Proceedings of 9th National Irrigation Seminar

Irrigation Development and Management: Learning from the Past and Planning for the Future

June 10 – 11, 2016 (28 – 29 Ashad, 2073)

Dhulikhel, Kavre

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FOREWORD

Presently, our country has been going through subsistence economy development. Replacement of bulk import of foods from foreign country and progress on food security has been prime importance of the country. In one side climate change has been impacting the agriculture sector with increasing the number of high intensity rainfall and shifting the time period of rainfall, on other side high numbers of youths have been leaving the agriculture sector in order to work as labor in foreign country. Even though remittance has been shielding the economy of the country, it is not sustainable so far. So the prime importance of country on achieving the target of food security is development and expansion of irrigation infrastructure for providing the irrigation services to farmer's level, which eventually strengthen the country on self reliance on food. So, an irrigation service can directly support for poor farmers' economy through increment of agriculture production and agriculture productivity, which impact on fulfillment of basic need of the country. However, assurance of irrigation throughout the year rather than expansion of irrigation services is prime obstacle of irrigation sector. To explore the hindrance of irrigation development and aspects of development and management of irrigation sector in the changing context, DOI is organizing a national irrigation seminar each year since 2007 A.D. In continuation to it, Ninth National Irrigation Seminar with theme "Irrigation Development and Management: Learning from the Past and Planning for the Future"was organized on 2073/2/28 -29 (10-11 June, 2016) to bring national level stakeholders from government and non-government sectors in one forum to discuss the various issues of irrigation. This proceeding is a collection of findings of the seminar and hope that it will be helpful in fulfilling the future need for planning irrigation development and management.

On behalf of Department of Irrigation, I would like to thank INPIM-Nepal, IWMI- Nepal and ICIMOD-Nepal for being the co-organizer in hosting the seminar. My special thanks goes to Hon. Minister Mr. Umesh Kumar Yadav, Ministry of Irrigation for his encouraging support and guidance by attending the seminar full time for overall irrigation development and management. I am very much thankful to Mr. Kashi Raj Dahal, President, Administration Court for informative and meaningful presentation on "Federalism in Irrigation". Paper presenters are well acknowledged for their valuable technical papers and presentations. I am thankful to the participants for the active participation and lively discussions. I would like to thank Mr. Bashu Dev Lohanee, DDG, DOI and the seminar organizing committee for their laborious work in organizing the successful seminar. Lastly, I would like to extend my appreciation to all who were directly or indirectly involved to make this seminar successful.

Ramanand Prasad Yadav
Director General
Department of Irrigation

Contents

ACRONYMS

ADB-	Asian Development Bank
CDKN-	Climate Development and Knowledge Network
DFID -	Department for International Development
DG-	Director General
DOI-	Department of Irrigation
F/Y-	Fiscal Year
FAO	Food and Agricultural Organization
FGD-	Focus Group Discussion
GDP-	Gross Domestic Production
GHI-	Global Horizontal Irradiance
GIS -	Geographical Information System
GWRDB-	Ground Water Resources Development Board
ICT-	Information Communication Technology
IMC-	Irrigation Management Center
IMP-	Irrigation Management Project
IWRM -	Integrated Water Resources Management
MOI-	Ministry of Irrigation
RII-	Relative Importance Index
SDGs-	Sustainable Development Goals
SMIS-	Sunsari Morang Irrigation System
SWERA-	Solar and Wind Energy Resource Assessment
UNEP -	United Nations Environmental Program
USAID -	United States Agency for International Development
VDC-	Village Development Committee
WUA-	Water Users' Association

1. INTRODUCTION

1.1. Background

Department of Irrigation (DoI) has been organizing National Irrigation Seminars every year since 2007 A.D. The main objective of this seminar is to review the achievement of past events and explore future opportunities and challenges for the development and management of Irrigation sector. Senior level officials from Minister of Irrigation and its line agencies participated in the workshop. National Irrigation Seminar held on June 10-11th, 2016 (28 – 29 Ashad, 2073) at Dhulikhel Lodge Resort, Dhulikhel was its ninth edition. It was jointly organized by Department of Irrigation (DOI), International Network for Participatory Irrigation Management - Nepal (INPIM-Nepal), International Water and Management Institute - Nepal (IWMI-Nepal), and International Center for Integrated Mountain Development - Nepal (ICIMOD-Nepal). System Management and Transfer Programme (SMTP), Integrated Water Resources Management Project (IWRMP) and Community Managed Irrigated Agriculture Sector Project – Additional Fund (CMIASP- AF) have financed the seminar from DOI part. Fifteen technical papers and one special paper were presented in five different subthemes in the workshop. More than 150 experts and intellectuals from Ministry of Irrigation and Water sector attended the workshop.

1.2. Rational of the workshop

The history of Irrigation Development in Nepal dates back to 1985 B.S. with the construction of Chandra Nahar, the first irrigation system of Nepal. Irrigation system construction through Government budget was started from 1985 B.S., although, Farmers Managed Irrigation System (FMIS) was practiced traditionally before that time. The total irrigable land of the country is 17,66,000 hectare, and DOI has developed irrigation structure to 77.51% of total irrigable land. National Water Plan has set a target to irrigate 97% of total irrigable land by 2027 and to provide year round irrigation in 67% of total land.

DoI has been developing and running irrigation projects in several districts of Nepal with the goals of attaining equitable economic development, regional balance and food security. But, these goals can only be met with significant efforts like proper planning, sound policies, introduction and adoption of new technology and proper management skills.

There has been huge investment in irrigation structures in past but lesser budget has been allocated for its operation and maintenance cost. This tendency results system inefficiency, structural failure, low crop production, imbalance between supply and demand management. Hence, we need to adopt proper management plans for the sustainability and effectiveness of the system. Taking above mentioned concern into consideration, Irrigation National Seminar, 2073 was organized.

1.3. Seminar objectives

The overall objective of the seminar was to understand the real scenario of irrigation issues and challenges, to share knowledge and to identify problems for better development and management in the days to come. The specific objectives of the seminar were:

- To provide a common platform for experts to share experiences, lesson learned and discuss on issues, challenges and opportunities related to irrigation development and management.
- To bring together different sectors working in the field of water resources and to share their experiences, issues and to incorporate them in irrigation development.
- To create a platform for former irrigation experts and technical persons of DOI, and MOI to come together and discuss for future irrigation improvement.
- To discuss on multiple water use and to introduce new irrigation technologies for increasing irrigation efficiency.

1.4. Content of the Seminar

The theme of the Workshop was "Irrigation Development and Management: Learning from the Past and Planning for the Future". However, it was divided into nineteen sub themes. Thus five technical sessions given below were conducted. Those sessions were closely linked and formulated according to the expected outcomes and objectives.

1. Gender and Participation
2. Resource Assessment and Irrigation Efficiency
3. Multiple use of water
4. Legal and Management issue in Irrigation
5. New Approaches in Irrigation

There was a special presentation by Mr. Kashi Raj Dahal, Chairperson, Administrative Court, on Federalism in Irrigation. And one plenary session was conducted as last session. Following fourteen technical papers that focused in the above mentioned sub themes were presented in the seminar.

