract farming (e.g. bananas) where cultivation is done by a mix of local farmers and hired farm workers. It is not clear whether farm size increases will happen in Maktumba. E.g. the land of Naulo Singh lies fallow since his death a few years back as his son moved to better land further downstream. Nobody rents the fallow land now. Villagers mentioned that each household had enough land to manage, while outsiders would not come because agriculture was not easy in Maktumba with the rain, heat, lack of facilities, and the leeches and other vermin in the monsoon. Increasing farm sizes can only be done with mechanisation, for which people only might become ready after more people leave the area. The land is not too steep and seems suitable enough for machines. These and other similar potential changes need to be piloted by the private sector with support from government, chamber of commerce and maybe aid projects.

Outsourcing of canal repair.

25 years ago when Mechi Programme introduced bank accounts and stimulated cash contributions, no farmer would pay cash for canal repair. Communities were strong, cash was very scarce and technologies low-tech. Now a day, the villagers buy cement and pay masons and labourers. The first payment for labourers resulted from the fact that some households could not contribute their share of labour days, and those households began to pay the committee, which arranged extra labourers from in and outside the village. Outsider labourers were also contracted to speed up the work, and in few cases the whole work was given in contract. So more and more the canal repair is outsourced to masons, contractors and other infrastructure services. With systematic strengthening of such

commercial infrastructure services networks (material suppliers, masons, plumbers) all irrigation systems in the area will benefit from quality at reasonable cost and stand a better chance at survival.

The Future of Maktumba FMIS depends on Economic Development

Of these three possible trends (see 0, 0 and 0), actually only the latter (repair outsourcing) is already happening in Maktumba, although hesitantly, but the other two have a good chance, too. This trend is seen across the Nepalese mid-hills. The demand for hill products from India and China will remain very high, road access is increasing, market systems and services are improving, and rural youth unemployment remains high. The old rural Nepal is weakening as the close-knit self-reliant communities are slowly vanishing, but pockets of commercial vitality will remain and develop, and maybe the areas along the Maai river in lower Siddhithumka and Danawari can be among them, but only if the people get a chance to transition fast enough to be ahead of total depopulation. 90% of Nepal's farming, irrigation and economic changes have been brought about by the people themselves, but here and there outsiders can help a bit. If the survival of irrigation systems like Maktumba's is dependent on any outside interventions, it is probable that those are not irrigation interventions but market system development interventions that help farmers and the private sector develop viable economic pockets in which irrigation systems can be essential assets.

Like with the 1991 prediction for Maktumba's canal system functionality, we again tend to be pessimistic about the vitality and survival of Maktumba's community, it's irrigation system and it's economy, but we are also very well aware that our 1991-prediction for the canal system was wrong and therefore cross our thumbs. Let Nepal's communities surprise us again.

6.3 DESIGN ISSUES AND TECHNOLOGIES OF HILLY IRRIGATION INFRASTRUCTURES IN VIEW OF CLIMATE CHANGE: CASE STUDY OF KALLERITAR IRRIGATION SYSTEM

ASHISH BHADRA KHANAL[1]

INTRODUCTION

Nepal's climate is influenced by the Himalayan mountain range and the South Asian monsoon. The climate is characterized into four distinct seasons: pre-monsoon (March-May), monsoon (June-September), post-monsoon (October-November) and winter (December-February). Average annual rainfall is approximately 1530 mm. The highest rainfall occurs in the central and mid hill areas around Pokhara and northeast and east of Kathmandu valley. Temperature tends to increase from north to south and decrease with altitude. The winter season is coldest with the highest temperatures during the pre-monsoon period (NAPA 2010).

Analysis of recent observational data shows that the climate of Nepal is already changing. Temperature have increased strongly over recent decades, rising at much faster rate than the global average. There have also been changes in precipitation, including heavy rainfall extremes, though the trend is more complex and there are wide variations across the seasons and the regions in the country.

According to NAPA, temperature rise in Nepal is in the trend of 0.04-0.06°C annually. With regard to precipitation, NAPA states that there is a general decline in pre-monsoon precipitation in far- and mid-western Nepal, with a few pockets of declining rainfall in the western, central and eastern regions. In contrast, there is a general trend of increasing pre-monsoon precipitation in the rest of the country.

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Although climate change affects many sectors but it significantly impacts agriculture by increasing water demand limiting crop productivity and by reducing water availability in areas where irrigation is most needed or has comparative advantage.

In Nepal, the agriculture sector accounts for approximately three quarters of employment and one-third of GDP. Irrigation is prime input for the growth of agricultural sector, when crop water demand is higher, more discharge needs to be diverted to the canal, however if the canal section was not considered for climate change accommodation during design, the irrigation scheduling will be affected. Hence, this paper has made an attempt to find out the impact of climate change in hilly irrigation system of mid Nepal by observing the design canal discharge and discharge needed at present and future.

OBJECTIVE OF THE STUDY

- Assessment of current and projected impact of climate change on hilly irrigation system by using PDSP manuals;

SCOPE OF THE STUDY

Among many irrigation systems in Nepal, a medium scale irrigation system, Kalleritar Irrigation System near Kathmandu valley, from mid-hill region has been selected since hilly farmers have been experiencing climate change impact in their cropping calendar. Despite low irrigation efficiency (around 35% at present, theoretically it should be at least 60%) due to various technical factors, increase in evapotranspiration due to climate change forced the farmers for more water demand to be diverted from the source to the field.

METHODOLOGY

- Desk study
- Field study

LIMITATION OF THE STUDY:

ET_o data given in PDSP manual is no more relevant because of temperature change by global warming and needs to be updated. In order to calculate ET_o, The Department of Hydrology and Meteorology needs to provide other required data in different regions of the country, which is unavailable at present. For instance, Dhading Station, 1005 is the nearest station from the command area of Kalleritar Irrigation System, however the temperature data is not available so the ET_o has been calculated by interpolation method based on PDSP manual.

KALLERITAR IRRIGATION SYSTEM'S BACKGROUND

Kalleritar Irrigation system lies in Kalleri Villlage Development Committee of Dhading district in central part of Nepal. This system is about 52 km west from the capital city Kathmandu in the Kathmandu-Pokhara Highway (Prithvi Higway) across the Trishuli river from Galchi. Construction of this project started in 1983 by the governmentof Nepal and the first water commission started from July 9th 1988. The total project cost at that time was NRs. 7.9 million including the cost of headworks (NRs 1,174,000). After 1993 flood, which damaged the aqueduct of Koshi khola and several other reaches of canal, it was rehabilitated in 1998 under Irrigation Sector Program (ISP) by the support from Asian Development Bank. The rehabilitation cost was NRs. 6 million. No major rehabilitation has been done since then, however Department of Irrigation (DoI) allocates some O&M budget for this scheme every year.

Figure-1: *Headworks*

Figure 2: *Topo Map with red line showing the study area*

As per the first design report available, the net command area of the project is 200 ha which is in the opposite bank of River Trishuli at 480m amsl. The total canal length of the system is 11 Km and the design discharge of headworks in the source of Khani Khola is taken 140 cumecs. The velocity of the stream was calculated using manning's method and the discharge was calculated by velocity multiplied by area. This discharge was compared with the Dicken's discharge and the higher discharge was taken for the design of weirs. Similarly the canal was designed for discharge 540 lit/sec. However in the rehabilitation time this discharge was changed to 400 lit/sec.

METEOROLOGICAL DATA ANALYSIS

The Department of Hydrology and Meteorology (DHM) is maintaining a network of hydrometric and meteorological stations in Nepal. There are about 51 hydrological stations and about 282 meteorological stations operational in the country. Some of these meteorological stations also collect agro-climatological data necessary for estimation of crop water requirements.

The temperature and precipitation from the following nearby stations are gathered to assess the impact of climate change in Kalleritar irrigation system.

Table 1: Station's name

S.No.	Station No.	Station Name	Latitude	Longitude	Elevation
1	1002	ARUGHAT	28.05	84.81	518
2	1004	NUWAKOT	27.91	85.16	103
3	1005	DHADING	27.86	84.93	1420
4	1038	DHUNIBESI	27.71	85.18	1085

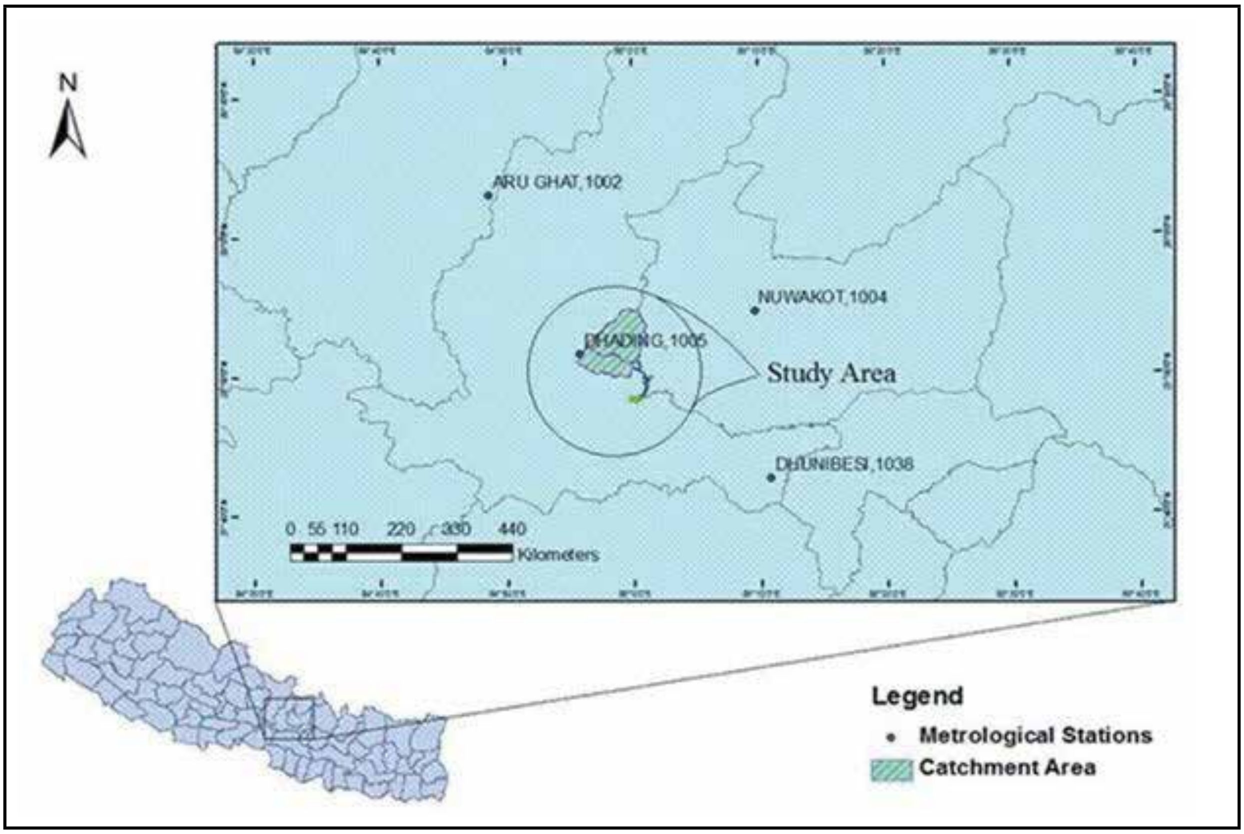


Fig 3: Nearby Meteorological Stations

Temperature:

Temperature of station 1002 is not available. Temperature of 1004 and 1038 are available but some intervals data are missing. Temperature of 1005 started recording only after 2008 so not included in this analysis. The following shows the graph and temperature trend.

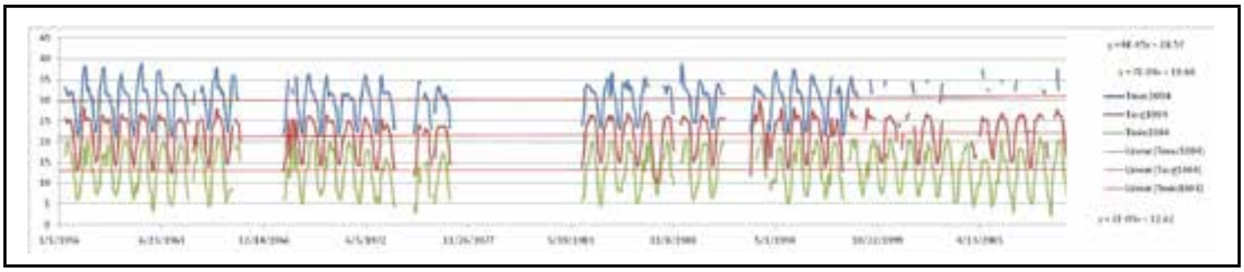


Figure 4: Temperature of station 1004

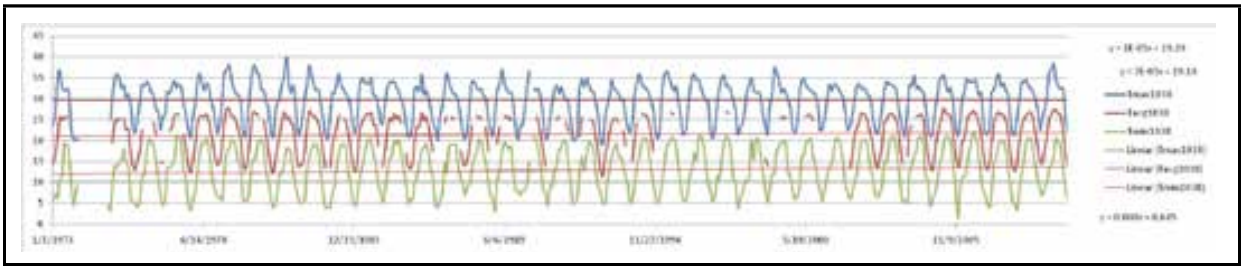


Figure-5: Temperature of station 1038

Based on these two stations data available and without doing any simulation it is clearly seen that temperature is in rising trend by 0.025 degree Celsius annually. This is less than the average taken by NAPA.

Precipitation

Precipitation data is available in almost all four station albeit some years data are missing in two stations which is seen in graph too.

In the precipitation analysis, four seasons were taken to see the pattern of rainfall that is pre-monsoon, monsoon, post-monsoon and winter. It is observed that in all the stations used in this study pre-monsoon precipitation has increased and it will definitely affect cropping calendar of farmers.

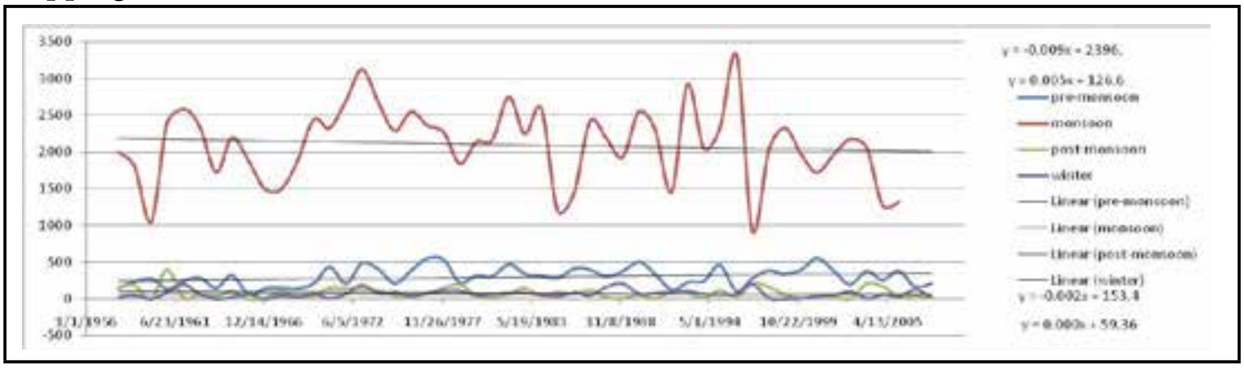
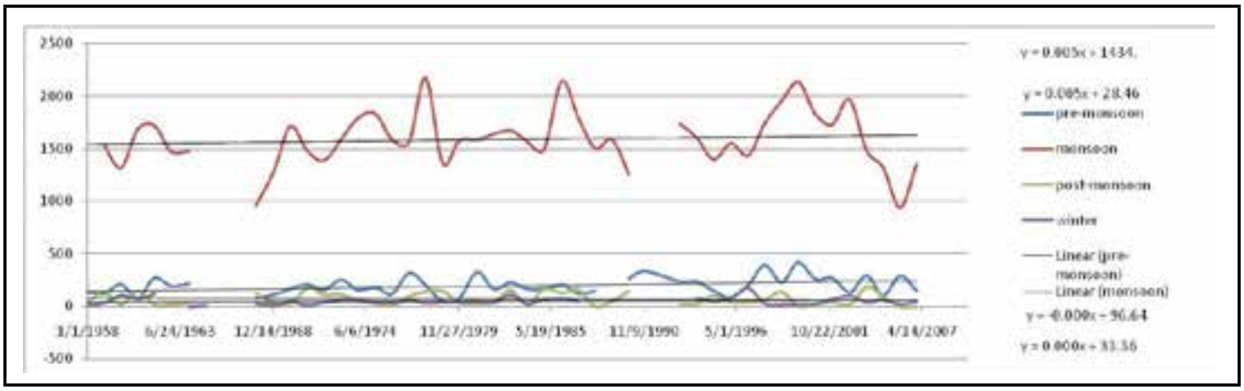


Figure 6: Precipitation of station 1002



Firure 7: Precipitation of station 1004

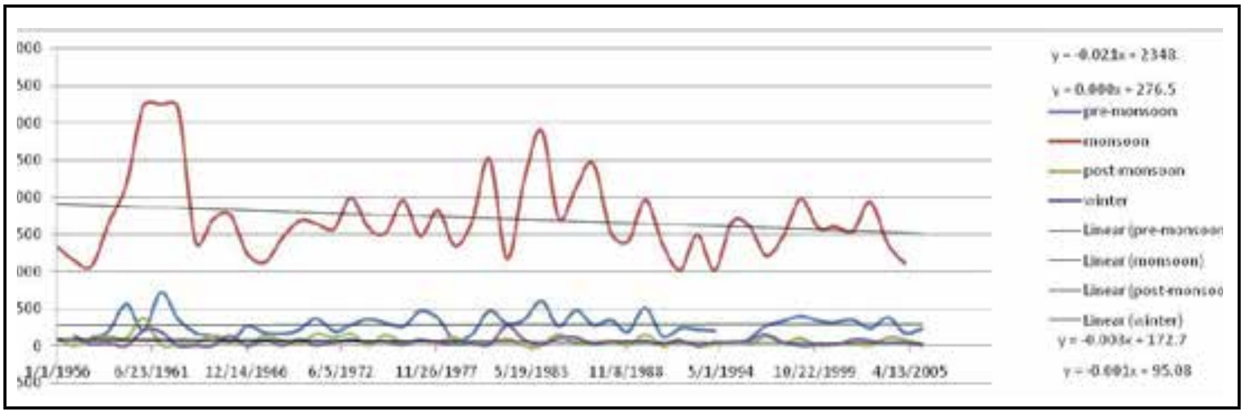


Figure 8: Precipitation of station 1005

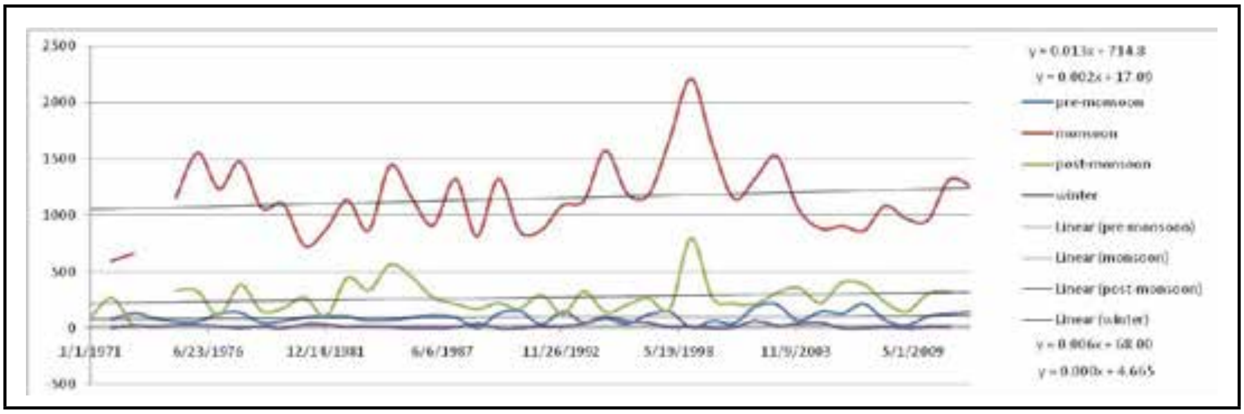


Figure 9: Precipitation of station 1038

WATER AVAILABILITY

As long term hydrological data are not likely to be available at the sites of most of the proposed intake structures, river flows will therefore have to be estimated using methods developed for ungauged basins. In the case of availability of river flow data at or very near the proposed intake site, frequency analysis can be used to assess the water availability.

80% dependable river flow is the commonly used parameter to estimate the water available for diversion.

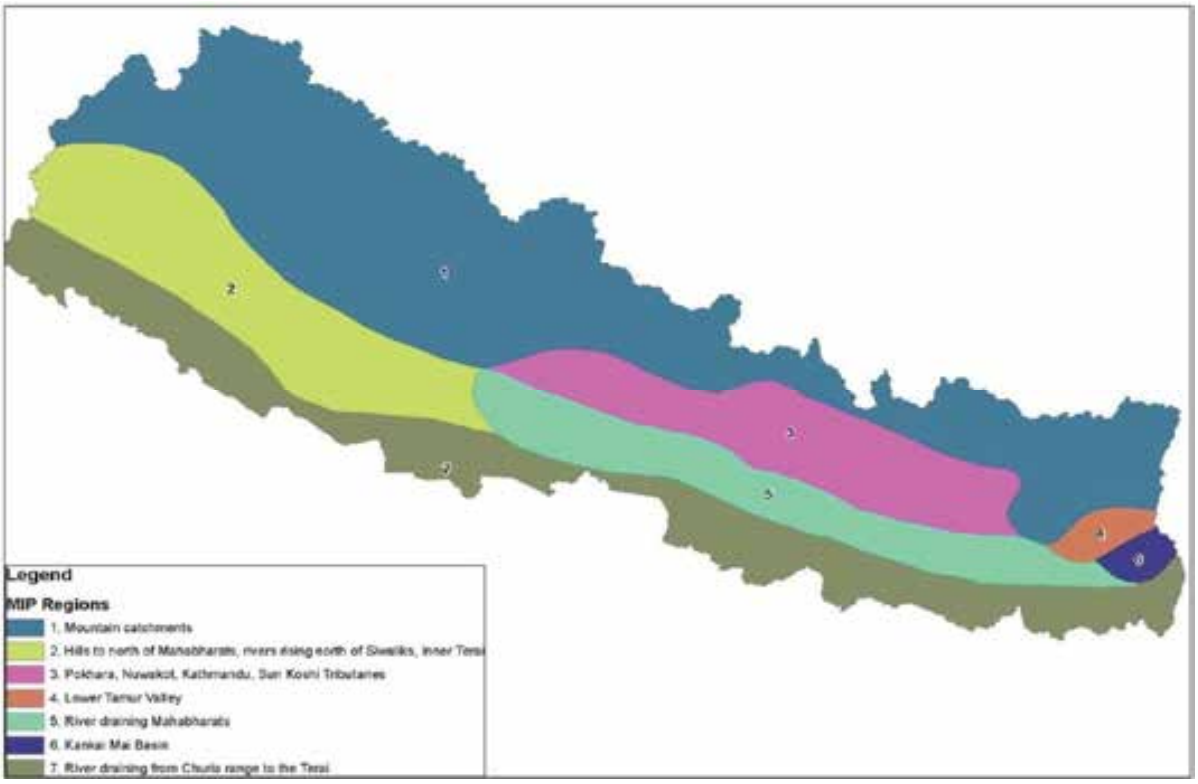


Figure 4: HyHydrological Regions of Nepal

In the ungauged river, Regional Hydrographs using Spot Measurements are used. The MIP Design Manual (1982) has developed regional hydrographs using spot measurements and is widely used in irrigation design and planning in Nepal. The country has been divided into seven hydrological regions as shown in Figure 4. For each region a monthly hydrograph showing mean, 20% reliable and 80% reliable flows have been calculated. The ordinates of the regional hydrographs have been non-dimensionalized by dividing each by the April flow.

For using the non-dimensional hydrograph to predict the mean and 80% reliable flows, the measured flow should essentially be for a month during dry season (September – May) to eliminate the influence of storm flow.

Discharge measurement in the river:

The discharge in Khani Khola and Koshi Khola, source of Kalleritar irrigation system were measured by float area method on 17th May, 2013 and recorded 317 lit/sec and 182 lit/sec respectively. Since it lies in the MIP region 3, the mean hydrographs were calculated from non dimensional coefficient by dividing the monthly means by the mean flow of April (month of least flow); given in the PDSP manual. Then 80% reliable flow of the river is found which is compared with the total crop water demand in the command area and the water balance is found. Then the design discharge for the canal is chosen taking the highest demand with some factor of safety. This process has been done for now and 30 years later keeping in mind of affect in Et_o by temperature.

FINDINGS

Table 2: Design Discharge

S.No.	Description	Discharge	Unit	Remarks
1	Originally Designed	540	lps	designed in 1983 A.D.
2	Rehabilitation Design	400	lps	designed in 1998 (319.68 lps) 25% contingency discharge added (800lps in salent feature)
3	Design Discharge calculated now	505	lps	calculated using evapotranspiration data taken from PDSP manual table D2, Station Khairinitar (Index No. 815)
4	Design Discharge calculated for present evapotranspiration	520	lps	Interpolation of station 815 to the Kalleritar system by PDSP manual method.
5	Design Discharge calculated for forecasted evapotranspiration	540	lps	Projected discharge by using new Eto for 2043

When the canal was designed in 1983 there was no PDSP manual so in the design report water balance calculation was not found. It seems that the design engineer at that time has taken the duty 2.7 lit/sec/hec and designed the canal in order to be in safer side with 540 lps. But in the report prepared in 1996 the design discharge was calculated 400 lps. At present it is found 505 lps with the Et_o taken from the station no 815 given in the PDSP manual of 1990. However if it is interpolated to the site as given the procedure in the same manual it will be 520 lps. In the next step increasing the temperature as prevailing trend, Et_o is calculated for thirty years later and the water balance is calculated then it is found that the water requirement in the command area during that time will be 540 lps which is the same discharge taken by the design engineer at the beginning.

While calculating $Et_{o,}$ Penman's method has been used which is more reliable compared to others method. The graph below shows the difference of values that are found by different methods to calculate Et_o and the Table 3 shows the Et_o forecasted.

$PET = \frac{AH_n + E_n\gamma}{A + \gamma}$ for Penman's method to calculate the value is

Where,

PET= daily potential evapotranspiration in mm per day;

A = slope of the saturation vapor pressure vs temperature curve at the mean airtemperature, in mm of mercury per º celcius;

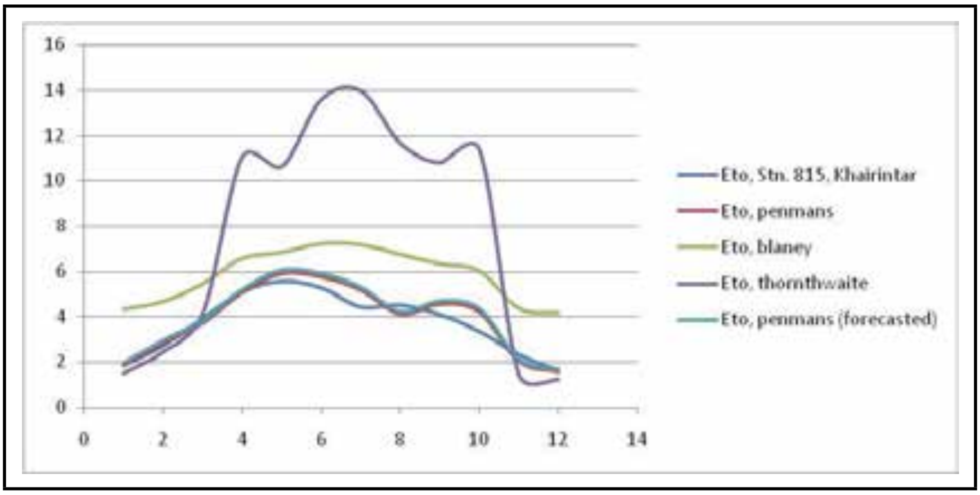
H_n = net radiation in mm of evaporable water per day;

Ea = parameter including wind velocity and saturation deficit

= psychometric constant = 0.49 mm of mercury/ºc

Balney criddle Method and Thornwaite also use to calculate the ETo but because of high variation Penman's values are used for the calculation purpose.

Figure 5: ET_o Factors



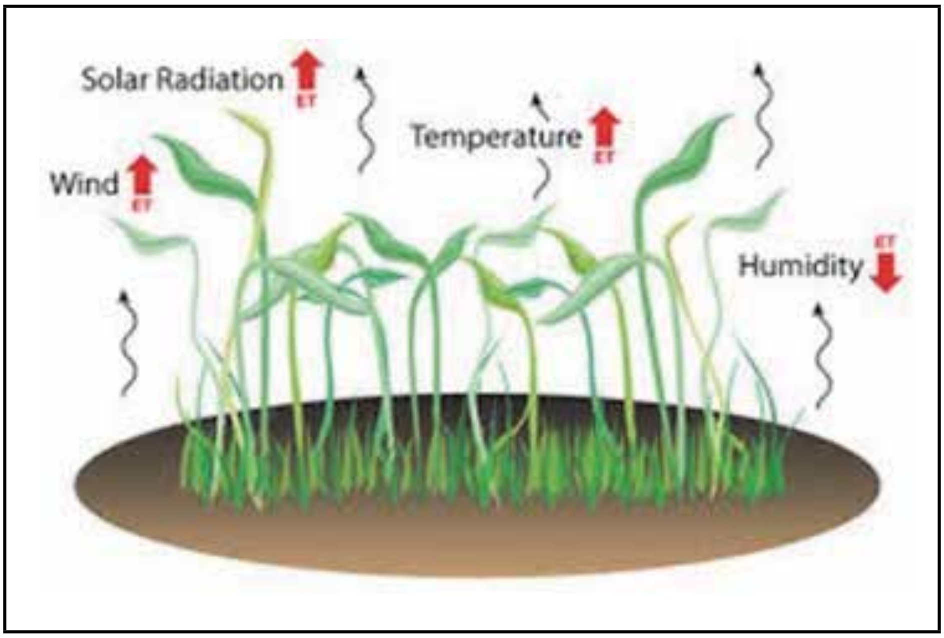


Figure 6: comparing the ET_o by different method

Table 3: Et_o Forecast

Month	Temp, 1005	Temp, command area	Forecasted Temp, command area	Humidity, 1005		Ppt, 1005	Sunshine	Wind speed, 804, pokhara stn	Eto, Stn. 815, Khairintar	Eto, penmans	Eto, blaney	Eto, thornthwaite	Eto, penmans (forecasted)
	°C	°C	°C						mm/day	mm/day	mm/day	mm/day	mm/day
JAN	16.2	21.76	22.60	0.8814	0.409954	0	8.35	2.035	1.87	1.89	4.32	1.51	1.98
FEB	18.25	24.02	24.86	0.8674	0.380221	0	8.82	3.927	2.74	2.85	4.66	2.46	2.97
MAR	20.62	26.33	27.17	0.8131	0.412216	41.4	8.31	3.813	3.96	3.73	5.45	4.13	3.85
APR	25.76	32.06	32.90	0.7343	0.336214	73.2	7.97	3.787	5.13	5.06	6.59	11.05	5.20
MAY	25.56	31.42	32.26	0.7915	0.443912	5.2	10.29	2.387	5.59	5.89	6.85	10.61	6.06
JUN	27.65	32.97	33.81	0.8507	0.507714	77.4	8.54	1.760	5.3	5.75	7.25	13.59	5.91
JUL	28.32	33.22	34.06	0.848	0.521911	590.8	6.86	1.500	4.45	5.17	7.20	13.97	5.31
AUG	27.19	32.28	33.12	0.8467	0.619345	424.6	4.51	1.577	4.54	4.12	6.76	11.66	4.23
SEP	27.11	32.20	33.04	0.8709	0.595019	99.7	7.15	1.703	4.12	4.55	6.34	10.80	4.70
OCT	27.47	33.10	33.94	0.8466	0.41173	64	7.42	1.629	3.38	4.21	6.03	11.39	4.36
NOV	18.29	21.48	22.32	0.8036	0.581368	0	8.48	1.710	2.35	2.06	4.36	1.45	2.15
DEC	15.82	20.96	21.80	0.8576	0.465256	0.1	8.13	1.719	1.64	1.59	4.15	1.24	1.68

Owing to increase in ETo, crop water requirements is in increasing trend and on the other hand the discharge of the river is more erratic due to changing pattern of precipitation in different seasons. Hence the water shortage in traditional cropping schedule is likely to occur and farmers need to start adaptation practice for climate change impact.

CONCLUSION AND RECOMMENDATION:

- Based on the findings, climate change factors need to be incorporated in new irrigation canal design.
- This study has not used any downscaling method or any software for simulation, so the data can be further downscaled to find more accuracy in the crop water demand.
- The study has not done any analysis for the water demand of traditional variety of crops and new hybrid crops now switched by most farmers and it is recommended for future study to see the impact of climate change in hybrid crops.
- The method of in-situ practice in various regions to calculate ET_o needs to be established by Department of Hydrology and Meteorology or Department of Irrigation in order to get accuracy of the effect of climate change in evapotranspiration.
- The hill irrigation systems which were designed without considering climate change, need to improve efficiency in water control and delivery. In addition the farmers need to be trained for optimum utilization of diverted water to crops and switching cultivation practice from main staple crop to fruits or vegetables in order to save water and adapt climate change.

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6.4 ADDRESSING CLIMATE CHANGE IMPACTS ON FARMERS MANAGED IRRIGATION SYSTEM THROUGH ADAPTATION MEASURES

SHREE BHAGAVAN THAKUR[1] AND
BATU KRISHNA UPRETY[2]

INTRODUCTION

Agriculture, the main economic sector, in Nepal accounts nearly one-third of the national gross domestic product, represents 13% of total foreign trade and has engaged two-thirds of the country's economically active population (CBS, 2012). About 21 % of the total land is cultivated and 54 % has irrigation facilities with only 0.68 ha per household land holding size. Agriculture is mostly rain-fed and climate sensitive. Over 50% of farmers are smallholders with cultivating land usually less than 0.5 ha.

In 2005/06, eastern Tarai faced rain deficit due to early monsoon, resulting to nearly 10% of the agriculture land left fallow and crop production was reduced by 12.5% on the national basis. The mid-western Tarai experienced heavy rain with floods which reduced production by 30% in the same year (Regmi, 2007). Both floods and droughts have declined food production significantly.

Water supports agriculture and other livelihood functions. Water profoundly influences photosynthesis, respiration, absorption, translocation and utilization of mineral nutrients, and cell division besides some other processes (india.agronet.com, 2017). As much as 85% of global water is used for irrigating

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the agriculture land, of which 15 to 35% is predicted unsustainable (IFPRI, 2016). Irrigated land can have up to five times high yields than that of the rain-fed areas (Devrajan, 2011). Irrigated agriculture produced 40% of food and agriculture commodities from 17% agriculture land. This informs food security critically dependent on irrigation (Wallingford, 1997).

Nepal has practiced irrigated agriculture as early as during the era of Gautam Buddha and Lord Buddha was involved himself in resolving disputes among irrigators. Irrigation development can be put under four phases: (i) primary phase or the period prior to planned development (before 1956); (ii) infrastructure development phase (1957-1970); (iii) intensive development phase (1971-1985); and (iv) integrated development phase (1986 to date) (JVS, 2017). In 1985AD (B.S.), the Government of Nepal constructed first modern irrigation canal, the Chandra canal. Experiences and lessons learned from this canal initiated construction of several irrigation canals throughout the country.

In 1956, about 500,000 hectares was irrigated land mostly from Farmer's Managed Irrigation System (FMIS). This area has increased by 880,000 hectares (74%) under FMIS of total 1.2 million ha in 2009. The FMISs were built, operated and maintained by farmers themselves with little or no help from the Government and/or outside agencies.

Nepal is experiencing temperature rise and change in precipitation pattern. The 2015 study of climate and climatic variation over Nepal showed 0.037 ^{0}C/year and 0.012^{0}C/year of an average trend of mean annual maximum and minimum temperature respectively during 1971-2012 period (NHMRCC, 2015). There is no clear indication on precipitation change but average precipitation has increased by 0.7 mm/year based on spatial interpolated data. The 24-hour accumulated extreme precipitation is higher over Churiya, exceeding 400mm/day. The study reported 13 June as mean summer monsoon onset date and 25 September as the withdrawal date based on average of 1968-2014 data. Duration of monsoon is increasing at the rate of 5 days/decade.

Table 1: Climate trend in ecological regions

Region	Maximum Temperature Trend (^{0}C/year)	Minimum Temperature Trend (^{0}C/year)	Precipitation trend (mm/year)
Tarai	0.015	0.017	-1.3
Siwalik	0.024	0.013	0.6
Middle Mountain	0.043	0.013	-2.3
High Mountain	0.053	0.008	0.2
High Himalaya	0.052	0.009	6.6
Country	0.037	0.012	0.7

Source: NHMRCC, 2015.

Climate variability confirms 'too much water' (accelerating flood) and 'too little water' (drought) resulting to severe water scarcity and this is aggravated due to climate change impacts on agricultural productivity through irregular and inadequate irrigation facilities.

Glacier melt, precipitation, groundwater are major sources of water. The perennial rivers like Koshi, Gandaki, Karnali and Mahakali originate in the Himalayas and carry snow-fed flows with significant discharge, even in the dry season. The perennial rivers like Mechi, Kankai, Kamala, Bagmati, West Rapti and Babai rivers originate in the Midlands or Mahabhabharat range and are fed by precipitations as well as groundwater recharge, including springs with seasonal fluctuation in discharge. Seasonal and small rivers in the Tarai originate from the southern Siwalik range with little flow during the dry season and is characterized by flash floods during the monsoon. In a nutshell, water origins are expected highly vulnerable to climate variability and change.

Agriculture sector is not performing well due to shortage of water for irrigation. Farmers are the biggest global water users and farmers operate, directly or indirectly, at the world market for agricultural products (Alvaro *et. al.*, 2010). It is most likely that climate change will make the situation worse. Adaptation to changing water resources is often studied at the local scale.

Irrigation system of Nepal has also been classified on the basis of governance. Systems that are owned, developed and managed by farmers are known as FMIS and those which are owned and governed by the State are referred to as Agency Managed Irrigation System (Pradhan, 1989). On the basis of topography, it is classified into Hill irrigation system whose river water and gradients change rapidly as they flow downhill, and Tarai irrigation system where water is drawn from relatively large rivers flowing across the flat Tarai (Pradhan, 1989). There are physical and institutional differences between these systems in terms of rate of change of gradient, idle canal length, efforts required at canal maintenance, farm types irrigated, the size of the command area, and rules governing resource mobilization & water allocation (Pradhan 1989). Based on water sources, there are two types of irrigation, *i.e.* surface and underground irrigation. FMIS is the vibrant systems occupying special status in national economy and food security system. FMIS has the long history, active institution, democratic governance, and act as per their regulations and community consensus (Pradhan, 2000).

With this in perspectives, this paper aims to understand and share information on the impacts of climate change on irrigation system in order to inform policy-makers, development workers, climate change advocates and farmers to take into account the climate change adaptation measures and promote climate-resilient design and implementation of FMIS to cope with the adverse impacts of climate change.

METHODOLOGY

This paper is based on the review of published reports, journal articles and research papers, both national and international. The government policies, plans, and strategies were also reviewed to understand national focus and priorities in exploring opportunities to make FMIS climate change-resilient.

DISCUSSIONS

The major source of river water, the glaciers, has reduced from 5312 Km^2 in 2010 to 4212 Km^2 in 2014 (MoSTE, 2014). Nepal has 225 Billion Cubic Metres (BCM) of water available annually and only 15 BCM has so far been utilized for economic and social purposes (MoSTE, 2014). Insufficient rain and temperature rise cause drought, whereas intense rain in short period reduces groundwater recharge by accelerating runoff and causes floods. Both situations induce negative impacts in the agriculture (ICIMOD/UNEP, 2007).

In Nepal, climate change will likely increase in average annual water yields from Himalayan Rivers at least for the next 15- 20 years. It is anticipated that water yields of our rivers would fall dramatically since glaciers would have mostly melted-out by 2035 (Paudel and Gautam, 2011). The Intergovernmental Panel on Climate Change (IPCC) forecasted that the Himalaya will be converted into a black rocky mountain without snow and ice by the year 2035 (Paudel and Gautam, 2011). Although the forecast may not be true to that extent, Nepal will likely face severe water scarcity along with other South Asian nations. Glacial and snow melting is an important source of the lean flows of four large rivers (Kosi, Narayani, Karnali and Mahakali). Medium-sized rivers also depend on impacts of climate change on the Himalayan snow/ice conditions. It is evident that rivers, the main sources of irrigation, are highly vulnerable to climate change. It is likely that FMISs will also be affected by climate change. As Nepal's greenhouse gas (GHG) emission is insignificant (only 0.027% of the global total) and her effort in reducing GHGs emission will be 'meaningless' at the global level, it is natural that Nepal should focus on climate change adaptation.

Realizing the adaptation needs in periodical plans

Irrigation facilities developed from first to third Plan period fall under 'infrastructure development phase'. During 4th to 6th Plans period, multi-lateral agencies like the World Bank and the Asian Development Bank funded irrigation facilities to convey water to farmers' fields with canal networks, hence this period is named as 'intensive development phase'. From the 7th Plan onward, there has been a paradigm shift in irrigation development as farmers' participation through organized associations, rehabilitation of farmers' canals, management transfer etc. received more attention.

The 13th Plan stressed on capacity building of user committee for making sustainable, efficient and effective management and execution of irrigation systems. It focused on environment, climate change adaptation, participatory development and employment creation while developing, designing and implementing irrigation infrastructures. The mainstreaming of environment, climate change and hazard risk management during the formulation, operation and execution of irrigation projects has broaden the traditional concept of irrigation development and management. Similarly, 14th Plan realized that risk management of climate change-induced effects on water availability is the major challenge of irrigation sector (NPC, 2016). It also stressed on ensuring user's participation for sustainable management as well as development and extension of irrigation system and achieving goals of Agriculture Development Strategy and promoting climate change adaptation. Efficient use of irrigation system and participatory management is equally emphasised. The Component 3 of the Pilot Programme for Climate Resilient (PPCR) under water management describes local water management practices covering FMISs, community-managed drinking water schemes, and locally managed water mills.

The goal 2 of 2030 Sustainable Development Goals is to "end hunger, achieve food security and improved nutrition and promote sustainable agriculture", and the goal 6 focuses to "ensure availability and sustainable management of water and sanitation for all". To achieve them, it is necessary to make irrigation facilities climate-friendly and resilient.

Promoting the source-based and adaptive irrigation system

The Agriculture Perspective Plan (1995-96) targeted irrigation as one of the major inputs for increasing crop productivity and commercialization of agriculture. The Agriculture Development Strategy, 2014 has targeted to provide year round irrigation facility by 18% in year 2010 to 60% and 80% by 10 years and 15 years respectively (MoAD, 2014). The Strategy has realized the impact of climate change and emphasizes to introduce climate change adaptation in order to increase farmers' resilience to climate change.

The Irrigation Policy, 2014 describes climate-related risks associated with the irrigation infrastructure. Drought condition reduces the effectiveness of irrigation systems and can cause long-term damage to infrastructure and losses in crop production. Similarly, flooding causes direct destruction of infrastructure and sedimentation within irrigation systems. The Policy underscores the importance of availing sustainable and reliable year-round irrigation facilities to all agricultural lands so as to contribute to agriculture productivity by extension of irrigation services for reducing poverty.

This demands promotion of conjunctive use of ground and surface water-based irrigation systems along with new/non-conventional irrigation systems such as rain water harvest, pond irrigation, sprinkler irrigation, drip irrigation and treadle pump irrigation. The irrigation systems developed so far are limited to run-of-the-river system. To make the system effective for round the irrigation, it is necessary to develop storage facilities for winter season. The Irrigation Policy emphasizes development and implementation of reservoir-based and inter-basin water transfer facilities and integrated water resources management. The Policy opens avenues to develop climate change-friendly irrigation facilities to achieve its objectives, avail round-year irrigation facility through effective management of existing water resources, develop institutional capacity of water users for sustainable management of existing systems, and enhance knowledge, skills and institutional working capability of technical human resources, and water users and NGOs relating to development of irrigation sector. The Policy aims to study the impact of climate change and water-induced disasters to implement adaptation programmes.

The National Adaptation Programme of Action (NAPA), 2010 includes priority activities-related to irrigation like integrated watershed management in Churia to ensure ecosystem and community adaptation to climate change, on-farm soil and water conservation initiatives to support hill and mountain communities vulnerable to climate change, water management in river basin areas at municipal level, flood management to reduce the vulnerability of communities and increase their adaptive capacity, promotion and up-scaling of Multi Use System (MUS) for the benefit of poor and vulnerable communities in mid-hills and Churia range of Nepal, and up-scaling and implementation of non-conventional irrigation systems in water stressed areas. Some of the irrigation practices such as MUS, hydraulic ram pump, treadle pump, drip irrigation, and micro-sprinkler are catalogued as climate change adaptation approaches and technologies.

The Climate Change Policy (2011) aims to improve livelihoods by mitigating and adapting to the adverse impacts of climate change, and adopting low carbon emissions socio-economic development path. The Policy provides multiple opportunities to promote climate change adaptation and make the development infrastructures climate-friendly and resilient.

Expanding multiple use of FMIS

Water is used for several purposes such as for drinking water, agricultural practices, power generation, changes in economy/technology watershed characteristics and others. Water makes the soil fertile for crops to grow, ensures proper growth and edibility of the crops. Besides water utilizing for agriculture in FMIS, it is used for drinking water and sanitation based on drinkable condition, micro-hydropower generation, water mills, livestock drinking water, fish and duck farming, and industrial uses.

Understanding the impacts of the climate change on irrigation

The major crops grown under irrigated conditions are found to contribute to a higher level of crop productivity and net income than those in rain-fed conditions.

The principal threats to the irrigation sector in Nepal are temperature rise leading to an increase in evapo-transpiration rate, altering effective rainfall, increasing river flows leading to higher 80% reliable river discharges, and also increasing intensity of rainfall and decreasing return periods leading to an increase in flash floods, storms and landslides. These threats will lead to shifting irrigation demand and supply that will require a change in irrigation planning, and changes in flooding which will require modifications in irrigation infrastructure design.

Farmers have shifted from traditional cereal production to commercial vegetable production due to the scarcity of the water (Regmi *et.al.* 2000). Even with sufficient irrigation water in mountain "khet" (irrigated) areas but low temperature of irrigation water has a negative effect on crop productivity.

In the mid-hills, changes in rainfall and temperature and decrease in soil moisture availability will result in early maturation of crops, crop failures and reduced agricultural productivity. In addition, it will likely decrease run-off water to feed natural streams (used for irrigation) and re-charge natural ponds, reservoirs and lakes. In the Tarai region similar issues were noted, particularly reduced recharge rate of groundwater that has resulted in a reduction of discharge of water in shallow and even deep tube-wells for irrigation for crops (MoE, 2010).

Services from irrigation system is becoming poor due to alternation of precipitation pattern, changes in groundwater availability, change in surface flows (extreme rainfall patterns, flood, droughts, etc.). Most of the irrigation systems in Nepal are fed by medium or small rivers, which entirely depend on the rain. Moreover, water use efficiency and agricultural productivity in both the traditional farmer managed practices and large public irrigation system are found to be low. Among the other obstacles, inadequate irrigation is the major limiting input to increase agricultural productivity.

Though rainfall provides partial protection against drought, irrigated agriculture is very dependent on the rainfall. Any changes to rainfall patterns and other climatic parameters will affect both supply and demand for irrigation water and will have a direct impact on its system.