Technical Session I (Gender and Participation)		
S.N.	**Paper Title**	**Author(s)**
1	Water, Gender and Local Economy: with multi-functional perspective	Mr. Dilli R. Prasai
2	Preliminary Findings from a Field Study on Increasing the Resilience of Small and Medium Scale Irrigation Systems in Nepal	Mr. Prachanda Pradhan, Mr. Umesh Parajuli, Mr. Keshav Sharma
3	Farmer Managed Irrigation System and Gender Participation (A case study of sorah-chhattis mauja irrigation system, Rupandehi)	Mr. Ashok Chaudhary
Technical Session II (Resource Assessment and Irrigation Efficiency)		
4	Delineation of Groundwater Potential Zone in the Indo-Gangetic Plain through GIS Analysis	Mr. Dinesh Pathak
5	Operational Dynamic of an Irrigation System-Performance Assessment: A Case Study of Sunsari Morang Irrigation System (SMIS)	Mr. Randhir Sah
6	Assessment of Water Resources and Irrigation Potential in Nepal. A case study: Sunsari, Saptari and Dhanusha Districts	Mr. Birendra Yadav
7	Understanding and managing spring systems for sustainable groundwater development in mountain regions: Experiences from Doti and Baitadi Districts	Ms. Ambika Khadka, Mr. Romulus Okwany
Technical Session III (Multiple use of water)		
8	Multiple use of irrigation water: way towards sustainable irrigation management	Mr. Santosh Kaini
9	Optimum Multi Use of Downstream Augmented Water: A Case study of Budighandaki Hydro-Electric Project	Mr. Suraj Lamichhane
10	Optimal reservoir operation based on economic value of different water uses in the Komati Catch-ment	Mr. Krishna Prasad Upadhyay
Technical Session IV (Legal and Management issue in Irrigation)		
11	Arbitration Issues & status in Irrigation	Mr. Kalanidhi Paudel/ Bishnu Mani Adhikari
12	Practices and prospective of e-procurement sys-tem in Department of Irrigation	Ms. Deepa Gautam

Technical Session V (New Approaches in Irrigation)		
13	Strategic Approach to Small Scale Irrigation Development: Action Research Experience	Mr. R.R.S. Neupane
14	Water Lifting Technologies for Tar Irrigation	Mr. Sagar Kumar Rai
15	Potential of using Solar Lift Irrigation in Hilly Region of Nepal	Mr. Manoj Pantha
Plenary Session		
"Past and Future of Irrigation"		
Facilitator: Mr.Madhav Belbase Rapporteur: Mr. Rajendra Bir Joshi Panelist : Sheetal Babu Regmi, Shiva Kumar Sharma, Sharda Prasad Sharma, Prachanda Pradhan, Ratneswor Lal Kayastha, Bhubanesh Kumar Pradhan, Khem Raj Sharma		

Agenda of the program (with schedule) is attached in Annex I.

1.5. Participants

Irrigation experts and intellectuals from different organizations participated in the seminar. They were selected on the basis of the following categories:

- Paper contribution
- Special invitees
- Official representation from Ministry of Irrigation
- Official representation from Water and Energy Commission Secretariat
- Official representation from Department of Irrigation
- Official representation from Department of Water Induced Disaster and Prevention
- Official representation from International Water Management Institute (IWMI)-Nepal
- Official representation from International Network for Participatory Irrigation Management (INPIM)-Nepal
- Official representation from International Centre for Integrated Mountain Development(ICIMOD)-Nepal
- Consultant of DOI
- Seminar Management Committee

List of Participants is attached in Annex III.

2. PROCEEDING

2.1. Registration and Opening session

The seminar was formally inaugurated by chief Guest Hon. Minister, Mr. Umesh Kumar Yadav, and Minster of Irrigation (MOI) on 10th June 2016 at Dhulikhel Lodge Resort, Dhulikhel by watering the plant. Mr. Kashi Raj Dahal, Chairperson Administration Court and Mr. Dhan Bahadur Tamang, Secretary, WECS were the special guests. Mr. Jagat Prasad Joshi, Executive Director, GWRDB; Mr. Maheswor Narsingh K.C., Director, WR Development and TC; Mr. Ram Prasad Mehta, NFIWUAN were guests for this session. The session was chaired by Mr. Ramananda Prasad Yadav, Directer General, DOI. Mr. Dev Raj Niraula was the Mastery of the Ceremony. More than 150 personal were participated in the program from Ministry of Irrigation, different government agencies, National and International agencies and freelancing experts.

Mr. Sushil Chandra Tiwari, DDG, DOI welcomed the participants and paper presenters. He briefly highlighted the rationale of this seminar in the present context. Mr. Tiwari stressed on the importance of the workshop's theme for addressing the need of irrigation services and experiences gained through development of irrigation infrastructure from last five decade should be a good mentor for coming days. Mr. Tiwari encouraged participants for active participation in workshop sessions to contribute their respective roles, scope, possibilities and challenges towards effective of Irrigation Development. Mr. Bashu Dev Lohanee, DDG, DOI presented the design and content of the seminar in brief. He presented the different activities, highlighted the overview of the session structures and their objectives, content and expected outputs that could influences the future decision making.

Mr. Maheswor Narsingh K.C., Director, Water Resources Research and Development Center, highlighted the importance of experience sharing and role of senior irrigation engineer towards the betterment of irrigation development. Mr K.C. emphasized on intervention of new technology in irrigation and agriculture development.

Mr. Jagat Prasad Joshi, Executive Director, GWRDB, explained the status and uses of groundwater in Country. He stressed on the role of Ground Water Development Board in ground water development and management and associated constraints behind it.

Mr. Dhan Bahadur Tamang, Secretary, WECS highlighted the essence of the program with present and future necessities in irrigation management. He noted the previous policies related to the irrigation management as achievements and suggested reviewing past activities with existing research data for future course. "Many policy documents are prepared; some achievements are already at our hand; therefore timely action is needed to translate this seminar theme into practice", he addressed. He stressed on participatory irrigation development approach for sustainable agricultural practice. "For this, attracting youth in agriculture is major challenge for the present", he said.

"Without optimum use of available water resources, including surface and ground water, prosperity is not possible; IWRM principle must be followed to prepare new water resource strategy by analyzing prevailing research and by identifying their deficiency", he added. Mr. Tamang presented guidelines for new model of water development strategy through participatory approach assimilating related technologies. He mentioned new technology, new modality of water development, large project, participatory development as future way out. He said that IWRM principle and basin concept must be followed while preparing new water resources strategy.

The chief guest Mr. Umesh Kumar Yadav, Hon. Minister of Irrigation, mainly focused on long term water resource strategy to institutionalize the essence of new federal structure, which was achieved through huge struggle. He emphasized on development of water resources as tool to end prevailing discrimination and poverty. He further mentioned that poor are being poorer, therefore long term strategy must be planned to overcome struggle with poverty. Minister Yadav showed his commitment to implement conclusion of this seminar. He applauded the seminar conducted in an appropriate time as the nation is adopting federal structure. He urged to organize such seminar in the beginning of the fiscal year for its proper implementation to include the seminar agenda in the budget program. He cautioned about the future possible conflict regarding use of water resource in federal structure. "Population is growing and land is shrinking", Minister Yadav added, "MOI has capacity to cope with existing challenges." He also focused on the use of technology as per local needs in irrigation management system for water reservation and conservation both. Mr Yadav ensured to implement the decision to have all women officials at Irrigation Development Division, Kathmandu.

Finally, Chairperson Mr. Ramanada Prasad Yadav, DG, DOI welcomed the participants. He emphasized on the necessity use of technology for the benefits of farmers. He stressed on being curios and excited as diversion project is implementing first time in Nepal. So, irrigation department should now focused on intervention of new technology in irrigation development and should not however forget the important and practices of old development aspect. He added that these two days spend in vigorous discussions in the workshop will bring some fruitful outcomes for DOI working strategies.

2.2. Special presentation

A special presentation was allocated for Mr. Kashi Raj Dahal, President, Administration Court on theme "Federalism in Irrigation". Mr. Dahal emphasized on adaptation of water resource management policy on new federal structure of the country. Illustrating world trends on natural resources management and distribution, Mr Dahal suggested for development of effective water resource strategy to distribute water resources in equitable manner. He presented different models applied in developed countries as dualistic model, co-operative model or interlocking model, symmetric and asymmetric model, which has been applied in America, Germany, Canada and other countries. Identifying present challenges, he also mentioned irrigation water as a source of sustainability of national economy. "Suitable policy formulation and implementation, political consensus, and right working procedure are necessary to translate the constitutional provisions into practice", he emphasized.