The reduced run-off rivers, due to changing rainfall patterns in the catchment; increased flood flows due to more intense rainfall, increased demand for water due to higher temperatures and more erratic rainfall, and changes in crop suitability due to temperature changes are the major and important adverse effects for irrigated agriculture. It adversely affects the FMIS broadly. Furthermore, FMIS is facing challenges by population growth, pressure for increased demand on food, environmental degradation, and completion on the allocation of water (Pradhan, 2000).

FMIS as climate change adaptation measure and resilient irrigation facility

Rapid change in climate system has raised the concern of floods and droughts and their impacts on existing arrangements for irrigation design and management system. Experience informs that FMIS contributes substantially to the agricultural production of the country, is well managed and, in general, gives better yields. Usually, FMIS infrastructure is simple and lacks provision for water control and management. As the local knowledge, skill and materials as well as indigenous technologies have been largely utilized in the FMIS, this will be highly adaptive to climate change impacts and would be climate-resilient.

FMIS functions well due to adequate consideration of indigenous materials, modern knowledge of layout, construction, management, ecology and hydrology. It also considers irrigation structures simple and adaptive to geophysical environment. The perpetuation of accumulated experience, skill and the knowledge have enabled them balance water use, conserve natural ecosystem, generate employment and feed rapidly growing population, build social capital for collective action and maintain communal integrity, make best use of local resources and indigenous technology, and keep several FMISs alive (Shivakoti and Shrestha, 2004).

Local understanding indicates FMIS promotes "Climate-Smart Agriculture" which is defined as "sustainably increases productivity, enhances resilience, reduces/removes GHGs emissions, and enhances achievement of national food security and development goals" (FAO, 2010). Water smart "technologies which conserve water, suitable for drought/ flood conditions, increase water use efficiency, etc." is a component of climate smart agriculture. In view of promoting such agriculture practices, climate change adaptation should be prioritized through institutional, policy and procedural arrangements.

Adoption of alternative irrigation technologies in the Non- conventional Irrigation Technology Project (NITP) and IWRM principles in the supported projects indicates that Department of Irrigation (DoI) is already prepared to embrace adaptive responses to potential climate change threats (DoI and MosTE, 2014).

The Nepal Climate Change Support Project (NCCSP) has supported adaptation initiatives like irrigation canal construction and repair maintenance, irrigation pond, plastic pond, water harvesting structures, drip and sprinkler system and FMIS in most climate vulnerable 14 districts of far and mid-west Nepal (NCCSP, 2015).

Integrating adaptation into irrigation facilities

Although designed and managed on largely traditional ways, irrigation facility is highly sensitive to climate and its change. FMIS can generally be constructed at relatively low cost and emphasis should be given to prepare irrigation facilities climate adaptive, resilient and efficient in water scarce situation. It is imperative to understand change in air temperature, change in annual and seasonal rainfall, flood and sediment transport, including change in flows and flow duration.

As the models suggest that there will be an increase in flood magnitude and frequencies, it may result in damage of irrigation infrastructure during monsoon season. The existing water resources infrastructures, which have been designed and constructed earlier based on past flow data and regime, might be less appropriate or even inappropriate in the new flow regime under climate change. The models also reveal decreasing lean flows during non-monsoon seasons, when there is more irrigation water requirement. Increasing temperature would increase the water requirement on one hand and decrease the water availability during dry season on the other. This would result in a significant gap in crop cultivation between demand and supply of water for irrigation (MoSTE, 2012). As C4 plants are comparatively better efficient to C3 plants on water absorption and carbon di-oxide use, it might be appropriate to promote cultivation of C4 plants such as maize, sorghum and sugarcane to increase crop productivity.

Adaptation is very important in order to increase water efficiency. Flood and drought tolerant species could be developed and used. Crops which need more water can be replaced by the crops requiring less water. Identification of crops for developing drought resistant varieties, screening of local varieties for drought resistant genomes and development of stress tolerant crop varieties and identification of landraces tolerant to biotic and abiotic stresses are the adaptation measure related to irrigation (MoSTE, 2012). Similarly, water-efficient irrigation technology such as sprinkler, drip, rain gun, and overhead methods can be used in order to reduce the consumption of water.

Technology and practices such as zero tillage, minimum tillage, reduced tillage, residue retention, system of rice intensification and alternate wetting and drying for rice should be used and replicated as they are piloted with the view of increasing yield and enhancing water use efficiency.

The practices like sustainable soil and water conservation, rainwater harvesting, increasing cropping intensity, replacing chemical fertilizers by organic fertilizers, improving rangeland and forage, development and promotion of drought resistant varieties, use of sprinkler irrigation, green manuring, grazing land management for increasing carbon storage and promoting organic farming etc. may help the crops to adapt to climate change impacts.

In order to ensure increase in agriculture production and make the irrigation facilities climate-resilient, the Government of Nepal has prepared NAPA in 2010 and is implementing its prioritised most urgent and immediate adaptation needs through an approved National Framework on Local Adaptation Plans for Action (LAPA) in 2011. The Climate Change Policy (2011) provides multiple avenues to integrate climate change adaptation into irrigation and agriculture system to help them adapt to and build resilience to climate change impacts and urges to channel at least 80 percent of the climate change fund to field level activities. Furthermore, the Government has adopted a 'dedicated climate change budget code' to channel climate finance to the field level activities.

Addressing the long-term adaptation needs

In 2015, the Ministry of Population and Environment (MoPE), in its capacity as the focal point for United Nations Framework Convention on Climate Change (UNFCCC), Kyoto Protocol and the Paris Agreement has started the formulation of the National Adaption

Plan (NAP) to address medium- and long-term adaptation needs of the country. The NAP aims to reduce vulnerability to the impacts of climate change, by building adaptive capacity and resilience; and to facilitate the integration of climate change adaptation, in a coherent manner, into relevant new and existing policies, programmes and activities, in particular development planning processes and strategies, within all relevant sectors and at different levels, as appropriate. NAP formulation process undertakes approaches as mentioned in Box 1. Nepal intends to formulate NAP using experiences and lessons learned from NAPA, LAPA and good practices of other climate change programmes and projects. It further uses the initial guidelines adopted by Parties to the UNFCCC in 2011 and NAP technical guidelines prepared by the LDC Expert Group.

Box 1: NAP's National Approaches

- Establishing working groups to coordinate multi-stakeholder thematic areas
- Utilising existing coordination mechanisms;
- Building capacity and enhancing understanding on climate change adaptation;
- Building ownership and avoiding duplications on efforts;
- Promoting multi-stakeholder participation; Ensuring gender-sensitivity and inclusiveness; 'LEAVE NO ONE BEHIND'
- Generating, utilising and sharing knowledge and good practices;
- Supplementing to 'development efforts' with integration of adaptation actions;
- Aligning with national policies and linking with recent initiatives (Disaster Risk Reduction and Sustainable Development Goals); and
- Synergising ecosystem-based and community-based adaptations.

Box 2: Working Groups and Coordinating Ministries

a. Theme-based Working Groups and Coordinating Ministries

- Agriculture and food security (Nutrition) – Ministry of Agriculture Development
- Climate-induced disasters – Ministry of Home Affairs
- Forests and biodiversity – Ministry of Forests and Soil Conservation
- Public Health (and WASH) – Ministry of Health
- Tourism, natural and cultural heritage – Ministry of Culture, Tourism and Civil Aviation
- Urban settlement and infrastructure – Ministry of Urban Development
- Water resources and energy – Ministry of Energy

b. Cross-cutting Working Groups and Coordinating Ministries

- Gender and social inclusion – Ministry of Women, Children and Social Welfare
- Livelihood and governance – Ministry of Federal Affairs and Local Development.

The NAP is under formulation through a multi-stakeholder working group, country-driven process and 'leave no one behind approach'. As of mid-March 2017, 7 thematic working groups and 2 cross-cutting working groups with 200 members have been formed under the coordinator-ship of the Joint-Secretaries of the concerned ministries (Box 2). One of the working group is on agriculture and food security while water resource and energy working group also analyses impacts of climate change on irrigation and proposes adaptation measures for the medium and long-term. Initial understanding on medium and long-term for Nepal is 2018-2030 and up to 2050 periods. Hence, NAP will provide Nepal multiple opportunities to integrate climate change adaptation into her key development and economic sectors, including irrigation and agriculture sectors and make them climate-resilient and help climate vulnerable people, communities and resources to adapt to climate change impacts.

CONCLUSION

FMIS is covering large area of total irrigated land. Temperature rise and change in precipitation pattern causing drought and flood have negative effects on FMISs and their infrastructure, water flow, supply and demand of water, sedimentation, crop suitability, etc. It resulted in reducing agriculture productivity and food production and accelerating poverty. It is imperative to identify approaches that strengthen ongoing economic development efforts and enhance the adaptive capacity of farmers, climate vulnerable communities and ecosystems. The adaptation measures are essential for making irrigation facilities climate-resilient through research, policy arrangements, institutional capacity building and substantial investment in this sector. Lessons learned from the on-going implementation of NAPA-prioritized adaptation options and NAP process is expected to contribute to make FMIS and other irrigation systems, and agriculture practices more adaptive and resilient to climate change.

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7. NATIONAL POLICY, INSTITUTION AND INTERVENTION STRATEGY

7.1 WATER, FOOD SECURITY AND ASIAN TRANSITION: A NEW PERSPECTIVE WITHIN THE FACE OF CLIMATE CHANGE

PUSPA RAJ KHANAL[1]

INTRODUCTION: WATER SECURITY IN THE CHANGING WORLD

Water has always played an important role in agriculture, allowing the world to keep pace with growing population and demand for food. From the aqueducts of Rome to the ancient irrigation practices of Egypt and China, the evolution of our societies, and the food production that sustains them, would not have been possible without the ingenuity and adaptation of irrigation to bring water to where it is needed most. Human civilization has been shaped by its response to the water challenge of its time.

The Green revolution, which relied heavily on irrigation, has lifted millions of poor farmers out of starvation and poverty and contributed to the fast-socio-economic development of the Asian continent. A few decades later, affordable drilling and pumping technologies have revolutionized agriculture again, providing farmers with cheap and reliable access to water for their crops. The central role of water in meeting global food security is clearly illustrated by the fact that currently, about 40 percent of food production in the world comes from only 20 percent of irrigated land.

But we are in a changing world – and new challenges are emerging for water management. Asia is in transition, and experiencing unprecedented and dynamic economic growth. Successful structural transformation in many Asian economies and rapid rural urban transformation have helped elimination of

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absolute dimension of poverty especially in East and South East Asia. The rural economy is being integrated into national and wider economic spheres. A vibrant rural dynamic is emerging in Asia with new hopes and opportunities, but also with risks and challenges.

Despite these remarkable changes, population growth continues, and over one in eight in Asia still suffer from chronic hunger. Overwhelming majority of Asian population still live in rural areas, and poverty is largely a rural phenomenon. Agriculture plays central role in their livelihood. Most often, lack of water has been a root cause of low production as well as increasing vulnerability to natural disasters, climatic variability and recently the effect of climate change. Transferring the rural areas towards prosperity remains a daunting task in the 21st century. Water and food security, and poverty reduction all hinges on success to this transformation.

On the other hand environmental degradation and land use change continue with heavy consequences in the fragile eco-systems. This will limit both land expansion and water extraction in future with serious consequences to food security in coming days. Water demand however continue to rise as a result of both population and economic growth. In the 20th century, water withdrawals grew at almost twice the rate of population increase. Going forward in this century, it is anticipated that the world will need to produce 60 percent more food on average to feed a hungry world of more than nine billion people. The main challenge in our immediate future is to meet this demand while also providing water for other economic, domestic and environmental uses – and all within the context of increasing water scarcity.

In future, climate change will exacerbate the pre-existing water challenges resulting from population and economic growth. Climate change is expected to intensify water scarcity worldwide and increase water related disasters. Rainfall patterns are already changing, and droughts are becoming more frequent and severe. In Asia, available reports suggests that by the 2050, freshwater availability in Central South, East and South East Asia, particularly in large river basin will decrease. In contrast, the heavily populated mega deltas in the South, East and Southeast Asia will be at risk due to increased flooding from the sea and rivers. There is an urgent need for a concerted effort to incorporate water into climate policy and to reinforce the link between improved water security, sustainable food production and poverty reduction.

As we continue to move in this new millennium, a new approach to water management is needed that complements ongoing transformations and supports dynamic rural change processes, while ensuring sustainable ecological and economic development pathways. It requires a much more strategic approach, with much better understanding of the factors driving the change process. Asia is in transition, and the landscape of human activities is getting more complex. The dynamics of change will determine the pattern of agricultural growth, livelihood strategies and poverty contexts, and ensuring water security would be crucial given water's inextricable, deep interdependencies with humanity, economic growth, and climate change.

THE ASIAN TRANSITION

Asia is leading in economic growth worldwide. Between 2000 to 2012, its GDP (whole Asia and Pacific) increased from US$ 8.5 trillion to US$ 23.3 trillion at current prices. Likewise, its share in world GDP in terms of real US$ PPP increased from 23.2 percent to 38.8 percent between 1990 to 2014 and is expected to increase by 45% by 2025 (Barua, 2015). This share is much larger than that of US and EU economy. Asia today is the fastest growing continent in the world and, and the region's ascendancy in the global economy is expected to continue for foreseeable future.

Together with the economic growth, it has made impressive progress in poverty reduction. Rural poverty in the developing world declined from 54 percent in 1988 to about 35 percent in 2008. This was largely due to massive reductions in poverty in East Asia, where rural poverty now stands around 15 percent (IFAD 2011). Likewise, the proportion of hungry has been reduced by 12 percentage points from the initial 24 percent between 1990/92-2014/16. In other words, while one in four people was undernourished some 25 years ago, today only one in eight is hungry (FAO 2015). Currently, Asia is urbanizing faster than any other regions in the world and is projected to be 64 percent urban by 2050 (UN, 2014)

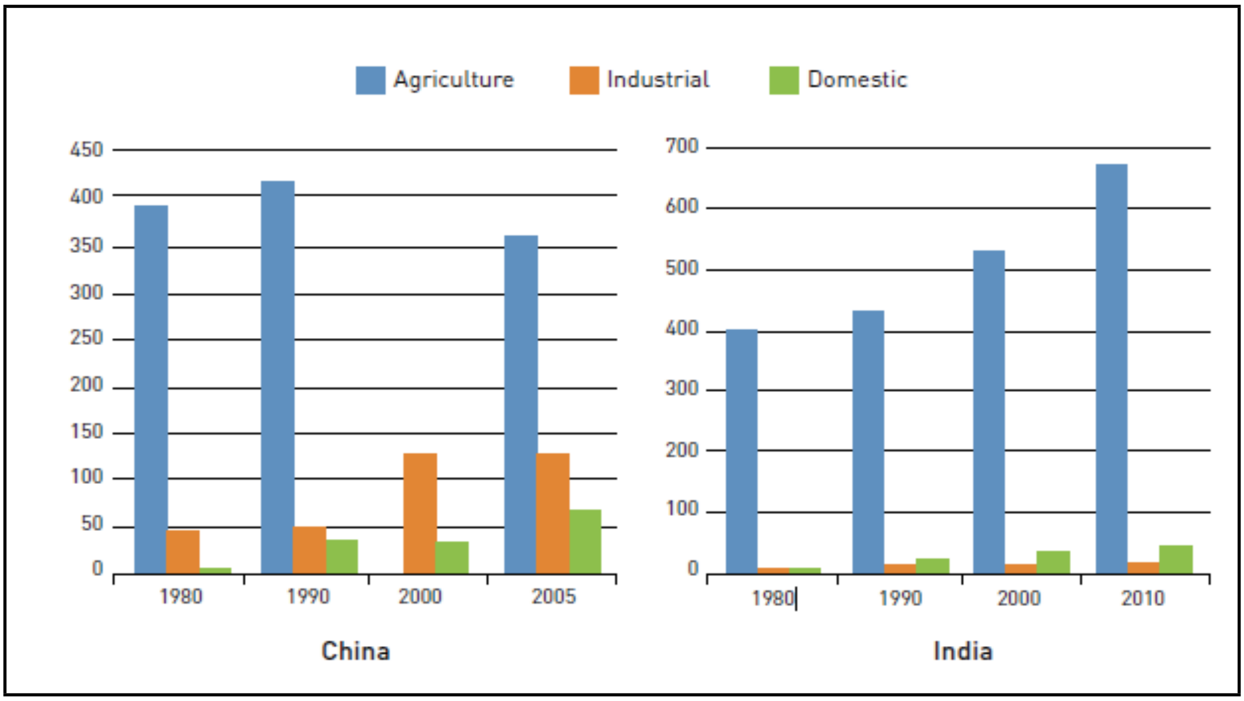
Despite striking growth and rapid rural transformation, over two third of the Asian population (excluding the advanced economies in Asia) still live in rural areas, and almost seventy percent of the poor are rural. With 490 million people still suffering chronic hunger, the region is home to almost 62 percent of such people in the world and are mostly concentrated in South Asia. Eastern Asia and South-Eastern Asia have shown great success in reducing the number of hungry. Southern Asia has not been able to reduce hunger as in other parts of Asia and continues to be the sub region with the largest number of hungry people in the world, a trend that is expected to continue for the foreseeable future.

Water, poverty and food security in Asia is therefore basically a rural phenomenon and rural agenda. The key challenge is to address issue of 490 million people who are still suffering chronic hunger in the region and bring prosperity to the rural mass who still are almost two thirds of the Asian population. A successful transitions towards higher economic growth is essential in Asia to address absolute dimension of poverty and hunger and rapid rural transformation. However, given the large number of rural population and high number of rural poor, these growth should be inclusive and equitable. The issue is not only about producing more food, but more importantly about making food available to everyone's plate.

ENSURING WATER SECURITY WITHIN THE CONTEXT OF TRANSITION

Increased economic growth, reduced poverty and increasing urbanization has brought profound agricultural and dietary transformation in Asia. The intake of high quality food stuffs like meat, poultry and horticultural products has been rising whereas that of grains like wheat and rice has been stabilizing. For example, between 1980 to 2010, consumption of poultry, fruits, vegetables, meat all increased by almost five times in China and many South East Asian nations followed the same trend.This, combined with population growth, will further increase agriculture water requirement in future. On the other hand, changing lifestyles will increase domestic and industrial water demand.

The impact of economic and population growth in water use can be clearly seen from the figure 1 which shows the trends in water withdrawal in India and China. While agricultural water withdrawal has almost stabilized in China, it continues to rise in India. Demand for water for both domestic and industrial uses is rising in both countries at different pace. With the current trends of population and economic growth, global water demand is projected to grow by some 55% due to growing demand from manufacturing (+400%),thermal electricity generation (+140%) and domestic use (+130%) with Asia taking major share. In the face of these competing demands, there will be little scope for increasing water for agriculture and competition for water will be even more acute (OECD, 2012).

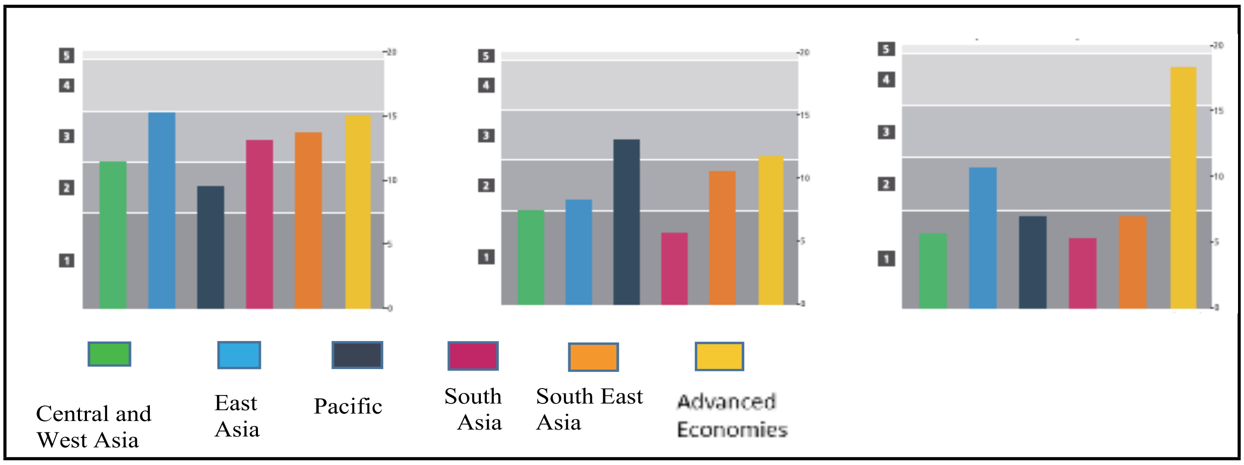


Source: Khanal, 2014

Figure 1. Changes in water withdrawal in China and India (Km³)

The recent Asian water development outlook (ADB, 2016) shows strong link between economic growth and water security. Countries with higher GDP are found to have higher water security. The issue however, is that countries with higher GDP have higher water security because they are rich or are they rich because they have higher water security. This is further explained by the GWP analysis which concludes that the relationship runs in both directions. Water-related investments can increase economic productivity and growth, while economic growth provides the resources to invest in institutions and capital-intensive water infrastructure.The conclusion is that water security increases with growth, but that also increases overall water use. It is however, difficult to quantify the share of each of these growth in total water withdrawal.

With its rising economic achievement, Asia has been reasonably able to maintain higher economic water security over the years, but has failed to maintain environmental water security as well as to security against water related disasters. This can be clearly seen from figure 2, which shows different dimensions of water security in Asia. Economic achievements in Asia, in large part, has been at the cost of environment.There is therefore an urgent need to reverse the past trends of unsustainable use of our limited water resources not only balancing supply and demand, but also preserving the eco systems of which water is the integral part



Note: The units on the right axis are the scores (1-20 scale); the ones on the left axis are the stages (1-5 scale from hazardous to model)

Figure 2. Different dimensions of water security in Asia: economic water security, environmental water security and security against water related disasters

Source: ADB, 2016

Entwined between the economic growth and environmental degradation, Asia now faces two momentous and complex transitions. The first is the structural transformation linked to economic growth and would be main driving factor for future water and food security, poverty reduction and hunger elimination. The second is about transformation towards a greener growth for sustainable food production. These two transitions are rarely considered together, and in many instances they do not align well together. Future water and food security will depend on the way these transitions will be managed. A key challenge is therefore how to adopt policies and strategies to successfully support and orient this double transition in a sustainable and equitable manner.

CLIMATE CHANGE AND UNCERTAINTIES: THE THREAT MULTIPLIER

Climate change is superimposed on existing vulnerabilities and exacerbates current challenges in in the management of water resources associated with ongoing global changes resulting from economic and population growth discussed earlier. Water is the vector by which most of climate change dynamics on societies and ecosystems are transmitted. The importance of sustainable water management in climate change context is already illustrated by the fact that 82 percent of the nationally determined contributions (INDC) presented for COP 21 have an adaptation sector and among these, 92 percent mention water!

The combined impact of the ongoing economic transformation and the climate change can be presented as shown in figure 3. It is again the rural poor who would be disproportionally affected due to their high exposer, higher sensitivity and low coping capacity.