He marked power sharing distinction of federal, state and local level structure. He explicitly illustrated the constitutional provisions related to water irrigation and their uses in the context of state structure and distribution of state power. The constitution of Nepal, 2072 has envisioned fulfilling the aspirations for the sustainable peace, good governance, development and prosperity through the federal democratic republic system of governance.

According to the constitution of Nepal (2072), central level large electricity, irrigation and other projects are listed under federal power. Likewise, state level electricity, irrigation and water supply services and navigation are enlisted under list of state power. Schedule-7 of the constitution has enlisted the list of concurrent powers of federation and state on state boundary river, waterways, environment protection and biological diversity. Water supply, small hydropower projects and alternative energy is listed in local level power. Services such as electricity, water supply and irrigation are enlisted in concurrent powers of federation, state and local level.

President Mr. Dahal sketched out an organization structure related to water resources distribution, which could be applied in new federal structural. Separate irrigation sections were suggested in all three levels.

2.3. Session I: Gender and Participation

This session was chaired by Mr. Dhan Bahadur Tamang, Secretary, WECS. Rapporteur for the session was Mr. Gauri Lal Upadhya, Senior Sociologist; DOI. Three papers were presented in the session. Sub-theme of this session was Gender and Participation.

The first paper was about Farmer Managed Irrigation System and Gender Participation: A case study of Sorah-chhattis Mauja irrigation system, Rupandehi. The second paper was about Water, Gender and Local Economy: with multi-functional perspective. The third paper was about Preliminary Finding from a field on Increasing the Resilience of Small and Medium Scale Irrigation Systems in Nepal.

2.3.1. Farmer Managed Irrigation System and Gender Participation: A case study of Sorah-chhattis mauja irrigation system, Rupandehi

Mr. Ashok Kumar Chaudhary presented paper on Farmer Managed Irrigation System and Gender Participation: A case study of Sorah-chhattis mauja irrigation system, Rupandehi. He mainly expressed his idea on women's participation in irrigation system. His research findings, as he presented, suggested increasing participation of women in irrigation sector. However, he revealed several obstacles in women's participation because of Parda system, traditional culture, and lack of awareness and low level of female literacy. He stressed on awareness and training for women on irrigation management to increase their participation as well as their farm productivity. He unfolded some trends in decreasing participation in the irrigation system due to increased education and income, off-farm employment and use of alternative means of irrigation.

2.3.2. Water, Gender and Local Economy: with multi-functional perspective

Mr. Dilli R. Prasai presented paper on the topic of Water, Gender and Local Economy: with multi-functional perspective. He pointed out women's rights, specially increasing their access, in water resources from human rights perspective. He suggested making efforts for guaranteeing women's ownership in water resource. He insisted on design of capacity development and technical knowhow for women. He further addressed on necessity of women participation in decision making process. He figured out that 10 per cent of world population was lacking access to drinking water. He also said that women had involvement in irrigation system but did not have recognition from water rights perspective. Women's voice recognition, capacity building, participatory irrigation and technical enhancement were his suggestions for women's rights in water.

2.3.3. Preliminary Findings from a Field Study on Increasing the Resilience of Small and Medium Scale Irrigation Systems in Nepal

Mr. Prachanda Pradhan, Umesh Parajuli and Keshav Sharma jointly presented paper on the Preliminary Findings from a Field Study on Increasing the Resilient of Small and

Medium Scale Irrigation systems in Nepal. They highlighted the scope of small and medium scale irrigation in agriculture and described that as the mainstay of national economy. Need of improvement in irrigation sector was also recognized in their presentation. As per their presentation, climate change will only make the situation worse, and will also be difficult to make future projection about how farmers respond to an uncertain climate. The research paper have also identified flood, sedimentation, low production, change in crop calendar, decreasing water level impacts of climate change. Strength of community-based organizations, infrastructure and importance of agriculture in local economy are identified as determinant factors in adapting climatic and other changes. The paper has also suggested enabling diversification into higher value crops with new markets and road access opportunities. Need of improvement in catchment-level management is highlighted.

2.4. Session II: Resources Assessment and Irrigation Efficiency

This session was chaired by Mr. Bhubanesh Kumar Pradhan, Ex-secretary, Ministry of Water Resources and rapporteur was Mr. Chetman Budhthapa, SS, DOI. Four papers were presented in the session focused on resource assessment and irrigation efficiency. The first paper described about Delineation of Groundwater Potential Zone in the Indo-Gangetic Plain through GIS Analysis. The second paper highlighted on Operational Dynamic of an Irrigation System Performance Assessment: A case Study of Sunsari Morang Irrigation System (SMIS), the third paper focused on Assessment of Water Resources and Irrigation Potential in Nepal: A Case Study of Sunsari, Saptari and Dhanusha Districts. The fourth paper focused on Understanding and Managing Spring Systems for Sustainable Groundwater Development in Mountain Regions: Experiences from Doti and Baitadi Districts.

2.4.1. Operational Dynamic of an Irrigation System- Performance Assessment: A Case Study of Sunsari Morang Irrigation System (SMIS)

Mr. Randhir Sah presented paper on Operational Dynamic of an Irrigation System -Performance Assessment: A Case Study of Sunsari Morang Irrigation System (SMIS). His presentation was focused on the operation performance of a Secondary Canal S9 of SMIS for design and actual operation condition of winter season (1-December, 2013 to 31-March, 2014). Mr. Shah pointed out that, in actual operation condition, actual supply was less than intended in the winter season and discharge was fluctuating day by day. The indicators adequacy and efficiency had small deviation from design case but the spatial and temporal variation coefficient were poor than design value due to structural limitation and frequency of supply were concentrated in January month. Comparing the operation performance between design and operation, he made recommendations for performance enhancement. He made conclusion remarks saying that water flow in S9 canal was continuous and lower order canal ran in 1:2 mode of operation during peak demand, therefore, strict follow up of operation procedure is required to obtain high performance of water delivery. He has also recommended for logical operation plan in future.

2.4.2. Assessment of Water Resources and Irrigation Potential in Nepal - A case study of Sunsari, Saptari and Dhanusha Districts.

Mr. Birendra Kumar Yadav presented a paper on Assessment of Water Resources and Irrigation Potential in Nepal: A Case Study of Sunsari, Saptari and Dhanusha Districts. His research paper was about available water resources for dry season based on the groundwater recharge and storage volumes in the ponds. Mr. Yadav used Surface (golden software) and Water Table Fluctuation method used for recharge estimation. His research findings have explored annual and monthly fluctuation of water table contours with spatial and seasonal fluctuation of water table in study districts. However, sufficient water availability is found to meet the demand of dry season cropping in all three districts, which reflects that there is potential to irrigate all rainfed land in winter and spring season. His study has showed that this type of irrigation system will finally increase agricultural production and productivity of the area and which will help in income generation of subsistence farmers as a tool of poverty reduction.

2.5. Session III: Multiple use of Water

This session was chaired by Mr. Sharada Prasad Sharma, ex-DG and Rapporteur for the session was Mr. Basu Dev Timilsina, SDE, DOI. Three papers were presented in this session. All papers were related to multiple use of water. The first paper was presented on Multiple Use of Irrigation Water: Way towards Sustainable Irrigation Management and the second paper was about Optimum Multi Use of Downstream Augmented Water: A Case study of Budighandaki Hydro-Electric Project. The third paper focused on Optimal Reservoir Operation Based on Economic Value of Different Water Uses in the Komati Catchment.

2.5.1. Multiple Use of Irrigation Water: Way towards Sustainable Irrigation Management

Mr. Santosh Kaini presented paper on Multiple Use of Irrigation Water: Way towards Sustainable Irrigation Management. This study focused on multiple uses of irrigation water. Chaud Irrigation Scheme was taken as the case study site which lies in Sarmauli VDC of Darchula district, Far-western Development Region of Nepal. His study has explored multilateral dimensions of irrigation water connecting them with sustainable irrigation management to food security. He remarked that food sufficiency has been uplifted to whole year after irrigation development which was insufficient for more than nine months before.

2.5.2. Optimum Multi Use of Downstream Augmented Water: a Case study of Budighandaki Hydro-Electric Project

Mr. Suraj Lamichhane made an analytical presentation on the principle of downstream benefit from augmented flow of reservoir operation of Budigandaki Hydroelectricity Storage Project within national boundary of Nepal. He presented details on potential downstream benefits like hydropower, irrigation, water supply, flood control, water transport and so on. Giving some successful international water resources examples, he has presented that water utilization projects of Nepal are financially viable, technically feasible and socially acceptable. The Budhigandaki Storage Project is presented as a unique opportunity for implementing new paradigm of cooperation for joint water resources development between Nepal and India. He has suggested identifying water utilities project not only on the basis of present monetary benefits but also on the assessment of socioeconomic impacts and possibility of future development. Mr. Lamichhane showed hydropower, irrigation, water supply, water transport, recreation as elements of downstream benefits. Feasibility study was carried out in large river in Nepal; however, little efforts are made in utilizing available water resources. The data showed that only 1.7 percent of total economically feasible (43000 MW) power is harnessed and only 52 percent of households have piped or taped supply for drinking water.

2.5.3. Optimal Reservoir Operation Based on Economic Value of Different Water Uses in the Komati Catchment

Mr Krishna Prasad Upadhyay presented paper on Optimal Reservoir Operation Based on Economic Value of Different Water Uses in the Komati Catchment. The study has found higher water stress in the catchment area because of increased water withdrawal and consideration of environmental flows. He stated that water use in the Komati catchment had increased since the commission of large dams after late 1960s. During his presentation, Mr. Upadhaya made analytical presentation of different water use in the basin undertaking current water allocation system and their economic values. Furthermore, he had shed light on irrigation, commercial plantation, domestic, industrial, inter-basin transfer, hydropower, recreation and environmental aspects.

2.6. Session IV: Legal and Management Issue in Irrigation

This session was chaired by Mr. Madhav Belbase, Joint- Secretary, MOI and the rapporteur was Mr. Kailash Shrestha, SDE, DOI. Two papers on Legal and Management Issues in Irrigation were presented in the session. The first paper was focused on Arbitration Issues and Status in Irrigation and the second paper was on Practices and Prospective of e-procurement System in Department of Irrigation.

2.6.1. Practices and Prospective of e-procurement System in Department of Irrigation

Ms. Deepa Gautam highlighted the essence of e-procurement system in government expenditure accounts for the public procurement process of DOI. She made detail analysis on the relatively important areas of strength, weakness, opportunity and threat. She recommended addressing the factors hindering the pace of e-Procurement as identified for maximizing the strength and seizing all possible opportunities of e-Procurement system. Presenting some loopholes in e-procurement system in DOI, she showed political intimidation and collusion as major hindrance in fair procedure. She recommended for past experiences to be drafted in suitable regulation/guidelines for e-Procurement system. She also emphasized for extensive and basic level training, effective government to government communication mechanism, and sound internet facility with continuous power supply to address the existing problems.

2.7. Session V: New Approaches in Irrigation

This session was chaired by Mr. Shiva Kumar Sharma, ex-DG, DOI and Rapporteur was Mr, Danda Pani Joshi, SDE, DOI. Three technical papers were presented in the session. The subtheme of the session was New Approaches in Irrigation. The first paper presented by Mr. R.R.S. Neupane, was about the Strategic Approach to Small Scale Irrigation Development: Action Research Experience. The second paper, presented by Mr. Sagar Kumar Rai, was about Water Lifting Technologies for Tar Irrigation and the third presented by Mr. Manoj Pantha was about Potential of Using Solar Lift Irrigation in Hilly Region of Nepal.

2.7.1. Strategic Approach to Small Scale Irrigation Development: Action Research Experience

Mr. R.R.S. Neupane presented the paper on strategic approach for small scale irrigation development projects. The paper highlighted the events during Irrigation Management Project (IMP) Period (1985-1992) with an aim to learn program effectiveness in achieving targets on small scale irrigation development. The project was launched at

Malebagar Farmer Managed Irrigation Schemes (25 ha) in Tanahu Districts of Nepal. He illustrated the strategic approach adopted for problem diagnosis, system planning and program implementation over traditional feasibility study approach and rehabilitation focused project development, appeared result oriented, effective participative and more sustainable development. According to his presentation, the approach and knowledge sharing of the study would be useful to the promoters of small scale farmer managed irrigation schemes in Nepal and elsewhere.

2.7.2. Water Lifting Technologies for Tar Irrigation

The paper presented by Mr. Sagar Kumar Rai highlighted water lifting technologies for flat agricultural lands called 'Tar' in hilly regions of Nepal. The paper focused on Machuwa and Akhuwa, two big and flat agricultural land lands so called Tars situated at the right and left banks of the Arun River. Both Tars belonging to the southern parts of the Bhojpur and Dhankuta districts, situated on the north dipping Phyllite type of rocks having east – west strike and contained about 100/100 ha agriculture land and made up of very fertile type of soil. The study found most of the local people of this area economically poor, socially backwards and suffering from malnutrition. The study also suggested that they didn't have enough food due to low agricultural production in absence of reliable irrigation facilities round the year.

The study found that dependency on rainfed agricultural production couldn't suffice the basic needs. People were only able to plant maize in those area. And, after the maize harvesting, the land was dry and barren through out the remaining period.

The study recommended providing reliable irrigation facilities in the Tars so that, the local people would be able to grow 3 to 4 crops in a year and able to produce enough agricultural production (grains, fruits and vegetables) from the land. The study suggests two possible technologies: a modified type of DTW and a modified type of lifting water. They were found simple, executable and affordable in the practice. The method cost in the range of 70 to 80 hundred thousand and can irrigate about 40 to 80 hector of land during the dry season.

2.7.3. Potential of Using Solar Lift Irrigation in Hilly Region of Nepal

Mr. Manoj Pantha presented paper on Potential of Using Solar Lift Irrigation in Hilly Region of Nepal. The paper deals with usage of solar energy technology for irrigation in hilly regions of Nepal and tried to identify areas that are suitable for using solar water pumps. Mr. Pantha has presented Nepal as a country gifted with abundant solar energy resources where more than 300 days of sunshine lies in a year. Mr. Pantha showed way out to reduce water scarcity problem in' difficult terrains' or 'Tars' through pumping water by using solar power. He presented this as a sustainable solution for food security and poverty reduction. He identified that about 120 thousand hectares of cultivable land, within a buffer distance of 2000 meter along the bank of major rivers in hilly region of Nepal, were suitable for single stage pumping (pumping head between 30 m to 200 m). He further estimates that benefits equivalent to about 0.95 USD could be obtained from agricultural products by using unit volume of water for irrigation. The study envisaged irrigation facilities on these 120 thousand hectares of suitable areas, about 860 thousand populations in hilly region will be directly benefited and country can save approximately 104 billion Nepalese rupees flowing out annually through import of agricultural products from foreign countries.

2.8. Plenary Session: Past` and Future of Irrigation

Mr. Madhav Belbase, Joint Secretary, MOI was the facilitator and Mr. Rajendra Bir Joshi was the rapporteur for this session. Mr. Sheetal Babu Regmi, ex- secretary, Mr.Shiva Kumar Sharma, ex-DG, Mr.Sharda Prasad Sharma, ex-DG, Mr. Prachanda Pradhan, Irrigation export, Mr. Ratneswor Lal Kayastha,ex-DG, Mr. Bhubanesh Kumar Pradhan,ex-Secretary and Mr. Khem Raj Sharma,ex-SMTP chief were key note speakers for the session experts.