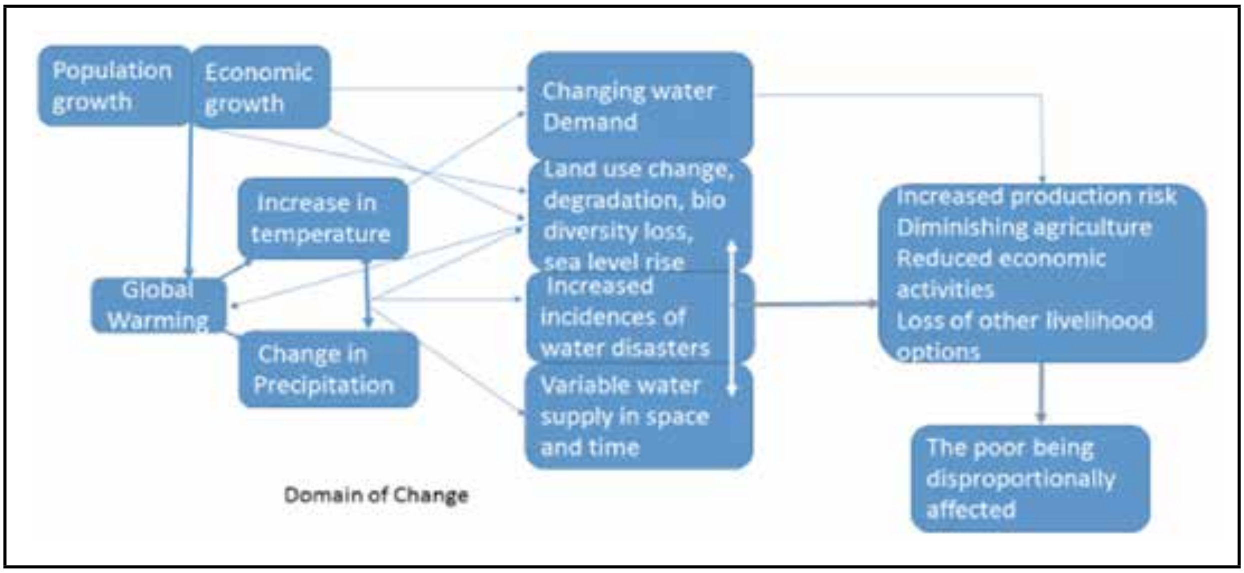


Figure 3. A conceptual framework on impact of climate change and economic and population growth in water management and food production

In general, climate change will intensify the water stress, change land and water use pattern, increase incidences of water related disasters, cause sea level rise affecting the coastal and delta environment and accelerate loss of ecosystem and bio-diversity. These factors are not independent of one another in the wider climatic cycle, but they may impact agriculture, rural and urban assets, and other economic sectors differently. The increase in water stress will be largely induced by the changing hydrological regime. The hydrological cycle will be impacted in two different ways. At the first level, changes in precipitation patterns and rising temperatures will result in higher evaporation and will affect the recharge process and groundwater-surface water interactions. This will alter both surface flows and groundwater regimes, causing changes in water supply both spatially and temporally. At the second level, climate change will affect existing water storage capacities. Rising temperatures means more rapid melting of the snow-capped mountains and reduction in the snow coverage area, which so far have provided natural water storage.

A recent study (Immerzeel et al. 2013) shows that glaciers will recede and net glacier melt runoff is on a rising trend at least until 2050; water availability during this century is therefore not likely to decline. The study concludes that river basins that depend on monsoon rains and glacier melt will continue to sustain the increasing water demands expected in these areas. However, a major impact will be the increased seasonal variability of available water resources which will demand additional water storage. It is projected that in the middle and high mountain areas, such as the Hind Kush region where most of Asia's large river systems originate, a shift toward more rainfall with less snowfall may occur due to rising temperatures. Likewise, the permanent snow line is expected to shift to higher elevations, resulting in lower snow storage.

All these factors will contribute to increasingly severe spatial and temporal variations in water, with a concomitant change in flood and drought risks. There is a growing recognition that climate change may already be affecting the frequency and intensity of droughts and floods. Asia has witnessed large-scale flood havoc in the past few years (e.g. floods in Thailand in 2011, Pakistan in 2010 and again in 2011, and the Yangtze River in China in 2010, as well as the most recent Himalayan floods in North India and northwest Nepal). Researchers even argue that more than 50 percent of agricultural output could be affected due to severe flood and drought events in the next three decades.

The rise in sea level and increased frequency and intensity of cyclones will have profound impacts on the deltas, i.e. the low-lying coastal zones and the islands of Asia where the population is dense and cultivation intensive. The severest impacts will be realized in the Ganges-Brahmaputra delta (Bangladesh and India) due to its high population densities and intensive agriculture, followed by the Mekong and the Irrawaddy deltas. They are vulnerable to erosion, inundation and flooding, and general land and water degradation due to saline and brackish water intrusion from rising tides. The economic and social impacts will be immense; those most at risk are the rural poor living in these areas.

Rising temperature and changing hydrological regimes described above will have profound impact in rural production system. A study by Nelson et al. (2009) using a crop growth simulation model predicts that by 2050, climate-induced reductions in developing country crop yields will range from 1 percent in the case of rainfed rice and wheat to18 percent for irrigated rice and 34 percent for irrigated wheat. The results of the analysis suggestthat agriculture and human well-being will be negatively affected by climate change:

- In developing countries, climate change will cause yield declines for the most important crops. South Asia will be particularly hard hit.
- Climate change will have varying effects on irrigated yields across regions, but irrigated yields for all crops in South Asia will experience large declines.

- Climate change will result in additional price increases for the most important agricultural crops – rice, wheat, maize and soybeans. Higher feed prices will result in higher meat and milk prices.

A study by Ericksen et al. (2011) on climate change and food insecurity in the global tropics shows the worst scenario for South Asia, especially the Indo-Gangetic plains, in terms of vulnerability to climatic variation. The worst scenario in South Asia results largely from its low coping capacity. The study finds that the growing period will shorten in South and East Asia, and many tropical zones will experience increased rainfall variability. The number of reliable crop-growing days will decrease to critical levels, below which cropping might become too risky to pursue as a major livelihood strategy in many places, especially in the Indo-Gangetic plains. Much of the tropics already experiences highly variable rainfall, above the median of 21 percent for cropped areas. Thus any increases in this variability will make agriculture even more precarious.

Climate change is now an accepted reality, and in some cases, is predicted to cause heavy damage to the region. South Asia is among the most vulnerable regions in the world to natural disasters related to climate change because of its exposure to water hazards, high dependency on agriculture and high incidence of poverty combined with a low coping capacity.The way water is managed and utilized will largely determine the nature and pattern of future production risks. Effective adaptation strategies through awareness raising and capacity development, technology innovation and new approaches to management of agricultural water will be critically important to minimize production risks, environmental sustainability and livelihood diversification.

RESPONSE TO THE CLIMATE CHANGE IN VARIOUS PRODUCTION SYSTEM IN ASIA

Discussions in previous paragraph clearly show that climate change will significantly impact agriculture by increasing water demand, limiting crop productivity and by reducing water availability in areas where irrigation is most needed. Estimate of incremental water requirement to meet future demand for agriculture production under climate change vary from 40-100 percent of the extra water needed without global warming (Turral et al. 2011).

In order to identify water management options in the face of climate change, it is essential to know the systems in which the challenges are severe and climate change risks are high. FAO (2011) has developed a risk typology based on the importance of irrigation and other forms of agricultural water management that will be impacted by climate change. Those applicable to Asia include:

1. Large surface irrigation systems fed by glaciers and snowmelt (notably northern India and China) may see a decline and variability in water supply;
2. Large deltas may be submerged by rising sea levels and will be increasingly prone to flood and storm (cyclone) damage or experience salinity intrusion through surface and

groundwater;

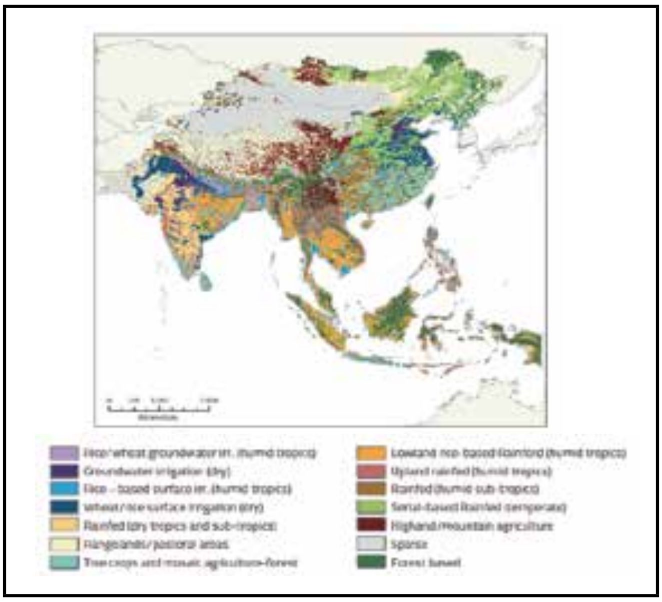
3. Surface and groundwater systems in arid and semi-arid areas, where rainfall will decrease and become more variable; and
4. Humid tropics with seasonal storage systems in monsoon regions, where the proportion of storage yield will decline but peak flood flows are likely to increase.

When carefully reviewed with the major Asian livelihood zones (Figure 4), the aforesaid agricultural systems closely represent the rice and rice-wheat-based irrigation systems, lowland rice based systems, rainfed (dry and humid tropic) and groundwater-based systems. These five zones represent over 70% of Asian population and are responsible for most of Asian food production. Building on this typology, Table 4.3 summarizes options for water interventions to adapt to climate change. The table lists only those livelihood systems where agricultural water management is highly vulnerable to climate change impacts.

WAY FORWARD: MANAGING WATER FOR FUTURE IN ASIA

The issue now is will Asia be able to meet its future water requirement? While water is not a scarce resource in overall terms, its spatial and temporal variation fuels regional scarcity. Overall, the region is relatively well-endowed with water resources: with a total area representing 15 percent of the Earth's land surface, Asia receives 22 percent of its precipitation and produces 28 percent of its water resources. However, water availability per capita is lower than in many parts of the world; its large population means the region has far higher domestic and agricultural water needs than other regions of the worlds.

Figure4. Major livelihood zones in Asia



Source: Khanal, 2014

The large range of climates characterizing Asia generates a variety of hydrological regimes. The region is host to some of the most humid climates giving rise to the major river systems of Asia (the Ganges, Mekong, Indus, Irrawaddy, Yangtze), while other areas have a very arid climate, with closed hydrological systems- there is no additional water available to exploit. As a result, the region exhibits a very uneven distribution of its water resources and water-use conditions. In large part, the hydrology of the region is dominated by a monsoon climate which induces large inter-seasional variations in river flows. On average, the southwest monsoon rainy season, lasting for about four months (June through September in South Asia, May to August in East and Southeast Asia), contributes 80 percent of the total annual river flow. The remaining eight months are dry in much of Asia. In this situation, average annual values of river flows are a poor indicator of the amount of water resources available for use.

Table 4.1. Water management options in the face of climate change in Asia

Systems	**River basin/ geographic area**	**Climate change drivers**	**Adaptability**	**Response options**
Rice or rice wheat- based surface irrigation	Large surface irrigation systems fed by glaciers and snowmelt such as those found in the Indo- Gangetic Basin, Mekong Basin and north China	Increased flow for a few decades followed by reduction in surface and groundwater, changes in runoff and peak flow	Low to medium	Increase water storage, demand management, groundwater management, drought and flood management
Rainfed low land rice-based systems	Mekong, Ganges and Brahamaputra deltas; lowland rice farming in these basins in South and Southeast Asia	Flooding, salinity (in coastal areas) damage to infrastructure, expected increase in groundwater recharge	Medium to high	Flood management, conjunctive use, atomistic irrigation, small-scale irrigation

Rainfed dry tropics and subtropics; humid subtropics	Central Indian Plateau, northeast India, north central part of Southeast Asia	Increased drought and flooding	Medium	Increase storage in Indian subcontinent, groundwater recharge and atomistic irrigation
Cereal-based (rainfed)	Eastern China	Variable rainfall, drought, flooding	Medium	Groundwater recharge, drought management
Groundwater based systems	Western India, northeast China	Increased incidence of drought	Medium	Groundwater interventions, participatory management

Managing this seasonal and internal variability of rainfall will therefore be crucial to secure water availability for future agricultural growth and economic development in Asia. These variability will be even more severe in the face of climate change impacts in coming decades. The future trend will be that of increased demand and reduced and variable supply.

This needs to be addressed through new practices and investments applying both hard and soft measures. The hardware measures, mostly targeted at supply enhancement, are infrastructure-based, e.g. dams, water transfers, new tube wells and flood levees. The soft solutions are directed at demand management, including ecosystem-based measures. The choice of options depends on how different production systems are going to be affected and may involve combinations of several measures, both hard and soft.

It would require a multi-layered water management approach to ensure water security in future that boost water productivity, conserve water resources, preserve eco-system services, maintain water quality across agriculture, fishery and livestock and facilitates multiple water use and their supply chains and adopts bottom up participatory process in resource management. Water storage, both surface and sub-surface will be critically important because of its importance in addressing variability. Equally important is to increase the use of green water and recycling and reuse of grey water while managing the demand in blue water. Such a multi-layered approach would also require changes in policy and institutions, and increased capacity of the local water management institutions.

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7.2 IMPACT OF EARTHQUAKE ON WATER RESOURCES IN SELECTED EARTHQUAKE HIT AREAS

SOMNATH POUDEL[1] AND ANJU AIR[2]

BACKGROUND

Natural hazards such as earthquake, flood, landslide, debris flow and thunderstorm has larger impact on physical, social and economic activities. Among these, earthquake has been notoriously devastating Nepal since time immemorial. Nepal is ranked on 11th position in terms of relative vulnerability to earthquake. The first recorded earthquake was of 1255 A.D. which killed one-third population of Kathmandu Valley. Since then, a number of earthquakes have been reported in the history of Nepal. The earthquake of M 7.8 was recorded by National Seismological Centre (NSC), near Barpak of Gorkha district, about 76 km northwest of Kathmandu on 25th April 2015 (Saturday) at 11:56 Nepal Standard Time. Due to its epicenter at Gorkha, the Earthquake is named as 'Gorkha Earthquake'. The main shock was followed by hundreds of aftershocks further damaging previously shaken buildings. This also caused terror and anxiety among the survivors. There were over 8,790 deaths and 22,300 injuries affecting the lives of almost one-third of population in thirty-one districts of Nepal. The Gorkha Earthquake resulted from unzipping of the lower edge of the locked portion of the Main Himalayan Thrust (MHT) fault. The Earthquake ruptured a 140 km long segment of the fault (Galetzka et al., 2015). National Planning Commission (NPC) estimated the value of total damages and losses equivalent to one third of the Gross

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Domestic Product (GDP) for Fiscal Year 2013- 2014 (NPC, 2015). Annual Disaster Statistical Review (ADSR) has listed the Gorkha Earthquake as the costliest natural disaster in 2015 costing US$ 5.7 billion loss to Nepal's economy (Guha-Sapir D, 2015).

In developing countries, the impacts are more documented in terms of physical, social and economic sectors. However, in developed countries the impacts are more studied on species, ecosystem and landscape levels. For example, the impact of Chi-Chi earthquake on Chenyulan River watershed ,Taiwan, was evaluated to identify the occurrence of landslide and debris flow (Lin et al., 2004). Likewise, the long term impacts of earthquake on the structure and dynamics of conifer and hardwood forested landscapes in New Zealand have been identified (Wells, Duncan, & Stewart, 2001). Wenchuan earthquake, China in 2008 (M 8.0) caused damage in the ecological environment profoundly and led to the loss of ecosystem services such as water retention, soil conservation and carbon storage. The disturbance to ecosystem services lessened gradually outwards from the epicenter (Wang, Fu, & Xu, 2012). The Wenchuan Earthquake has also caused remarkable impact on the Giant Panda (Ailuropoda melanoleuca) and its habitat (Zhang et al., 2011).

However, the impact of earthquake on water resources have been less studied but widely concerned in Nepal. This paper presents two case studies from Kavre-palanchowk and Kathmandu districts. The study was part of Water and Climate Resilience Program (WACREP) activity of Jalsrot Vikas Sanstha (JVS/GWP Nepal) in 2016. The earthquake has impacted on water quality and quantity. This study evaluated visible impacts on water resources caused by the Gorkha Earthquake. The studied water sources include stone spouts ([3]Dhungedhara), rivers, ponds ([4]Pokhari), springs ([5]Muhan) and dug wells ([6]Inar-Kuwa) in the study locations.

The main objectives of the study were (i) to assess the status of water resources (water quantity and quality) through visual observation (ii) to explore the associated impacts due to loss of water resources and (iii) to identify available protective measures/disaster preparedness with regard to water resources.

CASE STUDIES

KAVRE-PALANCHOWK DISTRICT

Kavre-palanchowk is one of the districts severely hit by the Gorkha Earthquake. The district has an area of 1,396 Sq. km. and a population of 381,937. The literacy rate of the district is 69.8% with the 58.7% economically active population. The total households are 72,846 and

3 Dhungedhara- Artificial channel made for easy collection of water made up of crafted stones.
4 Pokhari- An excavation or structure created in the ground by digging or drilling to access groundwater.
5 Muhan- is a place where groundwater naturally emerges from the Earth's subsurface in a defined flow. It discharges fresh groundwater onto the surface.
6 Inar-Kuwa- A shallow hole dug down into the water table for accessing water.

85.5% of local people have safe drinking water facilities (CBS, 2011). It is situated in mid-hilly area having subtropical climate with elevation range of 280m-3018m. It is bordered by Ramechhap to the east and Dolakha & Kathmandu to the west, Sindhupalchok to the north and Sindhuli & Makwanpur by south. It has 8 Rural Municipalities (RMs) and five municipalities including newly declared Namobuddha (earlier Dapcha-Kashikhanda) Municipality. The study area is part of the Ward No. 8 (comprising of five wards 2,6,7,8 & 9 from previous Daraune Pokhari VDC) of Namobuddha Municipality (Fig.4). The water sources in Kavre-palanchowk district has been categorized in Table 1.

Table 1: Sources of water in Kavre-palanchowk District (CBS, 2011)

S.N.	Sources of water	Percentage (%)
1	Tap water	79.1
2	Tube well	0.27
3	Covered well	6.18
4	Uncovered well	6.45
5	Spout	5.90
6	River/stream	0.67

The table shows that only 79.1% of the population has access to taped water supply while 0.27% of population uses tube well water, 6.18% uses covered well water, 6.45 % uses spout water and 0.67% uses uncovered well (Table 1) (CBS, 2011).

Figure 1: Highlighting the epicenter (Gorkha District), Kathmandu and Kavre-Palanchowk Districts

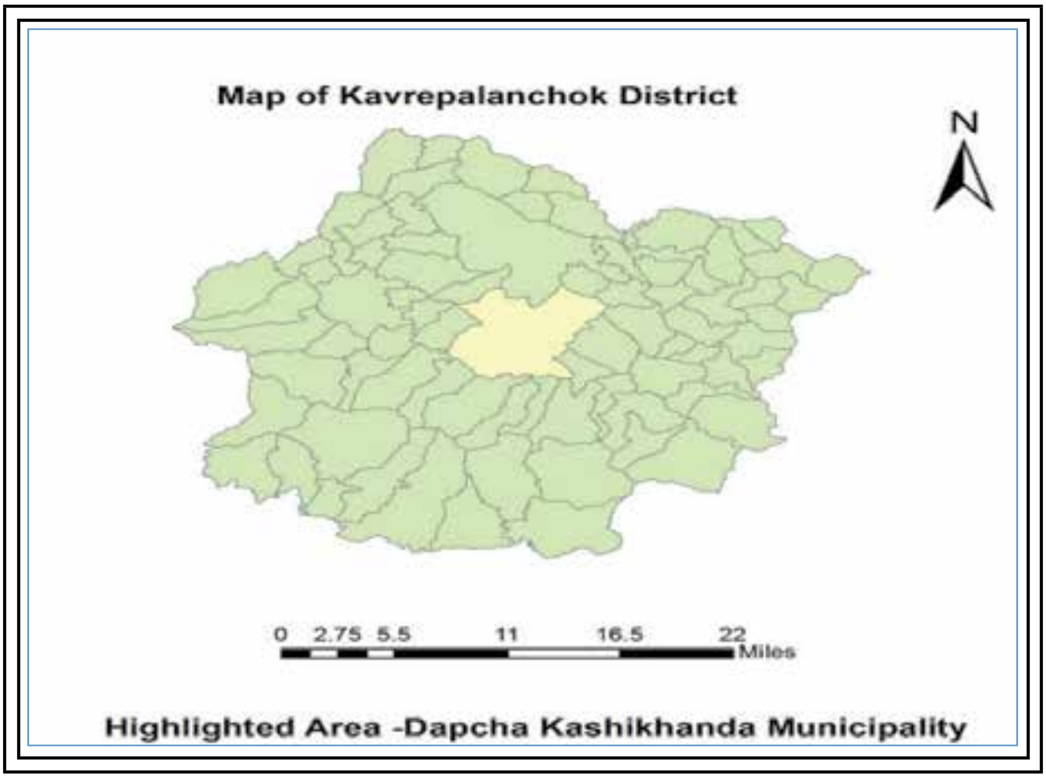

Figure 2: Map of Kavre-palanchowk Highlighting Dapcha-Kashikhanda Municipality, Kathmandu

Namobuddha is a recently declared municipality by merging Dapcha-Kashikhanda Municipality, Kanpur Kalapani VDC and 3 wards of Shyampati Simalchaur VDC of Kavre-palanchowk district. Focus Group Discussion (FGD) was done in this Municipality to identify the impact of earthquake on water resources and associated impacts with the help of checklist. The information on status of water resources in water level was obtained through the checklist. Stakeholders consisting of representatives from Water Users Association (WUA), members from Women's Group, Youth Club and Chairman and members of Daraune Pokhari Conservation Committee (DPCC) had been consulted to obtain data on water quality, quantity, associated impacts of water scarcity and protection measures for water resources.

The information on level of water sources in Namobuddha Municipality, Ward 8 (Ward No. 2, 6, 7, 8 & 9 of previous Daraune Pokhari VDC) have been described in Table No.2. Locals confirmed that the water sources have been drying-up in this Municipality since last 5-10 years. Although, the associated reasons are many, earthquake is substantially responsible for drying up of water sources in the study areas. The study found that almost twenty water sources (stone spouts, wells, ponds and springs) out of thirty-five have been dried after earthquake in the study area. Checklists were used for identifying water resources dried before and after the Earthquake. While, the water sources with stable water supplies are negligible (Fig. 3).

Table 2: Water Level Status of Namobuddha Municipality (Ward No. 8), Kavre-palanchowk District

S. N.	Name of Water Resource	Type of Water Resource	Completely Dried		Increased water level after earthquake	Decreased water level after earthquake	Stable Water Level
			After Earthquake	Dried before Earthquake			
1	Kalikuwa	Well				√	
2	Nursery Kuwa	"	√				
3	Gotedanda Ban Kuwa	"	√				
4	Phalate Kuwa	"	√				
5	Thuldhara Muhan Mathillo	Spring	√				
6	Thuldhara Muhan	Spring				√	
7	Pandherawanko Kuwa Upstream	Well	√				
8	Pandhera wanko Kuwa	Well		√			
9	Kafalbote kuwa	Well	√				
10	Khadkole Dhara	Stone spout	√				
11	Jaruwapani Muhan	Spring	√				
12	Nattepani Dhara	Stone Spout	√				
13	Jimalbote Muhan	Spring		√			
14	Jogipani Kuwa	Well	√				
15	Simpokhari	Well	√				
16	Kapikatte Muhan Upstream	Spring				√	
17	Kapikatte Muhan Downstream	Spring			√		
18	Dhap Dhara	Stone Spout	√				
19	Sisnepani Kuwa	Well					√
20	Saheleria Dhara	Stone Spout	√				
21	Simkhoria Dhara	Stone Spout					√
22	Bhundanda Muhan	Spring			√		
23	Pandhero Kuwa	Well	√				
24	Bhutkhoriya Kuwa	Well	√				
25	Maplekhor Muhan	Spring	√				
26	Khichha Kuwa	Well	√				
27	Bhalayo Kuwa	Well	√				
28	Pithok Kuwa	Well	√				
29	Sapaneshwori Muhan	Spring			√		

Water flow in Thulodhara has decreased substantially after the earthquake. Thulodhara is the main stone spout in Namobuddha Municipality area. The locals from surrounding areas also collect water from Thhulodhara. The main usage is for domestic purpose. The Kalikuwa pond has been releasing less water while Jimalbote spring has been releasing more since the Earthquake.

The water levels at Simpokhari and Jogipani kuwa have been completely dried after the earthquake. There is no stable supply of water in the area so locals have to depend upon the neighboring water sources. Sisnepani Kuwa and Simkhoria Dhara have stable water supplies while Kapikatte Muhan upstream has decreased water flow in contrast to Kapikatte Muhan downstream. Bhundanda Muhan has increased water flow while Pandhero kuwa and Bhutkhoriya is completely dried. Bhalayo kuwa has stable supply of water.

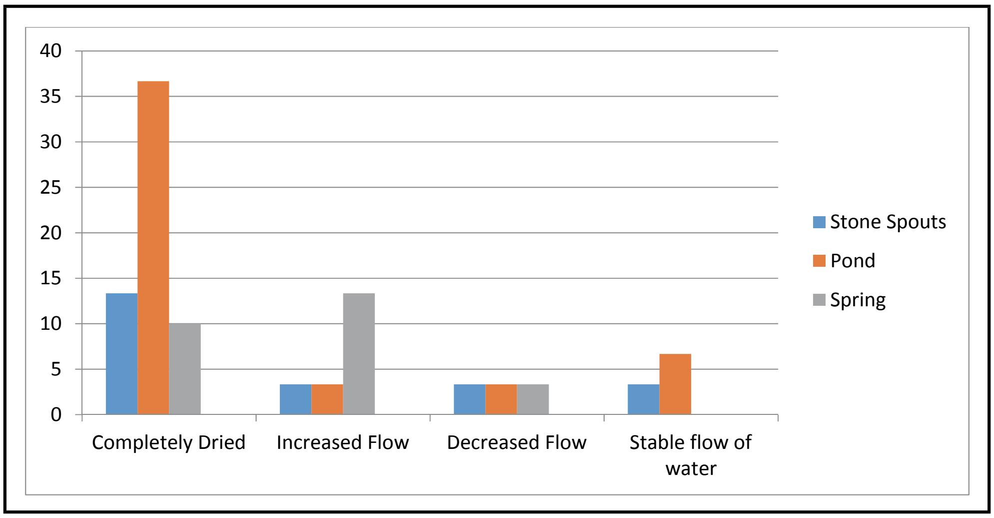

Figure 3: Status of water level in water resources, Namobuddha Municipality, Kavre-palanchowk

Ponds have been adversely affected by the Earthquake in Namobuddha Municipality. Most of the ponds have dried up after earthquake in Kavre-palanchowk while the water level of some ponds has decreased. The study showed that almost 36% of the ponds and 14% of stone spouts have been completely dried. Similarly, almost 14% springs got increased water flow (Fig.3). Previous studies have also described significant impact on water sources from Patlekhet, Chandenimandan, Mahadevsthan, Jyamdi, Koshipari, Mangaltar and Nala villages of Kavre-palanchowk district.

Locals reported few changes in the quality of water resources. The turbidity was high after the immediate days of earthquake. High turbidity has been seen at Bhoondanda water source of the Municipality after the Earthquake. The reason behind this could be the movement in the water table.

Haleti Khola in Kavre-palanchowk had increased water discharge for some time which didn't last for long. Thuldhara and Sangachowk in the Municipality got increased flow of water immediately after the Earthquake but decreased afterwards. These alterations can be termed as 'pseudo-changes'.

KATHMANDU DISTRICT

Kathmandu district is the most populated district in Nepal (Figure 3) with the population of 1,744,240 and 436,344 households in the area of 49.45 km^2. The population density is 4,416 per sq. km. The literacy rate of the district is 86.3% with 45.5% of economically active population. Only 62% of the population has access to taped water supply while 8.03% of population uses tube well water, 6.68% uses covered well water, 4.42 % uses spout water and 1.28% uses uncovered well (Table 3) (CBS, 2011). Kathmandu valley has been going through huge water crisis.

Table 3: Sources of Water in Kathmandu District (CBS, 2011)

S.N.	Sources of water	Percentage (%)
1	Tap water	62.0
2	Tube well	8.03
3	Covered well	6.68
4	Uncovered well	1.28
5	Spout	4.42
6	River/stream	0.34

Some water sources located at Kirtipur, Chandragiri and Dakshinkali Municipalities of Kathmandu district were studied. Kirtipur municipality is situated almost 7 km south-west of Kathmandu Metropolitan City (KMC). The altitude ranges from 1284m to 1524m above sea level. It has 19 wards covering 14.76 km^2 areas. It is encircled by Bagmati River in the East, Chandragiri Municipality in the West, KMC in North and Dakshinkali Municipality in the South. Chandragiri Municipality has a total population of 85,195. Matatirtha water spouts have been studied in this Municipality.

Dakshinkali Municipality is famous for religious tourism and recreational activities with historical temples and beautiful landscapes. The Chandra- Jyoti Hydropower Plant (500 KW) constructed in 1908-11 is the second oldest in Asia. It was also visited during the field visit. Saatmule and Sheshnarayan springs are the source of this hydropower plant and it has been declared as 'Living Museum' by the Government. At present the hydropower reservoir water is basically used for water supply in Lalitpur Sub-metropolitan City. Additional distribution of water by Kathmandu Upatyaka Khanepani Limited (KUKL) at Pharping also has affected in the quantity. Chandra-jyoti reservoir sources are presently in multi propose use (drinking, irrigation and hydropower) although, the plant was primarily established for hydropower generation in 1911 A.D.

Bagmati River is the largest river in Kathmandu Valley comprising 7 rivers and rivulets as its tributaries. It originates from Baghdwar, northern part of Kathmandu. The river is a part of Bagmati River Basin (BRB). The basin has a total catchment area of 3,750 sq. km. and total length of river in Nepal is 220km **(**BRBIP, 2016)**.** The BRB is divided into sub-basins. The area draining into the Karmaiya station is called upper watershed area and below

Karmaiya station, is called the lower watershed area. The upper watershed area which is 2720 km^2 covers the Kathmandu valley as well (Fig. 4) (Sharma & Shakya, 2006).

The average annual rainfall in the basin is 1900 mm of which more than 80% occurs in monsoon season. This is one of the most populated basin with a population density of 741 person/km^2 (Pandey, Babel, & Kazama, 2009).

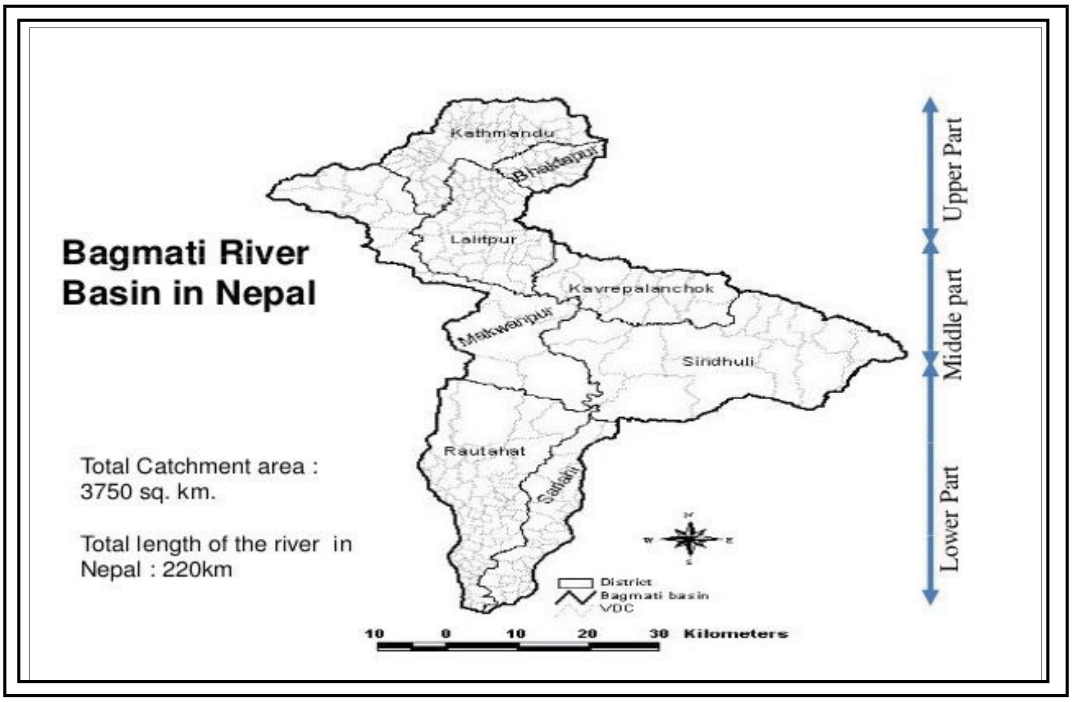

Figure 4: Bagmati River Basin (BRBIP, 2016)

The River is victim of massive urbanization, high population growth and unmanaged waste disposal. The untreated sewage is directly discharged into the river. The river is taken as cleanser of urban waste. This has also affected the aquatic ecosystem in the river. Some researchers have declared it as 'biologically dead'. The direct impacts of these activities can be seen in quality and quantity of water resources around Kathmandu valley (BRBIP, 2016).

Unlike Namobuddha Municipality, most of the stone spouts have dried up in the Chandragiri, Dakshinkali and Kirtipur Municipalities of Kathmandu District. The Matsyanarayan pond of Kirtipur Municipality was dry even before the Earthquake. The drastic rate of increment in drying up of water sources could also be the impact of urbanization and population growth. There were no changes observed in the level of Bagmati river water after the Earthquake.

The Key informants informed that the discharge and turbidity at Matatirtha, Saatmule, Naumule and Sheshnarayan spouts were quite high immediately after the Earthquake but unfortunately, it faded in due course of time. Matatirtha stone spout is also a source of water for local people as well as tanker water supply to the cities.

SOME ASSOCIATED IMPACTS

Locals of the Namobuddha Municipality informed that the agricultural activity and animal husbandry has been affected by the water scarcity. People have shifted towards intermittent water demanding crops. Locals depend highly on farming activities, mainly vegetable farming, for livelihood, which is affected by dearth of water. More than 50 hectare of land remained barren in the year 2016 in Namobuddha municipality alone. Cultivation of paddy and wheat has been severely affected in the Municipality. Although, canals/ irrigation structures in the areas were not damaged by earthquake. However, the irregular water flow has caused enormous problem for farming. Locals have to compromise with their water requirements.

Nationwide, the Earthquake destroyed irrigation canals in 31 hilly and mountain districts along with an estimated 1,877 number of small and medium scale farmer managed irrigation schemes. PDNA reported damages on the infrastructure and functionality of about 290 of 1,877 irrigation schemes by the earthquake (NPC, 2015).

Local people have to travel distant areas for fetching water. Besides this, social harmony has been deteriorating due to occasional conflicts led by water shortage.

Farmer Managed Irrigation Systems (FMIS) in Dakshinkali Municipality has been affected due to water scarcity. Kudaliphat in Pharping area receives irrigation water from Sheshnarayan spring. Similarly, Saatmule spring irrigates Simlephant. There is an agreement with the hydropower plant for the supply of water during the planting season. Although, the irrigation is limited to one month in a year, it has huge impact on local agricultural production. These FMIS have been affected by water scarcity and local agricultural production has been affected.

There was huge conflict caused by turbidity of water at Saatmule spring in Dakshinkali Municipality. People were unsatisfied with water quality distributed by KUKL. Sheshnarayan Pond is a center of belief for Hindu devotees. The water is considered holy and pure by Hindu believers. The decreased water level in the pond has also decreased the number of visitors. The aquatic diversity of Sheshnarayan pond is also affected by shortage of water. The quantities of fishes have been noticeably reduced after the Earthquake.

PROTECTIVE MEASURES/DISASTER PREPAREDNESS

Unaware of the natural hazards, locals are relying on bottled and canned water rather than conserving the water resources in sustainable way. Even, they lack self-realization to protect water sources from natural disasters. They have not been adopting preventive measures from disasters such as earthquake, landslide, floods and soil erosion

Despite these, in Namobuddha Municipality, a committee is formed for the protection of Daraune-Pokhari. The Daraune-Pokhari Conservation Committee (DPCC) has conserved Daraune-Pokhari with the aid from the Municipality and local people. Villagers believe that Daraune-Pokhari is the heart of water resources in this area which acts as a recharge pond and conservation of this will release more water in the vicinities. This has been seen important for the protection of associated water resources in the area.

Fortunately, BRB is being managed by HPCIDBC under Ministry of Urban Development, Government of Nepal. Under Bagmati River Basin Improvement Project (BRBIP), two dams will be built in the downstream of Dhap within Shivapuri Nagarjun National Park with a storage capacity of 850,000 m^3 and Nagmati Dam with the potential capacity of 8 million m^3. It has also a lucrative plan to install rain water harvesting structures to 2500 households for providing 45,000 m^3 of safe water supply and recharge of (135,000 m^3) groundwater. Another important part is to stabilize 12.5 ha of outward sloping agricultural land prone by community interventions to increase water retain and reduce soil erosion. BRBIP has planned community afforestation, agro-forestry, agri-horticulture and agri-silviculture in degraded as well as privately owned outward sloping agricultural lands. This is important as the outward sloping agriculture lands are considered as the source of runoff and erosion. The sloping agriculture technologies such as contour farming, regulated water draining channels cropping with fast growing fodder, shrubs, fruit trees and grasses having low shading effects to the undergrowth crops will increase the stability of soil (BRBIP, 2016). This project is intended to increase the water security in Kathmandu valley.

Not only this, the project has planned to establish system for integrated and participatory river basin management, improve river bank environment in urban areas, increase water availability in the basin during dry season and improve watershed conservation.

DISCUSSION

In both districts, the trends of drying-up of water resources have been increasing since last decade. The pattern has increased after the Gorkha earthquake. Mostly, pond, stone spouts, river and wells have been affected. These water resources are the primary sources of drinking water and irrigation for the local people. In spite of more than 50% coverage of tapped water supply in both districts, locals prefer traditional water sources for drinking purpose. A rationale behind that could the pure and clean water with relentless water accessibility.

The drying-up of water resources can also be linked with increasing water demand which pressurized the water sources in the vicinities. The rapidly increasing population density in the Kathmandu Valley has been forcing people to find alternative sources of water as the tapped water supply is once in a week for few hours only. The Valley is the most populated urban region and one of the fastest-growing urban areas in South Asia. Kathmandu holds 24% of the total urban population of Nepal (Rimal, 2011). Surface water resources are futile due to contamination. The only usable groundwater is also being over-exploited. The ownership and monitoring institutions can be blamed for this. The property owner owns and uses the groundwater but never tries to manage it. There exists an agency, Groundwater Development Resource Board under Ministry of Irrigation, for the management of groundwater but it lacks frequent activities for monitoring and evaluation.

Besides these, earthquake has a short and long-term impacts on water resources. It generates hydrological effects ranging from instantaneous to more sustained post-seismic changes in spring flow, river discharge and groundwater piezometric levels (Cox et al., 2012). Changes in the level of river water and spring flow are mainly caused because of the expulsion of water from upper or middle crust due to elastic compression or near surface permeability enhancements. Earthquake is also responsible for alteration of hydrology of the region for several years after the earthquake (Rojstaczer, Wolf, & Michel, 1995).

There have been reported several changes in the physco-chemical parameters of the water induced by earthquake. For this study, the observed physical parameter was turbidity of the water which can be caused by leaking tube wells and septic tanks (Blaikie, Cannon, Davis, & Wisner, 2014) during the immediate days of earthquake. Usually, wastes and silts are washed into waterways, increasing the concentration of suspended sediment and causing impacts on water quality. Potter et al. (2015) found low concentration of dissolved oxygen, high ammonia concentrations, and an accumulation of contaminant in river bed sediments in Canterbury earthquake (Potter, Becker, Johnston, & Rossiter, 2015). Such researches have not been carried out in Kathmandu and Kavre-Palanchowk districts.

The level of water fluctuated in the water sources as per the movements of seismic waves in the study areas. This may have caused pseudo-changes in the quantity of the water. The recovery of water-level may take minutes to months, depending on hydro-geological conditions of the confining layers and the distance from the fault (Chia, Wang, Chiu, & Liu, 2001). However, fracturing of solid rocks, aquifer deformation, and the clearing of fracture-filling material are equally responsible for changes in water level. Considering the fact that, detectable stream flow changes occur in areas within tens to hundreds of kilometers of the epicenter, (Montgomery & Manga, 2003) there have not been recorded any changes in the quantity of the water in Bagmati river. The physical parameter such as turbidity may have changed but unnoticed due to the deteriorated water quality.

Protective measures should be identified to manage the water resources effectively. Such measures should be from local to national level. In study areas, it has been seen that water from stone spouts were flowing regularly but it doesn't have a system to control it. The areas lack storage tanks for further usage of water. Locals also lack the technological information for storing and protecting the water for future use. Water catchments are being invaded by human settlement, agricultural fields and pasture lands. This has high potentiality for contaminating the available sources of springs, ponds and stone spouts.

To manage the water resources, both supply and demand management should be considered. The improvements of the storage capacities, improved irrigation, enhanced operation and maintenance, development of new sources of irrigation water supplies can be considered for supply management. Farm water conservation practices including soil management and conservation tillage practices, runoff control are equally important to minimize the adverse effects of water scarcity in the areas. For the management of demand, the economical, agronomic and technical management can be done (Pereira, Oweis, & Zairi, 2002).

CONCLUSION AND RECOMMENDATIONS

The study concludes that the water sources mostly, ponds, springs, stone spouts and rivers are affected. The turbidity has also been increased after the earthquake. Local people directly depend upon these sources which has impacted their activities. The impacts on agriculture, animal husbandry and domestic usage are noteworthy. Unfortunately, locals have no plan for conservation of these resources besides Dapcha-Kashikhanda Municipality (Namobuddha) in Kavre-Palanchowk and Bagmati river basin in Kathmandu valley. Daraune Pokhari has been conserved by local people. BRB in Kathmandu is being managed under BRBIP for increasing water security which shall enhance the water quantity of Kathmandu valley. Water supply schemes and irrigation systems in the areas are unaffected by the earthquake. The current drying-up of water sources and water scarcity is mainly because of the alteration of water table in the areas.

However, there has been increased trend of drying up of water resources since last 5-10 years. The study on catchment conditions, land use pattern, population growth and urbanization shall highlight more evidence on the actual phenomena. Reuse of available water can lessen the water scarcity. Lack of consciousness for water security & infrastructure management has also worsened the problems of water scarcity.

The study recommends the installation of rain water harvesting, restoration of traditional spouts for ensuring water security in the areas. Furthermore, identification of water stress and water availability shall solve the water scarcity. It is mostly said that there is no problem of water availability in Nepal; the existing problems are due to the socio-economic water scarcity. This type of water scarcity is caused due to lack of information, infrastructures, and coordination and implementation problems. In spite of wide coverage of piped water supply, locals still like to consume water from traditional water sources such as stone spouts, ponds and springs. It's a right time for Nepal to prepare District Water Resources Preservation Plan considering the fact that the country is facing a multitude of natural hazards impacting water use of people. There should also be institutional framework to conserve and monitor these traditional sources.

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7.3 An Appraisal of Environment Management Functions in the Nepal's Municipality: An Illusion

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The aim of this paper is to appraise functions of the Nepalese Municipality on environment management sector. Despite many functions which should be performed by the Municipality, like environmental protection, conservation, irrigation, solid waste management, we specifically analyze whether the Municipalities carry out decisions on Initial Environmental Examination (IEE) and Environmental Impact Assessment (EIA) to avoid adverse impacts on environment. We focus our attention on plantation along the Municipal road sides, setting environment policy and adaptation and mitigation activities of climate change. Also, we examine the funds made available for managing environmental friendly activities in the Municipalities.

INTRODUCTION

Performance appraisal of public sector organizations especially at the local government is always an issue to measure effectiveness in their operations that attracts interest. The reasons are the public services that local government provides (Stevens, 2005, 90). The local government has to perform its various functions e.g. education, health, social security, waste management, including environment management. Without measuring their performance, no one can say that local government is good or bad. In other word, performance appraisal is an instrument for good management (Daley, 1991). The generalized principles of local

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government should follow the rules and regulations and accordingly carry out prescribed functions. These kinds of functions are appraised based on input model or output model or both. The first one ensures the level of performance on the basis of prescribed rules and regulations especially focused on process of its operation. The second one concentrates its attention on its result achieved through the implementation of prescribed functions (Heinrich, 2002). The third model is mixed approach which pays attention on both the processes of its operations and outputs achieved by local government. Whatever the model of its operation, the performance of local governments needs to be examined. In the words of David N. Ammons and Stephen E. Condrey (1991), the performance appraisal of local government is warranty condition. However, there are main problems in assessing public sector performance: identifying the outputs, the absence of prices and the problem of attribution (Stevens, 2005).

Environment management which ensures environmental consideration into the Municipal developmental strategies, programs and project is one the important function of the local government among other. The performance of local government is assessed to what extent local government launches environment friendly activities or maintains environmental indicators within its acceptable level or both.

At present, the environmental condition is worsening due to both human and non-human factors which cause climate change and greenhouse effects in the environment (UN, 2015). As a result, the temperature of earth has increased. When temperature of earth increases, multi-faceted environmental threats are observed. For example, livelihood of animals disturbed. Ecosystem will be changed. Eventually, food chain will be broken. Bio-diversity is changing. Inequality among citizens is widened. The world economy is not remarkably unequal, but also remarkably threatening to the planet itself (IRF, 2013). Therefore, there is great concern on the Cities' Environment because more than fifty percent people lives in urban areas in the world whereas about one-third population in Nepal.

Roughly 50 years ago, scientist and groups of policy makers warned that humanity was on a dramatic collision course as the rapidly growing world economy and population threatened to collide with the planet's finite resource and fragile ecosystems. Since then, efforts to save living planets have been carried out but their effects are not observed as good as suggested because of greenhouse effect. The emission of carbon dioxide and methane, causative agent of green house effect is due to burning of fossils resource and human activities. On the other hand, there is less achievement in using renewable resources to save blue planet.

In this context, activities related to managing environment are crucial to make our environment habitable in global, national and local level. The municipalities are local governmental institutions which take the decision on developmental programs and project. The mandatory provision of LSGA is that Municipalities should keep in consideration and abide by environmental friendly activities when they start developmental programs and project. On the basis of this provision, environment management is one of key performance indicators of the Municipality. This indicator is also linked to grants which is given by central government. Therefore, the main focus of this paper is how decisions which are related to environment management are incorporated in the developmental programs and projects set by the Municipalities in Nepal.

The local environment would not be a habitable without implementation of environmental friendly activities at the local level especially the Municipalities. The results achieved through assessing the implementation process of environmental friendly activities would be valuable insight to take decision while setting developmental activities at the local level of Nepal. The paper gives concrete picture of IEE and EIA implementation at the local level, plantation and fund made available for environmental friendly activities. Accumulative inter-linkage of these variables of environment management traces gaps between prescription of municipalities and their implementation. This paper supports to find out municipalities' commitment and dedications for the sake of making habitable environment at the local level of Nepal.

METHODOLOGY OF THE STUDY

For the study purpose, 16 municipalities of which 8 old and 8 new municipalities, were chosen conveniently because of the data availability. The assumption for choosing these old (Dhankuta, Dharan, Itahari, Khadbari, Bhaktapur, Lalitpur, Madhyapur Thimi and Bidur) and new municipalities (Attaria, Bhajani Trishakti, Ghodaghodi, Parasuram, Gokaneshwor, Kageshowri Manahara, Sankharapur and Tokha) was to compare the performance level of both old and new Municipalities. Those municipalities which were established in and around 1990s are considered old whereas the municipalities established in 2013/14 are new municipalities. These municipalities cover Eastern, Central and Western part of Nepal and ecologically both the Terai and Hill part of Nepal. The checklist prepared by Local Fiscal Commission of Nepal to conduct Minimum Condition Performance Evaluation (MCPM) was used to collect primary information from respective municipalities. The checklist highlighted on IEE and EIA, plantation along the Municipal Roads, setting environmental policies, activities to reduce adverse impact of climate change, installation of environmental section in the Municipalities and fund made available for environment management. Required information was extracted from the minutes of the Municipalities, budget book, and account sections.

FINDINGS

Municipality is one of the local governmental institutions in Nepal. As per Local Self-Governance Act, 1999, the Municipality has to discharge the functions like financial management, physical development, environment management, health, education and sports development, cultural development, social welfare, industry and tourism development. The detailed functions related to environment management are as follows

(LSGA, 1999, 79p). The Municipality has to preserve rivers, stream, ponds etc and utilize them properly. The Municipality has to carry out irrigation plans within the Municipal areas. Likewise, the Municipality controls the possible river-cuttings, floods and soil erosion in the Municipal area. The Municipality has to assist and launch the environment protection programs while implementing the municipal developmental projects and program. Besides, the Municipality protects the forest, vegetation and other natural resources within the Municipal area. It should carry out and manage the acts of collection, transportation and disposal of garbages and solid wastes. Finally, the Municipality should carry out sanitation programs in the Municipality area.

To materialize these environment management functions and duties, the Municipality has to perform its functions as per Environment Protection Act, 1997 and its Regulation 1998. As per these acts and regulation, the Municipality should carry out IEE[3] /EIA[4] of proposed developmental project which is worth above five hundred thousand. In case of landfill side construction, there must be detailed report of IEE & EIA to avoid and mitigate the impacts on environment management.