2.9. Closing Session

The Seminar was concluded on 11 June, 2016. Mr. Umesh Kumar Yadav, Hon. Minister, MOI was the chief guest and Mr. Ramanand Prasad Yadav, DG, DOI was the chairperson of the session. Representative from NFIWUAN was the special guest of the session.

Closing session was started with overall remarks of the seminar by Mr. Bashu Dev Lohanee, DDG, DOI. He highlighted the key points raised in the workshop. Summarizing the seminar discussions, he stressed on policy improvement of irrigation sector. He said that the seminar was successfully completed more than expected.
Mr. Ashok Singh, DDG, DOI thanked all the participants for the lively discussion and active participation. He also thanked the organizing committee for making the seminar success with sound management.

Hon. Minister, Mr. Umesh Kumar yadav said that the seminar has provided a platform to learn new experiences from different sectors. He was thankful to the entire paper presenters. He marked it as a historic event. He suggested for organizing seminar in the beginning of the fiscal year early before budget formulation. He emphasized on adopting of new technology and on making it familiar with farmers. He recommended that findings of seminar discussion should be implemented on farmer's field Mr. Ramananda Yadav, DG, DOI, concluded the seminar by saying that this seminar was completed historically. He said that farmers have been benefiting by using new technology. He thanked all the participants for active and lively discussion. He expressed special thanks to its co-organizers INPIM-Nepal, IWMI-Nepal, and ICIMOD-Nepal for their regular support. He further expected their coordination and collaboration in near future. Full paper of presentation are given in annex II

3. CONCLUSION

The two day seminar program under the title "Irrigation Development and Management: Learning from the Past and Planning for the Future" became successful for the future pathways of Irrigation sector. The discussion and conclusion drawn from the seminar definitely will be one of the pathways for future irrigation development. Beside, the output of the seminar will be very helpful on the irrigation improvement and be pathways for efficient irrigation in coming days.

Some of conclusions made from the seminar are listed below:

1. Farmer Managed Irrigation System (FMIS) has long history of development and self-management through farmers. Economical and management burden of FMIS towards government is very low. In the same way, contribution towards irrigated agriculture is profound due to well management and participatory approach.

2. Multiple use of irrigation water demonstrates good strategy towards economic and healthier uplift of farmers. Multiple use of water enable farmers to pay for service fee which finally contribute towards sustainability of irrigation system through timely and regular operation and maintenance of the system.

3. Solar power and spill energy of flowing water could be new energy source for irrigating the remote and Tars patches in River corridors. Scope and opportunities of such innovative methods need to be assessed.

ANNEX-I

PROGRAM SCHEDULE

National Irrigation Seminar, 2073

"Irrigation Development and Management: Learning from the Past and Planning for the Future"

Program Schedule

Venue: Dhulikhel Lodge Resort, Dhulikhel
Date: 2073/2/28 – 29 (2 days) (10- 11 June, 2016)
Master of Ceremony: Mr. Dev Raj Niraula

DAY 1 (Jestha 28, 2073, Friday)		
9:30–10:30	Registration of Participants and Breakfast	
Inaugural Ceremony (10:30-11:30)		
Chairperson: Mr. Ramanand Prasad Yadav, DG, DOI		
Chief Guest: Hon. Minister, Umesh Kumar Yadav, MOI		
Special Guest: Mr. Kashi Raj Dahal, Chairperson, Administration Court		
Special Guest: Mr. Gajendra Kumar Thakur,Secretary, MOI		
Special Guest: Mr. Dhan Bahadur Tamang, Secretary, WECS		
Guest: Dr. Yuwak Dhoj G.C., Director General, DOA		
Guest: Mr. Jagat Prasad Joshi, Executive Director, GWRDB		
Guest: Mr. Maheswor Narsingh K.C., Director, WR Development and TC		
Guest: Mr. Ram Prasad Mehta, NFIWUAN		
Inauguration by Hon. Minister (Watering the plant)		
Time	**Activities**	**Resource Persons**
10:30–10:35	Welcome Address	Mr. Sushil Chandra Tiwari, DDG,DOI
10:35–10:40	Introduction to the seminar design and content	Mr. Bashu Dev Lohanee, DDG, DOI
10:40–10:45	Few words from guest	Representative, NFIWUAN
10:45 –10:50	Few words from guest	Mr. Maheswor Narsingh K.C., Director, WR Development and TC
10:50 –10:55	Few words from guest	Mr. Jagat Prasad Joshi, Executive Director, GWRDB
10:55 –11:00	Few words from guest	Dr. Yuwak Dhoj G.C., Director General, DOA
11:00–11:05	Few words from Special guest	Mr. Dhan Bahadur Tamang, Secretary, WECS

11:10–11:15	Few words from Special guest	Mr. Kashi Raj Dahal, President, Administration Court
11:15–11:20	Few words from Chief guest	Hon. Minister Umesh Kumar Yadav , MOI
11:20 –11:25	Few words from Chairperson	Mr. Ramanand Prasad Yadav, DG, DOI
Special Presentation		
11:30–12:00	Federalism in Irrigation	Mr.Kashi Raj Dahal
Technical Session I (Gender and Participation)		
Chairperson: Mr. Ratneshwor Lal Kayastha		
Rapporteur: Mr. Gauri Lal Upadhyay		
12:00 – 12:20	Farmer Managed Irrigation System and Gender Participation (A case study of sorah-chhattis mauja irrigation system, Rupandehi)	Mr. Ashok Chaudhary
12:20 – 12:40	Water, Gender and Local Economy: with multi-functional perspective	Mr. Dilli R. Prasai
12:40– 13:00	Preliminary Findings from a Field Study on Increasing the Resilience of Small and Medium Scale Irrigation Systems in Nepal	Mr. Prachanda Pradhan, Mr. Umesh Parajuli, Mr. Keshav Sharma
13:00– 13:30	Discussion on Session	
13:30-14:30 Lunch Break		
Technical Session II (Resource Assessment and Irrigation Efficiency)		
Chairperson: Mr. Bhubanesh Kumar Pradhan		
Rapporteur: Mr. Chetman Budhthapa		
14:30– 14:50	Delineation of Groundwater Potential Zone in the Indo-Gangetic Plain through GIS Analysis	Mr. Dinesh Pathak
14:50–15:10	Operational Dynamic of an Irrigation System-Performance Assessment: A Case Study of Sunsari Morang Irrigation System (SMIS)	Mr. Randhir Sah

15:10–15:30	Assessment of Water Resources and Irrigation Potential in Nepal. A case study: Sunsari, Saptari and Dhanusha Districts	Mr. Birendra Yadav
15:30–15:50	Understanding and managing spring systems for sustainable groundwater development in mountain regions: Experiences from Doti and Baitadi Districts	Ms. Ambika Khadka, Mr. Romulus Okwany
15:50–16:20	Discussion on Session	
16:20-16:40 Break		
Technical Session III (Multiple use of water)		
Chairperson: Mr. Sharada Prasad Sharma		
Rapporteur: Mr. Basudev Timilsina		
16:40–17:00	Multiple use of irrigation water: way towards sustainable irrigation management	Mr. Santosh Kaini
17:00–17:20	Optimum Multi Use of Downstream Augmented Water: A Case study of Budighandaki Hydro-Electric Project	Mr. Suraj Lamichhane
17:20–17:40	Optimal reservoir operation based on economic value of different water uses in the Komati Catchment	Mr. Krishna Prasad Upadhyay
17:40–18:10	Discussion on Session	
18:30 Onwards Reception Dinner		
DAY 2 (Jestha 29, 2073, Saturday)		
7:30 – 8:30 Breakfast		
Technical Session IV (Legal and Management issue in Irrigation)		
Chairperson: Mr. Madhav Belbase		
Rapporteur: Mr. Kailash Shrestha		
08:30 –08:50	Arbitration Issues & status in Irrigation	Mr. Kalanidhi Paudel/Bishnu Mani Adhikari
08:50– 09:10	Practices and prospective of e-procurement system in Department of Irrigation	Ms. Deepa Gautam
09:10–09:40	Discussion on the session	