Local Fiscal Commission of Nepal has set the standards to evaluate the environment management at the Municipality which includes, study reports of IEE and EIA, plantation along the Municipal roads to maintain greenery in the Municipal areas, setting environment programs, reducing or avoiding negative impacts of climate change, installation of environment sections to look after environment management and making available funds to carry out environmental managerial functions.

Table: 1: Environment management in Old and New Municipalities

Municipalities	a. IEE & EIA	b. Plantation	c. Env. Program	d. Climate Change	e. Env. Section	f. Special Funds
Old Municipalities						
1. Dhankuta	✓	✓	✓	✓	✓	✓
2. Dharan	✓	✓	✓	✓	✓	✓
3. Itahari	✓	✓	✓	✓	✓	✓
4. Khadvari	✓	✓	✓	X	✓	✓
5. Bhaktapur	X	✓	X	X	✓	✓
6. Bidur	X	X	X	X	✓	✓

3 Initial Environment Examination means a report on analytical study or evaluation to be prepared to ascertain as to whether, in implementing a proposal, the proposal does have significant adverse impacts on the environment or not, whether such impacts could be avoided or mitigated by any means or not.

4 Environment Impact Assessment means a report on detailed study and evaluation to be prepared to ascertain as to whether, in implementing a proposal, the proposal does have significant adverse impacts on the environment or not, whether such impact could be avoided or mitigated by any means or not.

7. Lalitpur	X	X	✓	X	✓	✓
8. Madhypur Thimi	X	X	X	✓	✓	✓
New Municipalities						
1. Attaria, Kailai	X	X	X	X	X	X
2. Bhajani Trishati, Kailali	X	X	X	✓	X	X
3. Ghodaghodi,	X	X	X	X	X	X
4. Parasuram, Dadeldhura	X	X	X	X	X	X
5. Gokarneshowr	X	X	X	X	X	X
6. Kageshowri Manahara	X	X	X	X	✓	X
7. Sankharapur	X	X	X	X	X	X
8. Tokha	X	X	X	X	X	X

Note: "✓" refers to YES whereas "X" denotes NO

Source: Field study, 2017

The field study shows that there are four study reports of IEE and EIA in old Municipality. There are no study reports in the rest of old as well as new Municipalities. Likewise, five old Municipalities planted trees along the Municipal road side whereas rest of the old municipalities did not. Besides, the environmental programs are carried out by five old municipalities only. Launching climate change adaptation and mitigation activities are carried out by three old municipalities and one new municipality. Installation of environmental section and allocation of fund for environment management have been carried out by almost all old Municipalities. The field study shows that environment management functions are somewhat carried out by old Municipalities than the new Municipalities.

DISCUSSIONS

There are questions how these old and new municipalities carried out IEE/EIA. Are IEE and EIA reports implemented to mitigate negative impacts on environment due to developmental projects and program? How many of the planted trees have survived along the Municipal road? How are the set environmental programs reflected in developmental program and project? Have the installed environment sections played crucial role to manage environment within the Municipal Area? Is the funds allocated for environment management used for environment management in the Municipal areas?

Initial Environment Examination (IEE) and Environment Impact Assessment(EIA)

As per Environment Protection Act, 1997, a proponent who is desirous of implementing any proposal shall have to submit such a proposal accompanied by the report on IEE or EIA of the proposal to the concerned agency for the approval. Environment Impact Evaluation Guideline- 2072 specifies the objective of EIA which are to integrate project cycle to environmental aspects; to identify and evaluate impacts of project proposal operation on environment; to mitigate and minimize adverse impacts on environment due to proposed project; and to understand the concerns of stakeholders and settle dispute if there is.

The Evaluation Guideline suggested the strategies to minimize adverse impacts of proposed proposal. They are implementation of health education program and launching awareness program in the affected areas. Similarly, it has suggested that the design of proposed project can be changed. Further, it has suggested to install pollution control equipment, treatment plant for water purification in the affected areas. Besides, there are rehabilitation activities for damaged natural resources, resettlement for displaced settlement, and compensation for affected people.

Old Municipalities i.e. Dhankuta, Dharan, Itahari and Khadbari examined adverse impacts while they implemented developmental projects in their respective areas. From field observation, it revealed that those Municipalities had no mechanism to monitor and evaluate whether contractor implemented the preventive measures for mitigating adverse impacts on environment. These reports of IEE were prepared just for compliance of Environment Protection Act, 1997. The basic spirit of act is to create habitable environment within Municipal area. There is no mechanism to monitor environmental situation within the area. On contrary, the rest of both old and new Municipalities did not care about the adverse impacts when they launched developmental projects and programs eventhough they had allocated budgets worth more than millions of Rupees. Despite mandatory provision to prevent and control pollution within Municipality area, almost all Municipalities are found having polluted air , sound and are dusty which cause significant adverse impacts on environment. These are hazardous to public life and people's health.

Plantation

Out of sixteen Municipalities, only six old Municipalities have planted trees along the road side. The main purpose of plantation is to maintain greenery in the Municipal areas. Dhankutta Municipality planted 1000 plants on landfill side. Dharan Municipality also planted 400 plants in ward no 23 along the road side. Likewise, Itahari Municipality planted nearly 1000 plants in East-West highway. Khadbari Municipality also planted trees in Pathadake and Tumlintar road. However as observed, no efforts were made to up-keep the trees thus planted. The responsibility of the Municipality is to protect them and allow growing so that greenery is maintained. Municipality planted trees and left them haphazardly. The result is wastage of limited resources. Rest of eleven both old and new Municipalities did not bother to plant trees eventhough it was mandatory task.

Setting environment conservation policy

Local Self-Governance Act, 1999 mandated local bodies to prepare environment conservation policy on the basis of local need and aspiration. It paves the route to identify local resources and utilize them for benefit of the people. This also takes consideration of local factors that has direct impact on environment to make environment conservation policy implementable. From the field study, it showed that only five old municipalities set own environment conservation policy while the rest 11 Municipalities did not do so. However, the environment conservation policy is questionable on the part of its implementability. The employees of municipality do not know its features and protocol of implementation. None of the projects takes it into consideration seriously. There are landslides, floods, fire in jungle, over exploitation of natural resources. These kinds of activity cause serious threat to the environment. The conservation aspect of environment is found as a neglected area of the Municipality.

Climate change

Climate Change Policy 2011 aims to establish a Climate Change Centre as an effective technical institution to address issues of climate change and also strengthen existing institutions. It also stresses to implement climate adaptation-related programs and maximize the benefits by enhancing positive impacts and mitigating the adverse impacts. Likewise, it also sets objective to reduce Green House Gas emissions by promoting the use of clear energy, such as hydro-electricity, renewable and alternative energies and by increasing energy efficiency and encouraging the use of green technology. Moreover, the policy aims to enhance the climate adaptation and resilience capacity of local communities for optimum utilization of natural resources and their efficient management and to adopt a low-carbon development path by pursuing climate resilient socio-economic development. Finally, it focuses on developing capacity for identifying and quantifying present and future impacts of climate change, adapting to climate risks and adverse impacts of climate change and improving the living standard of people by maximum utilization of the opportunities created from the climate change-related conventions, protocols and agreements.

The Climate Change Policy 2011 highlights on low carbon development and climate resilience through adopting a low carbon emissions and climate-resilient development path for sustainable socio-economic growth. It stresses on expanding the scope of carbon sequestration through scientific management of the forests, formulating and implementing land use plans and controlling deforestation and also reducing GHG emissions through additional development and utilization of clean, renewable and alternative energy technologies and formulating and implementing plans to address adverse impacts of climate change. The policy also pays attention to provide incentives to develop appropriate technology, its transfer and utilization for reducing the emissions of air pollutants at source that increase the atmospheric temperature and encouraging low carbon emission by providing financial and technical support and incentives.

Climate friendly natural resource management can be achieved not only by developing and implementing a scientific land use system but also by proper utilization, promotion, conservation of forest resources as a means of alternative livelihoods. The adverse impact of climate change can be reduced by the conservation of forest and soil. Other activities are clean energy, protection of water sources and environmental sanitation.

Climate change is sensitive and directly affects the economic growth and development of the country (CDKN, 2017). Out of 16 Municipalities, only four old Municipalities launched climate change adaptation activities. For example, to reduce adverse impact of climate change, Dhankuta Municipality organized drawing competition in 10 local schools, speech competition in seven schools, and awareness campaign. Likewise Dharan Municipality planted trees at Shardu Water Resource catchment area. It also trained locals to make smokeless oven at Ward no 26 & 22. Besides, the Municipality banned plastic bag in the Municipal area. Similarly, Itahari Municipality planted trees in open land. It established huge nursery to prepare small plants for plantation. It has also protected wetland and made recreation centre. It made a big pond in office area as well. Lastly, Madhyapur Thimi Municipality installed water purification plant, operated bio-gas plant, constructed three parks and planted trees, organized awareness program for climate change and adaptation, and prepared land use map.

Environment Section in Municipality and Special Fund

Environment section was established in nine municipalities out of the 16. These were eight old Municipalities and one new Municipality. The section chief did not know what to do for the betterment of environment. This is the tragedy. Eight old municipalities allocated fund for environment management. They have opened bank account as well.

CONCLUSION

From input model perspective, the Municipality has fed environmental friendly inputs. As per law, IEE and EIA have to be carried out to mitigate adverse impacts caused by launching developmental projects and program. Likewise, Municipality should bring into effect not only adapting to climate change, but also setting environment policies and program locally. To make these inputs functional, the Municipality should make fund available. Study revealed that the inputs for environment management resulted in t some effect, but lacked assessment as to how much these functions affected the Municipal area. From output models perspective, none of the Municipalities cared about the evidence based environmental conditions. Thus, environmental management is found as neglected area in the Municipality. They did not know what to do for environment management. In reality, they have not studied the act, rules, regulation and policies prescribed by government of Nepal. Very few municipalities formulated their own environmental policy. This is only eye wash because it has mandated for Performance Evaluation of Municipality. Municipalities considered the IEE and EIA as a barrier for the project implementation. So they only prepared report of IEE and EIA for the sake of legal compliance. They remain to realize it for environmental sustainability. None of Municipalities bothered for its implementation. Those functions which were carried out by the Municipalities were only for scoring in MCPM. None of Municipalities carried out protection and safe guard activities for plants which they planted. The main reason behind less importance of environment management in the Municipality is lack of human resource. In real term, Municipality did not have an employee who was aware of environment management. Thus, it can be said that the environment management is illusion because there is mismatch between prescription of environment management and practice carried out by the Municipalities.

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8. MAPPING CLIMATE, GENDER AND SOCIO-ECOLOGICAL CHALLENGES

8.1 UNDERSTANDING MASCULINITY IN IRRIGATION: IMPERATIVES FOR GENDER TRANSFORMATIVE DECENTRALIZED WATER GOVERNANCE

ANJAL PRAKASH, PHD[1]

Nepal has a long history of irrigation water management by farmers where they take the sole responsibility of operating and maintaining irrigation systems. In the absence of strong government intervention in the past, farmer managed irrigation systems (FMIS) have slowly evolved through collective effort of farmers to irrigate their agricultural land. According to the Department of Irrigation (DOI), Government of Nepal, FMIS irrigate about 645,716 hectare of command area which is about 67 percent of total surface water irrigation. FMIS are characterized by the use of low-cost technology appropriate for heterogeneous local conditions, autonomous decision making suited to local contexts, and collective action by farmers for the operation and maintenance of the irrigation systems. Over the recent decade, FMIS in Nepal have been facing increasing stress from globalization and market access, socioeconomic and environmental changes, and institutional and governance. Some of the key issues facing FMIS are competing water demands, feminization of irrigated agriculture labour, interest in off-farm income, changing technology, climatic variability, and weak water governance. Nonetheless, the impacts are not linear and homogenous across temporal and spatial scales. Since FMIS have survived decades of changes, it does possess characteristics of a resilient systems. Revival of FMIS does offer some hope for adapting to changing climate. However, more research is needed to understand how FMIS are evolving and innovating to address the multiple drivers of change.

While recognizing the importance of irrigation in the larger development of an agrarian economy, this paper focusses on an issue which is has not been discussed much. Women are at the

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center of farmers managed irrigation systems though they are less studied, understood and recognized. Historically, the irrigation institutions are dominated by men. With large scale migration of men and consequent feminization of agriculture labour, the issue of women's participation in decision making becomes important. The issue is understanding masculinity in the irrigation governance become central to the deliberations. Irrigation is historically conceptualized as a 'technical' subject ignoring the social and political dimensions of distribution of water and its management. The root of this concept is engineering rationality, natural science and masculinity. This paper reviews current studies and locates masculinity at the center of debates concerning revival of FMIS as climate resilient systems

8.2 ACHIEVING GENDER WATER EQUITY IN THE FACE OF CHANGING CLIMATE CONTEXT: LESSONS FROM LOCAL WATER PLANNING PRACTICES IN NEPAL

PRANITA B UDAS AND CHANDA G GURUNG[1]

The major challenge faced by farmers with increased temperature and erratic rainfall is variability in water availability at the source. Farmers are troubled with either too much or too little water. Drought and floods are the major problems farmers have faced. In the hills, the springs are drying off, while irrigation canals turn into drainage canal during rainy season. Local water planning is crucial in this context to minimize water conflict emerging from water competition for various uses, as well as to manage water induced disaster. Often water related decisions and control are in the hand of local elite as access to water also add to power base of individual and groups. Concerns for gender water equity and justice is often marginalized in this process. Gender sensitive and responsive water planning could avoid this marginalization to a large extent. This paper presents gender analysis of local water planning practices, popularly known as Water Use Master Plan (WUMP) of Village Development Committee, implemented in Nepal since late nineties. It highlights the lessons learnt from WUMP practices on achieving equity in water management planning and access. The WUMP practices have been recognized by water supply and local development sectors, whereas the recognition from irrigation sector is limited. The paper concludes that implementation of irrigation projects based on WUMP priority can be an effective modality for irrigation sector investment to achieve gender water equity in changing climatic and sociopolitical scenario.

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8.3 GENDER AND WATER GOVERNANCE: WOMEN'S ROLE IN IRRIGATION MANAGEMENT AND DEVELOPMENT

DILLI R. PRASAI[1]

PRELUDE

Gender governance depends on democratic, and gender-sensitive governance since typically women, who are or feel marginalized from the public sphere and administration do not feel empowered to take action or participate in governance. More importantly, they do not take steps to make changes to ensure that governance is gender-sensitive. As a result, laws, policies and government institutions do not reflect the needs of all citizens, nor may they be conducive to encouraging progress, and protecting women's rights. Some women may feel that they cannot participate in the public sphere due to concerns over male/female socially acceptable roles. In studies of South Asia including Nepal for example, cases of women who sought to enter public life faced intimidation or even oppressed by formal or informal state-institution due to traditional notions of female domestic duties which were in conflict with any participation in public life. Gender equality is key for sustainable, effective and inclusive water governance. Gender equality refers to the equal rights, responsibilities and opportunities of men and women, including equal access to, control over and use of services and resources. Inequality varies between societies and over time and gender inequalities often intersect with poverty, ethnicity, age, ability and sexuality generating complex and differentiated barriers to safe and dignified lives for all. This paper has tried to carry out substantial linkage between the issues and practices of *gender and water governance.*

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PROBLEMS EMPHASIZED

Irrigation management is normally defined as "a process by which institutions or individuals set objectives for irrigation systems, establish appropriate conditions and identify, mobilize and use resources so as to attain these objectives while ensuring that all activities are performed without causing adverse effects" (IIMI, 1992). Irrigation management with a gender perspective starts by identifying the end-users, and by understanding their needs and interests. The basic premise here is that unless the actual users are willing and able to use the water delivered by the irrigation system efficiently and effectively, the objectives of the irrigation system will not be achieved. Hence, developing a gender perspective to irrigation management consists of answering the following questions:

1. What are the objectives of the irrigation system?
2. What are the needs of female and male water users?
3. What ways can irrigation professionals contribute to accommodating the irrigation system to the needs of both female and male water users?

LINKING THEORY AND PROBLEMS OF AN IRRIGATION SYSTEM

Defining the objectives of an irrigation system is itself a controversial and difficult matter. Different parties involved will have different priorities and different interests. Among the many objectives irrigation is expected to achieve are increasing agricultural productivity, increasing political stability, decreasing poverty, achieving national food security and so on. Women in Development (WID) or gender advocates may add an additional objective to this list, which is that irrigation needs to contribute to the well-being of women, or even that irrigation should lead to the empowerment of women. Unfortunately it is rare for all these objectives to be achieved at the same time. High productivity at the irrigation system's level does not automatically mean that all households who are involved in irrigation benefit from it, or benefit to the same extent. Nor does a high productivity or income at the household level always imply that all the household members have equally contributed and equally shared in this income. There is no way in which all the different objectives and interests of the different parties involved in irrigation can be easily matched, or that potential conflicts of interest can be easily solved. However, to plan and implement irrigation interventions realistically it is crucial to realize that differences and potential conflicts exist. This recognition begins with bringing some consistency into the various levels of goals and objectives. The level of satisfaction of female and male members of households using irrigation water is not only one important measurement of the effectiveness of irrigation systems , it is also one important factor determining its effectiveness. Unless water users employ their own labour and capital in a way which makes good use of available and anticipated land and water resources, the ultimate benefits of irrigation will be restricted. Although many differences may exist between the users of an irrigation system (based on land size, ethnicity, age, etc.), the focus here is on potential differences between male and female water users. Usually, if users' needs are taken into account at all, these are most often the male water users' needs. Women are often not considered, but there is enough evidence to substantiate the belief that they have specific needs with respect to irrigation. These needs do not necessarily conflict with those of men; they may be complementary or shared (Prasai,2016).

THE EMPIRICAL IMPACT OF IRRIGATION ON MEN AND WOMEN

The direct impact most often attributed to (and aimed for) irrigation is increased agricultural production. The literature on gender and agriculture provides a long list of examples of how women and men may differentially contribute to, and are differentially affected by, increases in agricultural production. These differences relate to:

1. The allocation of labour, land, water and other resources to the cultivation of irrigated crops; to construction and maintenance activities and to participation in users' organizations.
2. The use of the outputs of irrigated agricultural production, e.g. consumption, storage for use, exchange or sale.

Several studies of irrigation development in Nepal show that women and men may be differentially motivated to invest labour and other resources in irrigated crop production. Some show how women, as a result of new irrigation interventions, have lost access to land and to the proceeds of harvests in favour of their husbands and male relatives . Similar examples have been found elsewhere. A study of an irrigation project in the Cameroon for example, showed that women tried to minimize their labour contributions to the newly irrigated rice crop controlled by their husbands in favour of their individually controlled sorghum production. The serious intra-household conflicts over the income from rice was a significant factor in depressing the amount of labour available to rice production, which in turn negatively affected cultivated areas (Jones, 1983; 1986). Other studies document less visible and more indirect effects of irrigation management and development on women. Women in the hills of Nepal were very positive about new irrigation facilities, since these considerably reduced the time they needed for fetching water for domestic use (Backer, 2015). In India, the unforeseen impact of canal irrigation on the growth of fodder was particularly beneficial for women, since it enabled them to increase their milk and ghee production through which they could earn some individually controlled income (Basnet, 1992). The opposite effect may occur with groundwater irrigation, which may lower groundwater tables and thus reduce the growth of weeds used for fodder and trees used for fuel. This was documented in Bangladesh, where the consequent shortage of fodder and fuel significantly increased the time poor women had to spend gathering them. It gradually pushed them towards more marginal sources, such as leaves and bark of trees, which hastened the deterioration of natural resources (White, 1992).

The many direct and indirect linkages between gender and irrigation development are hard to foresee. They will be different in different cultural, institutional and environmental contexts and will vary with the type of irrigation technology used. However, this paper do illustrate that prevailing gender relations structure the direction and nature of irrigation related developments and therefore the success of irrigation interventions.

Gender analysis can thus help irrigation planners and policy makers to set achievable objectives realistically, and to assess the potential trade-offs in achieving these objectives. For example, a possible alternative approach is to allocate smaller plots to both men and women. A study in the Dakiri irrigation system in Burkina Faso in West Africa shows that the allocation of plots to both husbands and wives makes sense, both in terms of gender equity, as well as in terms of returns to investments in infrastructure. In Dakiri, the total amount of labour provided to irrigated agriculture is higher for households in which both husbands and wives have plots when compared to those where only husbands have been allocated access to an irrigated plot. Women are more willing to invest labour when they can control the product of their own labour, and this is more likely to occur when they have secured access to land (Dey, 1990). In this sense we can localize this practices in Nepali knowledge also.

GENDER SPECIFIC NEEDS AND THE OUTPUTS OF IRRIGATION MANAGEMENT

Some of the different ways that irrigation affects women and men will be reflected in their differential needs with respect to the irrigation system's outputs. Output measures assess the nature and quality of irrigation services delivered to farm households, services which will in turn be important in determining production, income and other livelihood indicators.

How do users evaluate the outputs of irrigation systems? An important concern is the amount of water delivered, or the *adequacy* of water deliveries. This may vary according to gender because men are often responsible for different crops than women. Very often, the main irrigated crop is controlled by the male member of the farming household. Women will often contribute labour to this crop, but very often they also grow crops of their own. These crops may be used for consumption, or they may be sold to provide women with a personal source of income. When there is an opportunity to do so, women will make use of irrigation water to grow these crops. They may take water directly from the channels, or sometimes they use drainage water. However, these crops grown by women are often not considered the 'main' crop, or sometimes it is not even realized that they are grown. As a consequence, their water requirements are seldom taken into account when devising water delivery schedules. In some cases , the use of irrigation water for growing crops other than the planned one, or for using water on plots outside the designed command area, will even be considered illegal. Men and women often have different tasks, and the adequacy of irrigation delivery can be affected by these. For example, irrigation water can be used to soften soil for land preparation. Land preparation is often done by men, so preseason applications of water reduce the amount of male labour needed. In paddy cultivation in Asia, women may be expected to do the bulk of weeding. Unless they work as paid labourers, women are thus likely to be in favour of increasing the pounding depth which reduces weed growth. In Nepal, women reported that the increased availability of irrigation water had considerably reduced the time needed for weeding (Backer, 2015).

A second measure for evaluating the outputs of an irrigation system is *equity*. Equity refers to the spatial distribution of water across the system. However, female farmers who grow the same crops as men, and who are thus in principle entitled to receive an equal amount of water, often find it difficult to claim and receive the amount of water they are entitled to. When water is scarce, women are often in a much weaker position to obtain water than men. This is why female irrigators in Nepal, though in principle preferring an on-demand rotation system of water deliveries, nevertheless saw a clear advantage in a scheduled rotation system. This system guaranteed water, without women having to go through the hassle of negotiating for it and running the risk of not getting any water at all (Carney, 1988).

The *convenience* of water delivery timing may be different for men and women. Female irrigators may have different preferred daily irrigation times because they have to plan their various productive and domestic activities alongside each other. Some of those activities have to be done at a more or less fixed time of the day, like preparing the meals. In Hill area of Nepal, there was a marked difference in the time women and men were willing and able to start irrigating their fields. Women preferred to start later, because of the domestic duties which they had to perform early in the morning (Prasai, 2014).

Irrigating at night may be particularly difficult for women, because of social norms which prevent them from going out at night. In Naharadigaul-Shiraha District, the few women that were directly involved in irrigation would send a male relative or neighbour when their irrigation turn was at night. If there was no other possibility, they would try to be accompanied by a family member or friend (Prasai, 2014). With regard to *water quality*, women are likely to place a higher value than men on having access to irrigation water which is clean enough to be used for domestic purposes. Also, the health hazard presented by the use of irrigation water for domestic purposes may be more of a concern for women, since they are often responsible for caring for the sick.

WOMEN'S PARTICIPATION IN THE COMMUNITY ORGANIZATION OF IRRIGATION.

In a way, the non-involvement of women, or of their needs and interests, in irrigation management has become a self-fulfilling prophecy. Because irrigation is commonly conceived as a male activity, and because women are not seen as direct stakeholders in irrigation systems, they have become excluded from efforts to organize water users. Since women's specific concerns thus remain outside formalized decision-making processes, they are often not recognized as 'real' concerns and remain marginal.

The inclusion of users in operating and managing irrigation systems most often occurs through the organization of users' groups or associations. In most irrigation cases, women appear to be almost absent from those groups. This is partly because membership is often confined to one member of each irrigating household, either the official landholder or the 'head' of household. Both criteria apply to men far more often than to women; the only women who can potentially participate in water users' groups are either widows or single mothers with no adult male living in the household. However, experience has shown that there can be many benefits from allowing women to represent households in irrigators' associations. But while the nature of women's needs may make their participation in irrigation management desirable, the inclusion of women's perspectives will often not just be a matter of allowing women to become members of users' organizations.

The experiences of female irrigators who are officially entitled to join users' groups, illustrate that women often find it difficult to bring their opinions and needs forward. Attending meetings and discussing matters in public may be thought of as typical 'male' activities, associated with political gatherings which are often traditionally confined to men. In some cases, women are not expected or encouraged to speak in front of men or in public. Moreover, they frequently lack the confidence and the experience to deal with irrigation matters in public, since all interactions with outside institutions mostly take place with men, and since men often receive the bigger part of information and training. Women in Panchawati VDC- Udayapur were reluctant to attend water users' meetings because they were sure that nobody would listen to them. In Udayapur, female farmers often prefer to send a male relative to meetings rather than going themselves. They may also ask a male friend or neighbour to represent their interests, send a letter to the irrigation officials, or try to meet separately with one of the office-bearers of the water users' organization.

It may also be that participation in meetings is simply not judged to be efficient and rewarding. In Ramphok- Ilam, women stated that it was of little use going to meetings, since the most important decisions were not taken in those meetings but during informal get-togethers of men (Prasai, 2014). In summary, while the differential needs and interests of women and men with respect to irrigation may call for the inclusion of both their perspectives in planning and decision making, women and men will often have different perceptions of the costs and benefits involved in participating in users' groups. The attractiveness of participation may be less for women, partly because the costs of time spent travelling or attending meetings may be relatively higher for them, but also because social norms and values are not always supportive of women engaging in public meetings. The inclusion of women's perspectives, their ideas, opinions, needs and interests will thus require an active and conscious effort. Women in Ilam said that they would first need to learn how to read and write, before feeling confident enough to participate in meetings. They also suggested that they should maybe get together as women, and try to organize among themselves first. In Ramphok irrigation scheme- Illam District, women were first organized separately. Special training sessions were held, both for women themselves as well as for field agents and other officials. Special female staff were also appointed and trained. This made women gain confidence and helped them to overcome some of their initial reluctance to attend 'male' meetings.

MAKING WOMEN'S WATER NEEDS COMPATIBLE WITH IRRIGATION MANAGEMENT

The poor success achieved so far in making irrigation planning and management more gender sensitive can be partly attributed to wrong assumptions about the capacity of existing irrigation management institutions to respond to new demands. Too much emphasis so far has been given to what is desirable (empowerment of women) and too little to what is possible. Irrigation management institutions and agencies whose main task is to make sure that the right amount of water is delivered at the right time and in the right place cannot be expected to be interested in the empowerment of women, and neither do they have a real capacity to change gender inequities. What is within their reach and mandate is the satisfaction of specific needs women may have with respect to irrigation management and development , although even this may sometimes be conditional upon changes in other sectors.

Successful recommendations to better recognize and accommodate gender needs and interests within irrigation contexts should thus be formulated in such a way that they contribute to, or at least are compatible with the objectives of the responsible institutions. The linkages between gender issues identified at tertiary unit level and more general objectives of irrigation management should thus be clarified. Some of the examples given in the previous sections point to potential areas for improving the performance of irrigation through a better recognition and accommodation of women's water needs. Unfortunately there is not always a direct positive correlation between greater gender awareness and a better performance of irrigated agriculture. Sustaining gender biases may, in some cases, even be functional for achieving some of the irrigation system's other objectives. However, in most cases gender inequities will have direct impacts on health, environmental sustainability, the productivity of other crops and so on. It may be that the opportunities for addressing issues that are closely related to irrigation, but which as yet remain unaddressed, will increase. The shortcomings of mono-disciplinary technical approaches to irrigated agriculture have become increasingly clear. Widespread dissatisfaction with the low performance of irrigation systems, growing environmental awareness, and the trend in developing countries to privatize the management of irrigation systems all call for a critical reassessment of existing irrigation management concepts, practices and institutions. This reassessment seems to offer more room for integrating gender.

The impacts of implicit gender discrimination in terms of environment and health will become more easily recognizable and visible. The inclusion of upstream watershed management in the responsibilities of irrigation institutions will give scope for recognizing the links between water used for irrigated agricultural production and the availability of and need for water for other uses. And a focus on more users' participation in operating and managing irrigation infrastructures creates the possibility of discussing and analyzing if and where women can and should be involved.

CONCLUSION AND NEW FEDERAL POLICY IMPLICATION

How can the design, operation and management of irrigation infrastructures become more gender balanced? There are three broad areas in irrigated agricultural production systems which need attention, and where a careful gender analysis will help to create more effective and equitable designs and policies: (1) system engineering and design; (2) legal, administrative and organizational arrangements which create rights and responsibilities with respect to the use of the system; (3) system operation, e.g. cropping patterns and water delivery schedules.

- ***System engineering and design***. It is important to analyze who will be using water, andwho will benefit from these uses. Rather than simply designing a system on the assumption that water will be used by male farmers for irrigating the designated plots in the command area, it should be investigated whether and how both men and women need and would use water that is made available through the system, and the design should accommodate these needs. Where a design entails re-settlement or settlement of a new area, care should be taken to ensure that women are provided with secure access to newly developed land and water, especially in situations where women traditionally relied on access to land resources. Design processes should incorporate consultations with male and female users, so as to include both of their wishes, needs and requirements.

- ***Legal, administrative and organizational arrangements***. Explicit consultations should be held with women users, and women's ideas and concerns should be included in water users' associations in some locally suitable way. Explicit attention needs to be given to how property and use rights to irrigation infrastructure are created and enforced, with an emphasis on gender differences in willingness and ability to invest labour or other resources in original construction and maintenance.
- ***Operation.*** Water delivery schedules should be devised in such a way as to accommodate both male and female needs with respect to quantity, timeliness, timing, equity and quality of water. Specific uses of water by women, like domestic uses or watering cattle, also need to be included when operating systems.

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8.4 UNDERSTANDING THE IRRIGATION GOVERNANCE AND MECHANISMS OF WATER RESOURCE MANAGEMENT FOR IMPROVED ADAPTIVE CAPACITY

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There is limited understanding to date eliciting the issue of governance within Farmer managed Irrigation System (FMIS) and how this can be addressed in climate change adaptation with regards to capacity of institutions to deliver inclusive adaptation outcomes. The main purpose of this research is to understand the irrigation governance and mechanisms of water resource management in the changing climate context to increase the adaptive capacity of the FMIS.

The methodology for this study include the Institutional Analysis and Development (IAD) framework which was adjusted for adaptation governance analysis. The action situation include providers and beneficiaries of a collective adaptation good, whose interdependence is characterized by three sets of variables (biophysical conditions, community attributes and institutions). The study used household survey, key informant interviews and focus group discussion as key tools.

The FMIS is prone to climate change impacts such as variability in precipitation, rising temperature and increasing climate induced hazards. The farmers, dependent within the system, have reported loss of water discharge (about 50%) from the springs due to extreme variability in precipitation and increased temperature that can be attributed to climate change. The decreased access and availability of water has forced farmers to use ground water pumping as an alternative.

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The extreme weather and climatic conditions have made the farming system more labour intensive and less productive. The evidences show that many farmers have shifted to other livelihood options other than agriculture. This has severely impacted the livelihood of the landless daily wage agricultural labourers as many of the labourers, especially women, have no other skills. In contrary, the institutional structure, currently in operation, is extremely weak in terms of mobilizing communities and poor in terms of providing equal access to all the farmers affiliated with the system. The institution is also unable to understand and strategize adaptive responses to deal with the growing impacts of climate change stresses.

The findings indicate that important factors shaping adaptive capacity of individuals, household and communities is their access to and control over water resources, access to water resource management knowledge and supporting networks and opportunities for enhancing capacity of institutions and individuals.

Key words: Climate Change, FMIS, Institution, Irrigation Governance, Adaptive capacity

9. FARMER PERCEPTION (CMIASP-AF)

NewarKulo, Panchthar Presentation by a) Mr. Mani Kumar Pradhan WUA Chairman
Sulitar IS, Chitwan Resentation by b) Mr. BhojBahadurRanaMagar WUA Chairman
Atrauliputtar IS, Tanahu Presentation by c) Mr. RamjiAryal WUA Chairman
Hadiya Dama Paini, Jhapa Presentation by; d) Mr. Uday Narayan Dhungana WUA Chairman
Chakhola IS, Kavre Presentation by e) Mr. Gobinda Prasad Nepal WUA Vice - Chairman

PERCEPTION OF FARMERS

NEWAR KULO - PANCHTHAR
ULITAR ISP - CHITWAN
ATTRAULIPUTTAR ISP - TANAHUN
HADIYA DAMA PAINI - JHAPA
CHA KHOLA ISP - KAVRE

BACKGROUND:

Adaptation and resilience of FMIS to climate change or variability essentially has a shared sustainability dimension. FMIS in recent years have been frequently visited by climatic adversities like early/delayed rain, draughts, intense rain or cloud burst, flash floods etc. causing sustained operation and maintenance of an irrigation system a titanic task. Over the period of time, FMIS have developed and internalized coping and adaptation mechanisms as many of them have visibly survived over decades or even for century. The session on "Farmers' Perception" was broadly aimed at providing platform where farmer could learn, share and disseminate strategies, experience and information that they had been adapting to sustain their irrigation systems. More specifically, the session within the seminar focused: (1) to share up-to-date information pertaining to small-scale farmers involved in production of traditional and alternative agricultural products; (2) to create awareness about ever changing climatic pattern and mitigating measures being followed by different irrigation systems; (3) to encourage linkages and networking between the irrigation systems to address the problems. In this regard, 4 FMIS restored and improved under ADB financed Community Managed Irrigated Agriculture Sector Project - Additional Financing (CMIASP-AF) were selected to participate in the conference. Likewise, 1 AMIS being renovated under the project was also hand- picked for participation. The farmers of the selected systems shared their experiences through deliberations and discourse.

THE DELIBERATIONS:

1. MR. MANI K. PRADHAN, WUA CHAIRMAN, NEWAR KULO, PANCHTHAR

The irrigation system unveiled a lineage in its leadership pattern. An exclusive family headed the system construction some 140 years ago and its heir continues to lead the farmers' organization. The long-drawn history of the irrigation system well demonstrates farmers' inherent capacity to run the system sustainably. Restoration of the system under CMIASP - AF support had addressed farmers' problems to a larger extent and stimulated farmers to adopt commercial or cash crops farming. Farmers are cognizant of the declining flow in river. So, the need for optimizing water use was well acknowledged. Farmers are equally aware of the necessity to diversify the crops as conventional agriculture has turned nonpaying. As a result, majority of farmers in the command area now has resorted to cardamom farming while 5 farmers have undertaken fish farming using canal water. Moreover, adoption of new technology like sprinkler is also promoted to efficiently use scarce water. Thus, farmers have visibly adapted to "scarce supply" by diversifying crops as well as use of improved technology.

2. MR. BHOJBAHADUR RANA MAGAR FROM SULITAR IRRIGATION SCHEME, CHITWAN

The irrigation system was constructed by farmers 20 years ago and farmers continue to pool resources from various sources to run the system. At present, the FMIS is under CMIASP-AF rehabilitation and is nearing completion. Early signs of system restoration are visible as farmers have shifted to vegetable cultivation and cash crops. Fish farming using the canal water is growing. The WUA is well aware of water management as it follows water scheduling during lean supply period. Strict rules are enforced through patrolmen deployed for water distribution and farmers are seemingly capable of managing water shortage which might have been the result of climate change.

3. MR. RAMJI ARYAL, ATTRAULIPUTTAR IRRIGATION SYSTEM OF TANAHUN

Unlike above, Attrauliputtar irrigation scheme of Tanahun is a government or agency built system (AMIS) destined for the management transfer after restoration. Together with decreasing water at source river, the 20 KM long canal has also been suffering from water seepage. To increase the conveyance capacity of canal and strengthening the diversion structure, the scheme is under structural improvements through CMIASP-AF. Given that the system was government run, farmers had less to do in earlier days. The real test of farmers to sustainably operate the system remains to be seen once it is transferred after improvement.

4. MR. UDAY N. DHUNGANA, HADIYA DAMA RAJPAINI IRRIGATION SYSTEM JHAPA

Despite the construction of Hadiya Dama Rajpaini, by farmers some 60 years ago, the system lost its primary water source, Timai khola that supplemented water to Hadiya khola. It was due to accelerated use of water by the enlarged dwellers around Barne and Timai area. The farmers thereafter resorted to Dama khola and conveyed water to enhance the supply through a hume-pipe syphon. And now, the recent "CMIASP-AF intervention had ensured water sufficiency promoting efficient use of water". Contrary to other cases the discharge of this system has reportedly increased. The river bed has degraded and farmers skeptically acknowledge that this could be the cause of climate change. However, sufficient water acquisition from the river seems to have prompted a laid-back attitude amongst farmers. Regarding agriculture, the traditional cropping pattern of paddy, wheat and maize still governs the CA although farmers are increasingly attracted to vegetable, beetle-nut and cardamom cultivation.

5. MR. GOVIND P. NEPAL, CHA KHOLA MAITA KUNTA IRRIGATION SCHEME, KABHREPALANCHOK.

The irrigation system also known as Rajkulo, was built some 65 years ago while its first users' committee was formed subsequently in 2014 B.S. Together with canal improvement, CMIASP-AF has equally caused to reinforce farmers' organization. The WUA has its separate office, meetings are regular and records are the latest. The WUA collects irrigation service fee for the up-keep of the system. Farmers have a penchant for new technology in agriculture which is reflected in adoption of SRI technique of paddy cultivation. Farmers of Maita Kunta grow 2 paddy crops and potato annually. Summarily Cha Khola Maita Kunta is a well performing irrigation system with a more organized water users' association.

CONCLUSION

- All agreed that traditional crops alone couldn't withstand the O&M costs of irrigation systems. Sharing of experiences on use of SRI by the WUAs of Newar Kulo and Chaa Khola was well taken in by attending farmers as coping mechanism to water shortage.
- Farmers have shifted to cultivating a variety of crops depending on water availability in the canals. Crop diversification has been taken as strategy to cope with water deficiency.
- Use of technology like sprinkler, SRI practices to optimize the usage of scarce water was appreciated as effective means to cope with the dearth of water resulted by climatic effects.
- System improvement works carried by projects like CMIASP-AF are supportive to increase the efficiency or conveyance capacity of canal thereby reducing the effect of climate change.

The conference offered the farmers opportunities to share internal dynamics of communities, visualize from multiple perspectives on what really works and build an in-depth understanding about climate change.

PART III
PANEL DISCUSSION:

PANELS DISCUSSION ON IMPACT OF CLIMATE CHANGE IN FARMERS MANAGED IRRIGATION SYSTEMS OF NEPAL

Panel list 1:

RAJENDRA ADHIKARI
DIRECTOR GENERAL, DEPARTMENT OF IRIGATION

Agriculture contributes considerably in Gross Domestic Product of Nepal. Almost three quarter of population are engaged in agriculture for their livelihood. Nearly two third of irrigated agriculture has been supported by farmers managed irrigation systems. Monsoon rain is the main source of water for irrigation. Any adversity by climate variability on monsoon rain impacts directly on the livelihood of vast majority of population of country and in effect results the food insecurity in the country.

We have been discussing on the impact of climate change on FMIS since last two days. Many papers have been prepared by our researchers in quantifying the range of adversity encountered by the farmers in Nepal. Department of irrigation has been engaged in making the farmers managed irrigation systems more resilient to the adversity of climate change impact by utilizing departmental skills and expertise acquired by its years long experiences in dealing with the climate change hydrology.

There are many dynamics in the phenomenon of climate change, but when we relate climate change impact on irrigation system in general and Farmers Managed Irrigation Systems in particular, we can say that Farmers managed irrigation systems have always been an adaptive measures or mitigation measures in the context of variable climate generated by variable hydrology. Had it been rainfall just to meet the crop water requirement, it would have been the ideal case and consequently there would not have farmers' irrigation systems. Irrigation is needed to cope up the climate variability.

It has been widely acknowledged by our team of experts working in the field that the alteration in water cycle, both in space and time, has influenced the irrigation systems at the source and at the canal alignment.

The erratic nature of rainfall results in flash flood that transports massive amount of riverbed sediment from on part of the river and deposits near the water intake structures of the farmers irrigation systems, as the intake structures causes the temporary obstruction for the free flow of sediment laden river water. This way, the sources of irrigation water at intake point are in the process of depletion. Permanent cutoff along the river width, either fully or partially, is built in order to regenerate the required water discharge at the intake source of farmers managed irrigation schemes.

The change in eco hydrology, mainly in mountainous region comprising of ridges and valleys, affects the long alignment of farmers systems as they have to cross many terrace landscapes within ridges and valleys constituting of diversified ecosystems altered by the presence of carbon concentration, sunshine hour duration, and condition of evaporation and transpiration due to diversified vegetation. Along the long canal alignment, one stretch in valley may encounter heavy rainfall where as other part in ridge running dry. By incorporating sufficient numbers of cross drainage and canal escape structures we can make the part of canal alignment more resilient to counter the adversity caused by the concentric and localized rain. The hill side retention are normally strengthened well in comparison to the bank side, because the hill side canal structure has to be stronger to resist the force caused by the landslide.

Nepal is one of the few countries which spare nearly 40% of its land area in the name of conserved forest, providing natural means of atmospheric carbon sinking produced by the industrial neighbors. Farmer's communities are in the fore font in making community forest as model to support global environment. The Nepalese farmers are having double roles to combat with the negative impacts caused by climate change – atmospheric carbon reduction in the community managed forest and providing irrigation to mitigate the water deficiencies caused by altered hydrological cycle. In having strategically adaptation plan against climate change, high priority would be given in the development of climate resilient irrigation infrastructure that belongs to the farmers' communities.

Panel list 2:

DR. SUGDEN FRASER
HEAD, IWMI-NEPAL

1. **Impact of climate change hard to deny – farmers perceptions point to increased variability**
   - Erratic monsoons
   - Delayed start
   - Precipitation extremes
   - Extreme heating and cold snaps
2. **Critical to acknowledge that vulnerability to climate change is rooted in social structures.**
3. **Take groundwater for example**
   - Provides water 'on demand' – key for resilience
   - There is no shortage of groundwater in the Eastern Gangetic Plains
   - Not scale neutral – water access not water availability
   - Primary challenge is access to groundwater – cost of boring; cost of pump set; operating cost.
   - Tarai districts and larger region – deeply inequitable agrarian structure
   - Critical constraints for marginal farmers who cannot cover the costs, as well as for tenants – who face incentive constraints
4. **Also, critical issues relating to gender and groundwater**
   - In context of climate stress, combined with social structures, high out migration – leading to feminization of agriculture

- vulnerability can follow gendered lines – as women often face unique challenges in accessing irrigation essential for climate change adaptation

5. **Another example relates to built infrastructure. In mountain regions, enhancing water storage is critical for climate change adaptation/**

   a) Small scale ponds and reservoirs

      i. Important but like with groundwater, incentives to invest are limited due to high costs of production, small and marginal holdings

      ii. Institutions necessary to manage community storage infrastructure under threat due to high male out-migration, and development agencies haven't adequately engaged with women.

   b) Larger dam storage, linked with hydropower

      i. Who benefits from trade-offs?

      ii. Irrigation water often goes to better off farmers with access to land, whereas landless fisher people or flood recession farmers in the Koshi floodplains may lose out

6. **IN CONCLUSION: Addressing climate change not just about technical solutions**

   a) Need to engage with structural issues – in particular, distribution of land

      i. LONG TERM land reform

      ii. SHORT TERM more favorable policies - e.g. groundwater subsidies are out of reach to tenants or often women whose husbands have migrated, they often do not have land ownership certificates.

   b) Needs to be a changed approach to gender by development organisations. Still focused on the 'traditional' female domain of water for household reproductive use.

Women are now managing the entire agricultural economy, yet remain largely excluded from many irrigation interventions both large scale and small scale. Build upon success of MUS as a women led intervention, to expand this to other irrigation systems which still remain within a gendered male space.

Panel list 3:

MR. MADHAB BELBASE
JOINT SECRETARY, WECS

Points highlighted in the Panel Discussion of the FMIS seminar from my side

Water resources sector is one of the hardest hit sectors due to climate changes. There have been observed remarkable changes in the rainfall pattern and stream flows, besides rise in temperatures, in Nepal, in past few years. Major identified climate-related risks in Nepal include increased frequency and intensity of floods and droughts (associated with increasing water scarcity), intensified erosion caused by changes in rainfall patterns and land cover, sedimentation and siltation reducing groundwater recharge and water storage capacities (as a result of the interaction of land use changes and hydrological cycles),

Climate change has impacts on the demand side as well as on supply side when we talked about irrigation sector. On the demand side, due to increase in temperature, the crop water requirement will increase, consequently, the irrigation infrastructures, may require, structural modifications to supply the water required for the increased demand. On the supply side, the water availability in the rivers/ stream will be changed. There will be less water available for winter and spring crops, which may not be enough to meet the requirements. During monsoon, we have been experiencing intense rainfall and flash floods causing damages of irrigation systems, particularly famer's managed irrigation system in hills and mountains. As an example, the intense rainfall of August 2014 in mid western region, damaged nearly 400 irrigation systems in Surkhet district alone. All of the systems have not yet been reinstated. In my opinion, this is the major threat for the sustainability of the FMIS in the future. The time series data of the past and statistical analyses to predict the future flood events, may not useful in the future.

The other important challenge that the FMISs currently has, is the migration of the young people from the rural areas for foreign employment, as no work force is available to operate and maintain the systems. The fourth challenge, is the haphazard construction of roads and other infrastructures, causing increased landslides and sedimentation.

Anthropogenic factors are worsening climate change effects on risks. Unsustainable rates of pumping exceeding recharge rates are threatening water availability and quality. Land-use changes especially in mountainous areas are accelerating erosion reducing water infiltration and groundwater recharge and increasing the risks of floods and downstream siltation.

In this context, the responses climate change include the followings:

- A key foundation for such a response is a better understanding of climate-related risks, the identification of knowledge gaps and the development of adaptation frameworks for the water sector.
- Development of suitable climate change models
- Optimum observation networks and strong data-base
- Improve water use efficiency and cultivate high value crops
- Develop a suitable model for irrigation cooperative
- Creation of mass awareness
- Design irrigation systems, particularly, hill irrigation, with minimum infrastructures, adopting new technologies, including solar pumps, and other mechanical pumps
- Development of suitable model to carry out hydrological analysis
- Conduct research for provisioning suitable fuses for important hydraulic structures

Panel list 4:

DR. RAM CHANDRA KHANAL

The panel members were asked to focus on what is status of the climate change, what scenarios we can expect in future and what needs to be done in agriculture and irrigation sector together in the changing context.

Nepal has planned to be graduated from LDC to DC by 2022. This requires huge investment and national economic growth in key economic sectors of Nepal. Agriculture is one of the sectors which is going to be transformed rapidly due to climate change and other general development trend including urbanization and advancement in technology to name a few. There will also be a huge change in water demand for agriculture irrigation, drinking water and industrial use. For this, there will be two clear development trajectories. Either we follow traditional development pathways which are energy and resource inefficient, environment unfriendly and increase GHGs emission rate. The second is the quicker adoption of climate resilient strategies for managing change and promoting transformation without undermining the development need of people and its contribution on poverty reduction while ensuring the cut in GHG emission.

Climate change has obvious impacts in agriculture and irrigation. It has impacted on temperature, precipitation and C02 level change. While temperature has changed the whole ecological structure, precipitation has however invited the extreme events either thought 'too much' water and 'too little' water. Most of the literature in this discourse showed that water is the first sector which has been severely affected by climate change. But, we also need to appreciate the fact that there are many other factors, probably more important at least in short term, that affect in managing food – water nexus. But, the scientific communities around the globe have accepted the negative impact of the climate change both in short and long term.

The issue and impact of climate change was a technical matter a few decades ago, it has now moved to a political and developmental debate and is being considered as a threat to livelihoods of people who are in remote areas and without adequate resources to adapt to the risk induced by climate change.

Nepal government has adopted many policy frameworks for enhancing agriculture growth by promoting effective use of water resources. But, the policy frameworks are not context specific, has not considered the value of food-water nexus in the changing context and the existing blanket recommendations are not in position to show results at local level. Besides, co-ordination and collaboration with agriculture and irrigation sectors are very week and several examples of weak collaboration can be seen both at national and local level. There is still wide gap of demand (agriculture) and supply (irrigation) and how the efficiency can be improved.