Tea Break 10:00-10:10		
Technical Session V (New Approaches in Irrigation)		
Chairperson: Mr. Shiva Kumar Sharma		
Rapporteur: Mr. Danda Pani Jaisi		
10:10 – 10:30	Strategic Approach to Small Scale Irrigation Development: Action Research Experience	Mr. R.R.S. Neupane
10:30 – 10:50	Water Lifting Technologies for Tar Irrigation	Mr. Sagar Kumar Rai
10:50 – 11:10	Potential of using Solar Lift Irrigation in Hilly Region of Nepal	Mr. Manoj Pantha
11:10 –11:40	Discussion on Session	
Break (11:40 - 12:00)		
Plenary Session (Past and Future of Irrigation) (12:00- 13:00)		
Facilitator: Mr.Madhav Belbase		
Rapporteur: Mr. Rajendra Bir Joshi		
Panelist : Sheetal Babu Regmi, Shiva Kumar Sharma, Sharda Prasad Sharma, Prachanda Pradhan, Ratneswor Lal Kayastha, Bhubanesh Kumar Pradhan, Khem Raj Sharma		
Closing Ceremony		
Chairperson: Mr. Ramanand Prasad Yadav, DG, DOI		
Chief Guest: Hon. Minister, Umesh Kumar Yadav, MOI		
Guest: Representative, NFIWUAN		
Time	**Activities**	**Resource Persons**
1:00 –1:05	Overall remarks of the seminar	Mr. Bashu Dev Lohanee, DDG,DOI
1:05 –1:10	Remarks from guest	Representative, NFIWUAN
1:10 –1:15	Few words from Chief guest	Hon. Minister, Umesh Kumar Yadav,MOI
1:15 –1:20	Vote of Thanks	Mr. Ashok Singh, DDG, DOI
1:20 –1:25	Concluding remarks from Chairperson and closing of the Seminar	Mr. Ramanand Prasad Yadav, DG, DOI
Lunch		

ANNEX-II

FULL PAPERS

WATER, GENDER AND LOCAL ECONOMY: POLICIES AND PRACTICES AN ANTHROPOLOGICAL REVIEW

Dilli R. Prasai
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Abstract:

It is the reality that , women are more attached to the water rather than men in our society. All over the places of our surroundings i.e. kitchen , nursery/garden, cultivation, washing and cleaning water must be needed in every places and spot , in this way all of these activities performs by women in our household as well as society .So the impact of water is more relevant and extend in gender and particular women community. Water, Health & Sanitation has become a global issue in recent years as it has direct connection with the day to day life of people. The crisis of safe drinking water, sanitation and its connection with public health has typical features both in urban and rural population. The problem in urban area is due to the lack of natural resources whereas it's been a problem in rural areas due to lack of awareness and proper management.

One of the notable features of the present highly competitive world is that both Water and gender relationship in social as well as development sector. Women used to expenses more or less 60 % of time with water either in domestic, kitchen garden, animal husbandries, agricultural or other purpose in 24 hour . Women and development have increased at alarming challenges issues at the different corners of the world.

Key Wards : Gender, cultivation ,global economy, natural resources, development

1. INTRODUCTION

In Nepal, gender differences in human development indicators are wide. On all accounts, men fare better in terms of social, health, economic and political participation indicators. In regards to the lack of access to clean water and sanitation, women and girls suffer disproportionately. Girls are discouraged from attending school without adequate toilet facilities, especially during menstruation; women suffer from adverse health complications such as urinary tract infections and uterus prolapsed, due to bladder retention and fetching water from far distances. In Nepal, gender inequity and exclusion are major barriers to poverty reduction and need to be addressed. In the water and sanitation sector, there is the recognition that while men and women need to be involved in order to promote efficient and sustainable water and sanitation services, specific interventions are required to ensure equitable access for women and disadvantaged groups (Shivakoti, 2015).

Due to cultural and historic reasons, women are often the primary collectors, transporters and users of water in developing countries. They tend to have the main responsibility for health, child care and are managers of domestic water as well as promoters of home and community based sanitation activities. This division of labour generally results in women's and men's different priorities for water use and management. Yet, in many societies women's views are not systematically represented in decision making bodies, and gender-based inequalities are often made invisible in debates and cultural norms. Women have accumulated knowledge about water resources, including location, quality and storage methods, as well as insights in common habits and problems within a community, which are important information for programming. Hence, women's active participation in water and sanitation solutions can improve health, improve status, increase women's safety, creating opportunities for income generation, as well as providing them with other public and influential roles.

According to CBS 2011, women participation in economic activities is 55.2% versus 71.6% of men indicating a poor status of Nepalese women and existence of a challenge to meet gender equality in the country. In fact, women are involved more in non-productive activities such as in household chores and other farm activities which do not account value for their work. Likewise, Nepal ranks 83rd out of 109 countries in the GEM with a value of 0.486 in 2014. Poor participation of women in local election and insignificant number of women in professional and administrative work as compared to men has put Nepal among the lowest-ranking countries. In addition, this also reflects exclusion of women in decision-making and control over resources. Gender disparities are together with inadequate infrastructure, pollution of water sources, poor hygiene, and retrogressive cultural taboos such as those related to menstruation, impediments that need to be removed in order to ensure access and the right to safe water and adequate sanitation for women and men, girls and boys (HDR, 2014).

1.1. Water supply

Women play a central part in the provision, management and safeguarding of water. Women and girls spend significantly more time acquiring water than men and boys. Water collection can foster social cohesion and provide women with an opportunity to communicate with other women and people outside their homes. On the other hand, it is a heavy task that also can expose women to threats of violence and health hazards when they need to go far distance to collect water. Lack of access to water also decreases women's roles in contributions to agricultural production, food security and business opportunities.

1.2. Sanitation and hygiene

A focus on gender differences is of particular importance with regard to sanitation facilities. Inadequate access to sanitation and hygiene disproportionally affect poor women and girls, as they are often faced with additional challenges related to menstrual hygiene, personal safety, sexual harassments and violence. Without access to latrines, many women and girls become 'prisoners of daylight', using only the night as privacy. Night-time trips to fields or roadsides expose them to risk of physical attack and sexual violence. To ignore their natural bodily functions out of fear causes discomfort but also increases the risk of being affected by health problems such as urinary tract infections, chronic constipation and mental stress. Furthermore, in many countries, school attendance by girls is lower and dropout rates are significantly higher in schools that have no access to safe water and no separate toilet facilities for boys and girls (Sapkota, 2012).

2. CROSS-CUTTING APPROACH

2.1. Need-based approach

Improved water resources management, greater access to safe water and basic sanitation have clear linkages to improved human rights and a Human Rights Based Approach. Active participation of both men and women in the decision making of the type of water and sanitation service installed, as well as shared responsibility of managing the water and sanitation services, are important due their different roles and needs. Secure access to land for both men and women is essential for securing access to water, and for obtaining the resources to invest in future livelihoods. Training women and men in safe sanitation and hygiene practices within the household is a cost-effective way of raising awareness and skill. Multiple-use water program tend to address women's needs more effectively, rather than one-dimensional projects. Improved access to toilets and water facilities in schools can increase girls' attendance in school.