There are many aspects critical to promote food and water nexus in the changing climate. Nepal has adopted many policy frameworks and some of the important frameworks are Agriculture Development Strategy (ADS), Nationally Determined Contribution (NDC), proposed National Adaptation Plan (NAP) and draft Low Carbon Economic Development Strategy (LCEDS). These frameworks have ample room to increase synergies of agriculture and irrigation but they further require detail strategies. It is also important to improve institutional capacity of these two sectors. Followings are some important specific interventions that need to be considered.

1. Improved technologies and practices: we need to have technologies that are water efficient (such as drip irrigation, pipe irrigation), varietal improvement (drought resistance, flood resistance, short duration varieties, high yielding varieties, conservation of climate resistance local varieties).
2. Improve access to technologies: through involvement of private sector, cost sharing (farmers and government), demonstration, storage and others of water efficient technologies
3. Conservation and promotion of local level indigenous knowledge related to water conservation and use (such creation of community pond, multiple use of water)
4. Promotion of soil and water conservation strategies
5. Use of climate analogues (to see the present status and future scenarios of the climate change and project the future climate conditions) for promotion of technologies that are water efficient
6. Involve private sector for technology promotion and use
7. Promotion of landscape approach / watershed management / ecosystems based adaptation
8. Integrate climate risk management in planning, implementation and assessment of interventions- promotion of index based insurance could be explored

To conclude, managing natural resources such as agriculture and water at local level is a complex process as it involves various elements and their simultaneous but non-liner interactions over time, space and institutional level. Resilience thinking can be one strategy to address these complexities to address the risk of climate change in agriculture and irrigation sector.

Panel list 5:

DR. PUSPA KHANAL

There is an urgent need to review the approach to irrigation development in the country. Irrigation in Nepal, including the FMISs originally started with the objective of providing supplementary irrigation to monsoon rice, and the situation still remains the same today except in few systems. The command area drastically reduces in winter and spring seasons in absence of adequate water supply. Lack of round the year irrigation facilitates is one of the key constraining factor in agricultural growth and productivity.

The county is already experiencing a dynamic agricultural and dietary transformation driven by both economic growth and increasing rural urban linkages. Future irrigation must support the agricultural transformation process focusing on commercialization of agriculture. This requires more reliable, adequate and flexible irrigation. It is therefore essential to move beyond the concept of supplementary irrigation and aim towards round the year irrigation supply investing in both large scale surface water diversion or storage schemes and increasing groundwater uses. This will not only help towards successful agricultural transformation, but also provide water services for other livelihood needs.

Panel list 6:

DIPAK GYAWALI:

There are a few fundamental facts to keep in mind as we talk about the impact of climate change on farmer-managed irrigation systems and what needs to be done to make them more adaptable to the dangers ahead:

a) Climate change problems (global warming of the atmosphere, disruption of old weather patterns, increase in frequency and intensity of extreme events etc.) were created by the energy sector since the start of the Industrial revolution in the mid-19th Century by burning excessive amounts of fossil fuel and disposing of the carbon dioxide waste into the atmosphere; but its impact has been on the water sector with increased frequency and intensity of floods and droughts, and <u>through</u> the water sector on the entire human society at large in all its economic sectors, from health to agriculture to tourism etc., etc..

b) Countries of the Global South did not create that problem (and the Least Developed Countries (LDCs) are even less responsible): it was created by the Industrialized North who must severely <u>mitigate</u> their fossil fuel consumption but they won't do that to the degree required because they claim it will harm their (and as a consequence, global) economy. Instead, the Global South and the LDCs are asked to prepare for the consequences of this historical behavior on their part through <u>adaptation</u> means.

c) While agreeing since the UNFCC in 1992 and formalized at Kyoto in 1997 that there was "equal but differentiated" responsibilities between the Global North and the Global South, these last two decades since then till the October 2016 Paris Accords have seen the diplomatic whittling down of the responsibilities of the Global North to providing the kind of support and finance to help the Global South cope with the consequences of global warming. The Paris Accords and the SDGs are "unfunded mandates" and for the Global South to pin their hopes on financial help from that end is to live in a fool's paradise. The Age of Aid as practiced since the Second World War has ended with the collapse of the Berlin Wall in 1989 and with it the imperative for the Industrialized Global Euro-American North to try and prevent the Global South (Third World) from becoming part of the Second (Communist) World through Aid blandishments, and the Global North is going to be more worried about their own backyards such as Trump's America, Brexited

Europe, refugees in their midst etc. than about what happens to a far-away country such as Nepal that cannot even properly govern itself!

There is little need to pin any hope on the Sustainable Development Goals (SDGs) which are also "unfunded mandates". Yes, there was a lot of chest-thumping in Nepal because we "over-achieved" the MDG goals in most of its indicators such as better girl-child enrolment, but nutrition etc. But this achievement cannot be causally linked to any Nepal government or EuroAmerican donor agency policies. On the contrary, it is because of Nepal silently but massively de-industrializing since 1990 and allowing her youth to find hard labour employment abroad in the Gulf, Malaysia, Korea and of course India. It has serious socio-political consequences but in terms of economy, it props up the country currently. See: http://bulletin.ids.ac.uk/idsbo/article/view/2822

What is problematic about all the bally-ho on climate change especially in Global South countries such as Nepal is that, despite a decade and a half of climate adaptation funding, Nepal's carbon footprint, at least in the electricity sector has ironically doubled with Nepalis fortunate to have access to electricity (about 40% of the population, the remaining 60% are under 24x7x265 hours of permanent load shedding) because some fifty percent of electricity they consume comes from Modi's Bihar from a dirty coal-fired power plant rather than from clean Nepali hydro. It is simple ground fact laughing at the face of the climate funding donors and their experts. See: http://nepalitimes.com/article/nation/nepal-india-thermal-power,3570 as well as http://nepalitimes.com/article/nation/How-%20to-%20avoid-power-cuts-this-winter-solar-energy-LED,3769 Adaptation to something such as climate change induced extremes that is almost ten full-term parliaments away is near impossible for both the Nepali administrative as well as the political system to do much about. However, they will all say they are all for doing climate adaptation because it makes them look good without really having to do anything or take any tough decisions about it!

Donors present a sorry picture as well: with the rise of Donald Trump, the leadership of the Euro Americans on this topic is doubtful with the business-as-usual scenario. However, the good thing about the rise of Donald Trump will be that it will prompt a serious re-assessment of what the actual climate change problem is minus the hype and hubris of climate advocates and a serious re-directing of efforts to solve real rather than too-far-off in the future problems. See: http://thebulletin.org/expert-views-climate-finance-age-trump10486 or https://www.thethirdpole.net/2017/03/06/trump-just-what-the-climate-doctor-ordered/

What are some of those real, on-the-ground problems? The first is that overall temperatures are rising, higher in the higher altitudes than in the lower ones. All models as well as all empirical observations point to that fundamental truth. However, what models also show is that very little can be said about precipitation: in Nepal, they could vary from -53%

to +135 percent!! See: http://i-s-e-t.org/resources/major-program-reports/vulnerability-through-the-eyes-of-vulnerable.html This increase in temperature alone will have impact on weather patterns that will change unpredictably, with extremes of flood and drought increasing in both frequency and intensity; it will have serious impact on soil moisture and thus growth pattern of flora; it will change humidity and temperature patterns which will allow both plant and animal disease vectors to migrate upwards and to areas that previously never experienced them; and it will also impact the nature of water storage, especially storage in groundwater, lakes, ponds and of course soil. It is important to study these problems more honestly, seriously and scientifically and not just knee-jerk blame climate change for everything.

As an example, a study by Nepal Water Conservation Foundation and ICIMOD on why springs as drying across the Himalaya (see: http://lib.icimod.org/record/32016/files/icimmodWP16-3.pdf) showed that it is too early to blame climate change for it because there are other drivers that are inducing it and when climate change impacts begin to be felt more acutely in the decades ahead, if we do nothing about the current problematic drivers, they will make things many times more worse. Now this problem is what Farmer Managed Irrigation Systems (FMIS) have to worry about because their systems are almost wholly dependent on streams that are spring-fed.

There is a need for FMIS to get into simple water science, to install simple rain and temperature gauge as well as spring discharge measurements and relate their water availability and use to precipitation. It is not done currently, which is forgivable for traditional farmers but not so for small and large hydropower generation companies! There is also a need to get involved in soil moisture and solar insolation measurement and record keeping. That would lead to real interesting climate adaptation science at the Toad's Eye level and village economy. There would have to also be continuous rainfall measurement devices to enable understanding how much water actually infiltrates into the ground and is stored there, available for next season's crops. The current Dept. of Hydro Met/WMO's one measurement a day is near useless for that purpose as it does not give any idea of the intensity of a 24-hour rain (which could all have come down in half-an-hour and lost in massive flood washout).

This activity has to be coordinated with the very lowest local body the village ward committees since districts are too big a unit for any serious attention at this level, let alone the national or international level.

Ultimately, it is about water scientists, technologists, bureaucrats as well as water users who have to – in the Age of Climate Change – do everything related to water (interdisciplinary water) that is not water per se that they have been used to dealing with as narrow specialists. It means everything in society touched by water.

ANNEXES

<u>ProgramScheduleDetails</u>

Venue: Hotel Himalaya, Kupondole, Kathmandu, Nepal

Tuesday, April 11, 2017 (29Chait, 2073)		
I. Plenary- Initiation and Honor Ceremony:Skyline Hall		
Time	**Activity and Person/s**	
8.30-9.00 am	Participants' Registration	FMIST staff and FMIST Volunteers (Tea/Coffee)
	Chair Chief Guest Master of Ceremony	Mr. Naveen Mangal Joshi, Chairman, FMIS Promotion Trust Mr. Ramananda Prasad Yadav, Secretary,Ministry of Irrigation (MOI) Ms. Monica Maharjan
9.05	Welcome Speech and Introduction of the Seminar Theme	Mr. Sushil Subedee, Member-secretary, FMIS Promotion Trust
9.15	Book Launching *Medini-Kamala Award* presentation to better performing FMIS. 1. Sringeghat Irrigation System, Kapilbastu, (Durga Sen) 2. Newarkulo, Pachathar(Mani K. Pradhan)	Mr. Ramananda Prasad Yadav, Secretary, MOI Chief Guest& Mr. Lava Raj Bhattarai: Medini-Kamala Trustee
9.25	Announcement of FMIS Promotion Trust's Icons of Honor: 2017 Dr. Upendra Gautam Dr. Md. Abdul Ghani Introduction of Icons of Honor	Dr. Prachanda Pradhan

9.35	Presentation of Honor: *DosallahOdhayera* (presenting shawl) Presenting Plaque Presenting Bouquet Dr. UpendraGautam Reading out the Commendation Plaques Dr. Md. Abdul Ghani Reading out the Commendation Plaques	 Mr. Naveen Mangal Joshi Mr. Suman Sijapati Mr. Sushil Subedee Dr. Prachanda Pradhan
9.45	Keynote Speech: "For a Wealthy FMIS and AFMIS"	Dr. Upendra Gautam
10.00	Keynote Speech: "Irrigation Systems: Sustainability and Resilience in Climate Change Scenario"	Dr. Md. Abdul Ghani
10:15	Remarks by the Chief Guest	Mr. Ramananda Prasad Yadav, Secretary, Ministry of Irrigation
10:20	Concluding of the Opening Session and Vote of Thanks	Mr. Naveen Mangal Joshi
10.25-11.15	**Group Photo and Tea at the Garden**	

Parallel Seminar Sessions	
Parallel Session-1:Skyline Hall	**Parallel Session-2:Rato Baithak Hall**
ICIMOD: Theme: Mapping Climate, Gender and Socio-ecological Challenges.	Theme: **Climate Change and Irrigation Management**
Session support: Mr. Sushil Subedee	Session Coordinator: Mr. SumanSijapati
Sub-session-1	**Sub-session-2**
Chairperson: Dr. Robert Yoder	Chairperson: Mr. Sharda Prasad Sharma
Reporter : Young Professional / Student	Reporter : Young Professional / Student
Time	**Activity and Person/s**

11.15-11.45	" Mapping climate, gender and socio-ecological challenges Moderator: Dr. Anjal Prakash (*detail session plan attached. Please see the last section of this program*)	" Impact of climate change on small and medium irrigation systems in Nepal. " Paper presentation by Dr. UmeshParajuli Floor Discussion
11.45-12.15		"Climatic Trends With Reference to Small Irrigation Management in Nepal" Paper presentation by Dr. Keshav Sharma Floor Discussion
12:15-12.45		“Water Measurement and Implications on Water Availability and Water Distribution and Impact of climate change on Irrigation Management: Examples of Sringeghat, Kapilbastu and Julfetar Irrigation Systems, Nawalparasi." Paper presentation by Mr. Rajendra Bir Joshi Floor Discussion
12.45-1.15		Perception on Climate Change and Reality in Small and Medium Irrigation Systems in Nepal" Paper presentation by Mr. Pravakar Pradhan Floor Discussion Concluding Remarks by Sub-Session Chairperson
1:15-2:15	Lunch	

Sub-session-3	**Sub-session-4**
Theme: Farmers**Perception of Farmers(CMIASP-AF)**	MUS: Challenges **and Applications**
Chairperson: Mr.Noore Mohammad Khan, CMIASP-AF	Chairperson: Mr. Som Nath Paudel
Reporter : Young Professional / Student	Reporter : Young Professional / Student

2:15-2.40	**NewarKulo, Panchthar** Presentation by a) Mr. Mani Kumar Pradhan WUA Chairman	2.15-2.45	" Upscaling MUSat Global Levels " Paper Presentation by Dr. Barbara VonKoppen. Floor Discussion
2.40 - 3.05	**Sulitar IS, Chitwan** Presentation by b) Mr. BhojBahadurRanaMagar WUA Chairman	2.45 -3.15	Economic Impact of the Multiple Use Water System Approach in Far West Nepal" Paper presentation by Dr. Corey O'hara, Dr. Luke Colavito, Dr. MadanPariyar, Mr. RabindraKarki Floor Discussion
3.05 - 3.30	**Atrauliputtar IS, Tanahu** Presentation by c) Mr. RamjiAryal WUA Chairman	3.15 -3.45	"Multiple Perceptions on Multiple-use Water Systems (MUS).A Reflection on Potential and Constraints for Institutionalising MUS in Nepal " Paper presentation by Dr. Floriane Clement & Ms. Farah Ahmed Floor Discussion

3.30 - 3.50	**Hadiya Dama Paini, Jhapa** Presentation by; d) Mr. Uday Narayan Dhungana WUA Chairman	3.45-4.15	" Local Financing for Functionality Sustainability and Service Level Improvement – An Opportunity for MUS?" Paper Presentation byMs. Sanna-Leena Rautanen Floor Discussion Concluding Remarks by Sub-session chairperson
3.50 - 4.15	**Chakhola IS, Kavre** Presentation by e) Mr. Gobinda Prasad Nepal WUA Vice - Chairman Floor Discussion Concluding Remarks by Sub-Session Chairperson		
4.15	**Tea at the Pre-function Area**		

Wednesday, April 12, 2017 (30 Chait, 2073)

Parallel Sessions		
Parallel Session-1: Climate change and methods of adaptation and approaches for increasing resilience		**Parallel Session-2, Water- Energy Benefit Sharing**
Skyline Hall		**Rato Baithak Hall**
Sub-session-5		**Sub-session-6**
Chairperson: Mr. Madhav Belbase, Joint Secretary, WECS.		Chairperson: Mr. Surya Nath Upadhaya, JVS
Reporter : Young Professional / Student		Reporter: Young Professional / Student
9.00-9:30	"Guidelines for Water Management of Highland Agriculture in Mae Sa Noi Village, Pongyang Sub-district, Maerim District, Chiang Mai Province " Paper presentation by Dr.Nathitakarn Pinthukas Floor Discussion	"Climate Resilience and Performance of Chapakot Irrigation System" Paper presentation by Dr. Khem Raj Sharma & Ms. Manju Adhikari Floor Discussion

9:30-10:00	"Water scantiness in Andhikhola River Basin: Farmers' adaptation strategies" Paper presentation by Ms. Shubhechchha Sharma Floor Discussion	"Integrating Irrigation Practices in Improved Water Mill Areas for Sustainable Livelihood" Paper presentation by. Mr. Mahendra Prasad Chudal Floor Discussion
10.00-10.30	" Integrating Resilience Concept In The Face of Changing Climate: Learning From Some NRM Projects In Nepal" Paper presentation by Dr. Ram Chandra Khanal Floor Discussion	" Solar Pumped Drip Irrigation." Paper Presentation byDr. Robert Yoder Floor Discussion
10.30-11.00	"Barriers Affecting Human LivingUnder Consequence of Climate Change in Chiang Mai, Northern Thailand" Paper presentation by JuthathipChalermphol, NathitakarnPinthukas, RujSirisunyaluck Floor Discussion Concluding Remarks by Sub-Session Chairperson	"Addressing Local Water Conflicts Through Multiple Use Water Systems (Mus):A Learning From Calcnr Program At Dhikurpokhari, Kaski, Nepal " Paper presentation by Dr. MadanPariyar, Mr. VijayaSthapitand Mr. Rakesh Kothari Floor Discussion Concluding Remarks by Sub-Session Chairperson
11.00-11.30	**Tea break at the Pre-function Area**	
Sub-session – 7		**Sub-session – 8**
Past and Future of Irrigation systems in the context of Climate change		**Theme: National Policy, Institution and Intervention Strategy**
Chairperson: Mr. Masoom Hamdard, Advisor, Ministry of Irrigation, Afghanisthan		Chairperson: Mr. Basu Dev Lohani, DDG, DOI
Reporter : Young Professional / Student		Reporter : Young Professional / Student

11.30-12.00	Multiple WaterUse Services: Economic cost/benefit analysis under Village water Resources Management Project. Paper presentation by Mr.Pallab Raj Nepal and Sushil Subedi Floor Discussion	Water, Food Security and Asian Transition: A New Perspective within the face of Climate Change Paper Presentation by Dr. Puspa Khanal, FAO Regional Office Floor discussion
12.00-12.30	“Maktumba FMIS Resilience: The Last 25 years and the Next “We Never had It So Good, but Now Our Youth is Leaving” Paper presentation by Dr. Arend Van Riessen Floor Discussion	Use of Remote Sensing & Geospatial Technologies in Agriculture Paper Presentation by Mr. Asit Srivastava Floor discussion
12.30-1.00	" Design Issues and Technologies of Hilly Irrigation Infrastructures in view of Climate Change: Case Study of Kalleritar Irrigation System" Paper presentation by Mr. AshishKhanal Floor Discussion	“Impact of Earthquake on Water Resources in Selected Earthquake Hit Areas" Paper presentation by Mr. SomNath Poudel and Ms. Anju Air, JVS Floor Discussion
1.00-1.30	"Addressing Climate Change Impacts on Farmers Managed Irrigation System Through Adaptation Measures" Paper presentation by Mr. Shree Bhagavan Thakur and Batu Krishna Uprety Floor Discussion Concluding Remarks by Sub-Session Chairperson	“People, Plan and Participative Municipal Planning of Natural Resources Management in Nepal: An Illusion" Paper presentation by Dr. Narendra Raj Paudel and Ms. SrijanaPahari Floor Discussion Concluding Remarks by Sub-Session Chairperson

1.30-2.30	**Lunch**
Plenary Session:	
Theme**: Meeting the Challenges of Climate Change: What Next?**	
Chairperson: Dr. Keshav Prasad Sharma	
Coordinator/Rapporteur: Dr. Khem Raj Sharma, Program Director, nec	
2.30-4.00	Panel : Panelist.1. Mr. Rajendra Adhikari, DG, DOI Panelist.2. Dr. Sugden Fraser, Head, IWMI-Nepal Panalist.3. Mr. Madhav Belbase, Joint Secretary, WECS Panelist.4. Dr. Ram Chandra Khanal, CDKN Panelist.5. Dr. Puspa Khanal, FAO, Regional Office. Panelist.6. Mr.Dipak Gyawali, Water Conservation Foundation. Floor Discussion Chairman’s comment Vote of Thanks and Closing of the Seminar
4.00	**Tea at the Pre-function Area**

Program of 1st Session, Skyline Hall

Farmer Managed Irrigation Systems (FMIS) at the Crossroads

Mapping Climate, Gender and Socio-ecological Challenges

April 11, 2017

11:15 am to 1:15 pm, Hotel Himalaya, Kupondol, Kathmandu

Nepal is well known for its tradition of farmer managed irrigation systems (FMIS). In this system, farmers are collectively engaged in irrigated agricultural development as an enterprise. Numerous FMIS in Nepal ranging from high lands to mid hills and tarai region, provides irrigation services to about 70 percent of the country's total irrigated area of little over of 1.2 million ha. However, due to recent changes in the socio-ecological systems, FMIS has come under increased pressure. Some of the systems are defunct while others are facing problems in operation and maintenance. There is an increased groundwater usage in the command area in tarai region and farmers are experiencing reduced flow of water systems. Due to increased migration in hills and tarai, feminization of agricultural labour has been reported. Understanding the recent challenges, this session is organized to understand the climatic, gender and socio-ecological challenges faced by FMIS. The session will map the socio-economic, gendered, environmental, institutional and governance challenges faced by FMIS today.

Programme Schedule

Chair: Dr. Robert Yoder, Former Head of Country Program, IIMI-Nepal

Moderator: Dr. Anjal Prakash, ICIMOD, Kathmandu

11:15 – 11:20 – Opening remarks by Dr. Robert Yoder

11:20 – 11:30 – Masculinity in Irrigation: Imperatives for gender transformative decentralized water governance – Dr. Anjal Prakash, ICIMOD

11:30 – 11:45 – Achieving gender water equity in the face of changing climate context: Lessons from local water planning practices in Nepal - Pranita B Udas, ICIMOD

11: 45 – 12:00 - Gender and Water Governance:Women's Role In Irrigation Management and Development – Dr. Dilli R Prasai, Tribhuvan University, Biratnagar, Nepal

12:00 – 12:15 - Understanding the irrigation governance and mechanisms of water resource management for improved adaptive capacity - Krity Shrestha, Practical Action, Nepal

Panel Discussions: 12:15 – 1:15

Mapping Climate, Gender and Socio-ecological Challenges in FMIS

Moderator; Dr. Anjal Prakash, Programme Coordinator – HI-AWARE, ICIMOD, Nepal

Panelists:

Dr. Van Koppen, Principal Researcher – Poverty, Gender and Water, International Water Management Institute

Dr. Chanda G Goodrich, Senior Gender Specialist, ICIMOD, Nepal

Dr. Floriane Clement, Theme Leader, Gender and Poverty, International Water Management Institute, Nepal

Mr. Basudev Lohani, Deputy Director General, Department of Irrigation, Government of Nepal

Farmer Managed Irrigation Systems Promotion Trust
Seventh International Seminar
on
"Irrigation in Local Adaptation and Resilience"
11-12 April, 2017
Hotel Himalaya, Kathmandu, Nepal
April 11, 2017

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Mr. Ramanand Prasad Yadav has kindly launched the book "Study on Application of Modern Technologies to Facilitate Commercial Irrigated Agriculture for Improving Rural Livelihood in Nepal", the research study is being carried through FMIST on the assistance of Food and Agriculture Organization. Regional Office, Bangkok.

Mr. Ramanand Prasad Yadav Secretary, Ministry of Irrigation launching the book on the occasion of Seven International Seminar on FMIS, Hotel Himalaya, Lalitpur, Nepal

Presentation of Honor Award in Opening Session

Upendra Gautam being honored with the traditional Nepali shawl by Naveen Mangal Joshi

Md. Abdul Ghani being presented the commendation plaque by Suman Sijapati

Md. Abdul Ghani being presented a bouquet by Sushil Subedee

Ramanand Prasad Yadav,Chief Guest delivering remarks

Medini-Kamala Award Presentation for better performing FMIS

Mr. Lava Raj Bhattarai, Presenting Commendation Plaque and cash to Newar Kulo, Panchthar

Mr. Naveen Mangal Joshi, Presenting Commendation Plaque and cash to Shringeghat Irrigation System, Kapilbastu

SESSION PRESENTATION AND DIALOGUE

PARTICIPANTS IN THEIR PENSIVE MOOD

Panel Discussion

Participants: A Moment of Togetherness

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