2.2. Participation based approach

Mixed crop and livestock integrated farming is the characteristic feature of Nepalese agriculture and widely prevalent in the country, irrespective of agro - ecological regions. In subsistence agriculture, both men and women involve significantly in sustainable agriculture production and management. However, there exists a gender division of labour between men and women in farming as well as in household activities. Therefore in gender relation there is defined role and responsibilities for men and women that has been socially accepted and practiced. In farming practice, men and women perform their task through mutual cooperation and interdependence to each other. Because of gender division of labor, gender differentiation in participation persists in agriculture. Gender analysis helps in understanding nature and extent of men and women's participation in various sector of agriculture such as crop, livestock, fisheries, and other related components. It also explains different roles and responsibilities of men and women such as who does what, where and when do they work, and for how long. Due to gender division in labour, differentiation in gender's work is obvious. The differentiation in allocation of labour, nature of labour, and extent of their use is influenced broadly by religion, culture, social, economic, agro-ecological, and political situation of the country. However, a multiple factors are responsible for gender variation in participation in agriculture activities within each region and socio-culture parameters. Women's involvement is highest in the hills and mountains, in small and marginal households, and lower in the terai (plains) amongst high caste groups (Paris, 2015).

2.3. Production based approach

Women play a significant role in all the various stages of crop production, processing and preparing for markets. Rural women are responsible for 60 to 80 per cent of food production in developing countries, yet female farmers are often underestimated and overlooked in agricultural policies and strategies (NEWAH,2007). According to the study carried out by NEWAH in 2007, women in the high mountain areas contribute more in agricultural work than men, more or equal work in the middle hills, and slightly less work in the Terai (low foothills and plains). However, in all agro-ecological zones, men generally perform tasks that require heavy physical labour such as plugging (although women all over rural Nepal can be seen carrying heavy loads of fuel-wood, water, and fodder. Women, on the other hand, chiefly perform tedious and time-consuming work such as weeding, harvesting, threshing, and milling. Studies have shown that women involvement is greater in the case of minor and subsistence food crops production such as millet, maize, soybean etc. However, in the case of cash crop and commercial production men involvement has been observed significantly. For example, rice is a staple food crop of Nepal and grown in larger scale in Terai region, where involvement of men is observed to be more as compared to that of women.

In general, women in Terai participate less in farm activities as compared to women in hill and mountain regions due to socio-cultural restrictions particularly in the case of higher caste such as Bhramins and Chhetris. This restriction is more relaxed in the case of other ethnic group such as Magar, Taming, Gurung, Sherpa, Lama, and Newar and social groups such as Dalits and Janjatis. However, irrespective of region, women involvement is more in the case of rain-fed agriculture than in irrigated one (ICIMOD, 2009).

Women involvement in farm food production also varies with land-holding size. The greater the land-holding size, the lesser women involved in their farming activities. Because in such case, hired labour substitutes women labour of family. This is very much true in the case of Terai region, where the higher castes, Brahmin and Chettris, own greater land-holdings and women involvement is found lesser as compared to men. However, land-holding size of other ethnic and social groups in the same region is smaller therefore women involvement as farm labour is greater. Nevertheless, in overall women's involvement has been reported significant in case of transplantation, weeding, and harvesting of rice irrespective of regions and socio-cultural pattern. In food production irrespective of the crops, women share more than 50% of labour work, from planting to maturity such as sowing, managing, weeding and hoeing, and harvesting. Likewise, in case of post-harvest operations, women involvement is greater particularly in cleaning, grading, storing, and packing for sale. Men's role are much confined in land preparation, digging pits for orchard, plugging, irrigation, and application of chemical fertilizers, spraying pesticides/insecticides, and pruning of orchards. Livestock, cow, bull, oxen buffaloes, sheep, goat, and pigs farming on small scale in the backyard is widely prevalent in Nepalese farming system. Besides livestock, poultry and fish play a subsidiary role to crops and contribute in meeting human needs both to consumption and sell for income. The socio-cultural, economic, and agro-climatic condition influences the number of holdings and pattern of livestock. In mountains where food production is difficult due to poor geographical condition, raising of livestock head is more as compared to Hills and Terai (ADB,2005). However, in all the three ecological regions irrespective of social and ethnic groups, both men and women contribute significantly in livestock production and management.

In general, women are more involved in raising small livestock while men for large ruminants. However, women contribution is higher in feeding, collecting fodder, cleaning sheds, and grazing of livestock while men involvement is noticed more in case of management such as disease treatment, milking, and buying and selling of animals and their products. Within the social and ethnic groups, women of Tamang, Gurung, Magar, and Dalits are involved in production of pigs and poultry whereas Bhrahmin/Chhetris and Maithali women do not raise due to cultural restrictions. Likewise, Dalit and occupationally low caste do not raise cow as in Hinduism it is considered a sacred animal.

2.4. Consumption (Water) based approach

Water is essential resource necessary not only for agriculture purpose but also for human beings and animals. Since water is very much linked with land, activities related to irrigation are exclusively under men's domain and their responsibilities. In the gender division of labour, decision with regard to management of water and its distribution are taken care by men whereas meeting household needs for drinking and sanitation (animals and household) are considered responsibilities of women (Gautam,2014). Despite sanitation is very much important with respect to health of household and animals, it is hardly addressed through gender perspective. This explains that role of women in management of water and sanitation is still invisible and their need for sustainable water use is yet to be addressed.

3. GENDER INTEGRATION IN NATIONAL POLICY AND PLANS

3.1. Policy and Constitution

Constitution of Nepal (2072) of Nepal has stated "women's rights" under fundamental rights, which is a great achievement of the democratic movement of Nepal 2006. Similarly, constitution has stated "Food Sovereignty" as a fundamental right. Though Interim Constitution of Nepal 2006 has provided equal property rights to son and daughters, in practice women are deprived to enjoy the rights provided by the constitution. There is a lack of general awareness among women and girls. Agricultural Policy (2004) was formulated by government of Nepal with a growing realization of retaining the fundamental aspects of the APP. Further, against the background of the process of economic liberalization, Nepal's commitments at the World Trade Organization and regional organizations, and Millennium Development Goals, the policy was brought into force by government of Nepal in 2004. The policy aims to contribute towards ensuring food security and poverty alleviation by achieving sustainable economic growth through increasing agricultural production and productivity, enabling the sector to compete in the international market, and conserving natural resources. The policy proposes support to resource poor farmers that account for 98% of the farmers in the country (Baskota, 2004). Government of Nepal developed a national agriculture policy in 2004 to reform the agriculture sector. In the policy, it is clearly mentioned that the women farmer participation will be 50 percent in the possible areas of agricultural extension program. It has emphasized on arranging on-the-spot farmer's training and collection of gender-disaggregated data to maintain and update record in agriculture sectors. The policy specially targets disadvantaged groups, dalits and other marginal farmers including landless agricultural labourers to engage them in agricultural production operations. This is planned through acquiring agricultural land, ponds, marshes, reservoirs or riverbanks and under contract or leasehold arrangements. In addition, financial institutions including Agricultural Development Bank was planned to mobilize to provide concessional loans to such groups. Further seeds, saplings, and technical services is planned to be provided free of cost to these groups. Looking at the massive emigration of youth from the country, the policy also aims to establish agricultural business and implementation and training management so as to attract them in agricultural sector (Adhikari, 2000).

3.2. Agribusiness Promotion Policy (2006)

It was formulated in order to give momentum of agricultural policy 2004 which has given emphasis of developing business oriented and competitive agricultural system to compete in the regional and world market. The policy will run special program to establish agriculture enterprises and its implementation for disadvantaged group, dalit, and women (GoN,2006).

4. MAJOR HINDERING FACTOR IN RELATION WATER AND GENDER

- No ownership right
- Limited and lack of quality participation
- Inadequate/poor database/Information Sharing
- Limited resource allocation (budget)
- Lack of recognition/low priority
- Lack of conducive environment
- Weak capacity
- Lack of gender friendly policy and its enforcement
- Lack of gender sensitive monitoring and follow up

5. IDENTIFIED GAPS

In spite of all efforts made after the restoration of democracy, a significant change in power relations has not been noticed. Although human development has been improved in the last decade still remarkable gaps exists between the advantaged regions or caste/ ethnic groups and women. The level of human development of women is still less than that of men and they still lack fair access to opportunities and resources. The gap widens more in case of Dalit, Muslim and Janajati who have had lower levels of human development for generations, continue to suffer today (Bhusal, 2007)

- In general, gender main-streaming is considered only in the context of poverty reduction and inclusion. This threatens to overshadow gender goals, which calls for a much broader approach to gender equality, as all women are discriminated, excluded and victimized, not only the poor women.

- Gender monitoring has been very much program and project specific, with little relationship to the annual budgeting process. As yet, gender related monitoring indicators have not been developed adequately.
- Gender is still not well integrated in larger infrastructure, economic and financial reform directed programs. Gender monitoring and evaluation is yet to be fully integrated in the macro-economic policy framework and country assessment studies
- Women's institutions within the GoN including MOWCSW, gender units in other ministries and gender focal points are very much underfunded, given their responsibilities of gender sensitizing the whole system. Many of the gender focal points are not of high enough status in the bureaucratic hierarchy to have much influence in the sector programs and policies.
- Gender analysis alone is insufficient to optimize women's contribution to Water and irrigation . Gender perspectives - views of both men and women – must be taken into account. Women must have opportunity to express their views to properly used water and irrigation sector and bring their perspectives into development and policy and programs of food security also .
- Gender as well as social groups disaggregated data on internally displaced people due to conflict are yet to be prepared which is essential for policy implications especially to reduce feminization of agriculture that leads to feminized poverty

6. CONCLUSION

General concept of Water , Gender in development program and planning is that women need support for their empowerment. In reality, for the success of any development initiative, there is need to empower women. For example, commercialization of agriculture is not possible until and unless production oriented economy is translated into market economy. For that, both men and women need to participate equally into market economy. Because women are the real producers of local economical agriculture production sector and they contribute significant proportion of labor force in local as well as national economy, their access to market means having an opportunity for earnings. Once a woman earns money, she could also make decision on its expenditure. In general women spend their saving for their children's health and education and thereafter on household welfare. This ultimately gives maximum return by creating a healthy and educated human capital. Thus future quality of human capital can be determined through empowering women. However, the first challenge is how to make as many as women to participate in development program and the second is how to bring them into decision-making level or to ensure their quality.

Ensuring Maximum Participation of Women in Agricultural sector

- It is imperative to prepare a critical mass of skilled women farmers in agriculture sector as well as at professional level in view of improving irrigation and water policy related with agriculture and management of natural resources. They should participate at the grass root level and decision making level.
- Conducting community discussion with an assessment of the level of women attendance and how to overcome obstacles to their participation served to create feeling of community responsibility of gender integration

Creating Conducive Gender-Friendly Environment for Women

A meaningful participation of women in water gender and local economy can only be ensured through building an enabling gender friendly environment. There are a number of ways but it should be socio-culturally acceptable and technically feasible and economically viable. Some specific actions that are recommended for bringing into practice are:

- Conducting training program at the local areas and off-seasons period of agriculture Involving both men and women of family in irrigation and water rights issues based training program to support women's participation
- Provide day care or babysitting facilities at the training center and Provision of breast feeding break and transport facility for women professionals
- Develop irrigation and agriculture tools and technology that are ease to handle by females

7. RECOMMENDATIONS

- Water rights and irrigation policy need to be urgently formulated to ensure equal land rights to men and women
- The government should have affirmative policy to women fishery groups in awarding contract of public fishery ponds
- Provision should be made in irrigation services to provide certain number of appointments to female in decision making level
- A system of gender based budgeting and auditing need should be introduced and practiced.

- Ministry of Women Children and Social Welfare should have a division for documentation, reporting, networking and coordinating of women concerned irrigation activities implemented by Ministry of irrigation and agriculture as well as I/NGOs
- More extension and training should reach to women. Given women's poor mobility, few can go to service and training centers for training and advice, so short duration-training at same village site and during off-season need to be conducted. irrigation skills training should include functional literacy programs which would enable women farmers to develop reading, writing, calculating, speaking, listening, interpersonal problem-solving skills while acquiring knowledge about agricultural matters

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Preliminary Findings from a Field Study on Increasing the Resilient of Small and Medium Scale Irrigation systems in Nepal

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Agriculture is a mainstay of the economy of Nepal, providing about 30% of the GDP and supporting livelihoods for the majority of the population. It is very vulnerable due to the monsoon climate as well as topography, and population growth has made land holdings too small to meet the subsistence needs of most people. Off-farm employment and rural-urban migration are increasingly important to supplement agricultural income. Irrigation is an important requirement for agriculture but, despite the long history of irrigation in the country, it is widely recognized that the sector is still in need of improvement, and that climate change will only make the situation worse. This two-year study, funded by the UK Department for International Development (DFID) through the Climate Development and Knowledge Network (CDKN) draws on field studies of representative irrigation systems as well as analysis of climatic data and future projections to understand how farmers respond to an uncertain climate. Farmer perceptions and actions have been correlated with actual climatic data for the recent past, and related to future projections of climate change. Increases in peak flows are anticipated but, more importantly, small changes in timing, intensity and duration of rainfall coupled with increases in temperature have already influenced cropping particularly in winter. The ability of communities to adapt to climatic and other changes depends on a wide range of factors. These include the strength of community-based organizations, the condition of infrastructure and the importance of agriculture in the local economy. Improvement of agricultural support services is needed to enable diversification into higher value crops, for which the growth of new markets resulting from rapid urbanization and improved road access provides an opportunity. Catchment-level management is increasingly needed to manage water equitably, particularly as return flows from upstream systems form an important part of the inflow for downstream systems, and both technical and institutional improvements are needed at system level. Resilience needs to be addressed at individual farmer, community and irrigation organization levels.

Keywords: Irrigation, climate change, Nepal, farmer-management

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1. Introduction

This climate change study of two years being undertaken in collaboration with the Department of Irrigation (DOI) to develop a "Framework for Enhancing Effectiveness and Resilience of Irrigation Systems in Nepal". Climate change has started to show its impact in many sectors including in irrigation and agriculture. This study highlights the impacts of climate change.

Climate change includes:

- Declining surface water availability, melting snow packs, devastating flood, longer droughts, shrinking reservoirs, desiccating soils, declining ground water levels
- Changes in temperatures resulting into decrease plant yields or giving opportunity for cultivation at higher altitude.
- It can create social disharmony and adverse impacts in many sectors

2. Objectives of the study are to;

1. Improve the approach and methodology for planning and delivery of efficient, effective, equitable and climate resistant irrigation systems
2. Assess the process, institutions, and policy for irrigation development and management and resource governance
3. Prepare a framework to increase the climate resistance and effectiveness of small and medium irrigation systems
4. Ensure the practical framework suitable for governing and implementation

3. Method of Study

3.1 Review of relevant Literature

1. Irrigation strategy and policy
2. Irrigation programs in Nepal
3. Climate change scenario in Nepal
4. National overview of the irrigation sector (Irrigation performance and climate vulnerability)
5. Irrigation data base and selection of systems (Small and medium systems)

3.2 Reconnaissance Study. Reconnaissance visit of 17 irrigation systems of medium and small scales were made from Jhapa to Kapilbastu districts. They were;

- Selection of medium size river basins like Biring river basin (Jhapa), Kamala in Sindhuli, Bagmati –Marin Khola, Likhu-Trisuli River basin, Narayani River

Basin, Tinau River basin and Banganga River basin, and)

- Based on these medium size river Basins, numbers of irrigation systems were identified for reconnaissance.

During the reconnaissance study following activities were carried out:

- Training to team members for reconnaissance study
- Identification of the basins for reconnaissance
- Background information of the systems
- Contact and consultation with local irrigation officials
- Checklist preparation
- Walk through of the systems (physical, water status and management of system, information about changes)
- Focus Group Discussion (FGD) with the farmers
- Coonsultation with WUA members
- Meteorological data collection from local stations

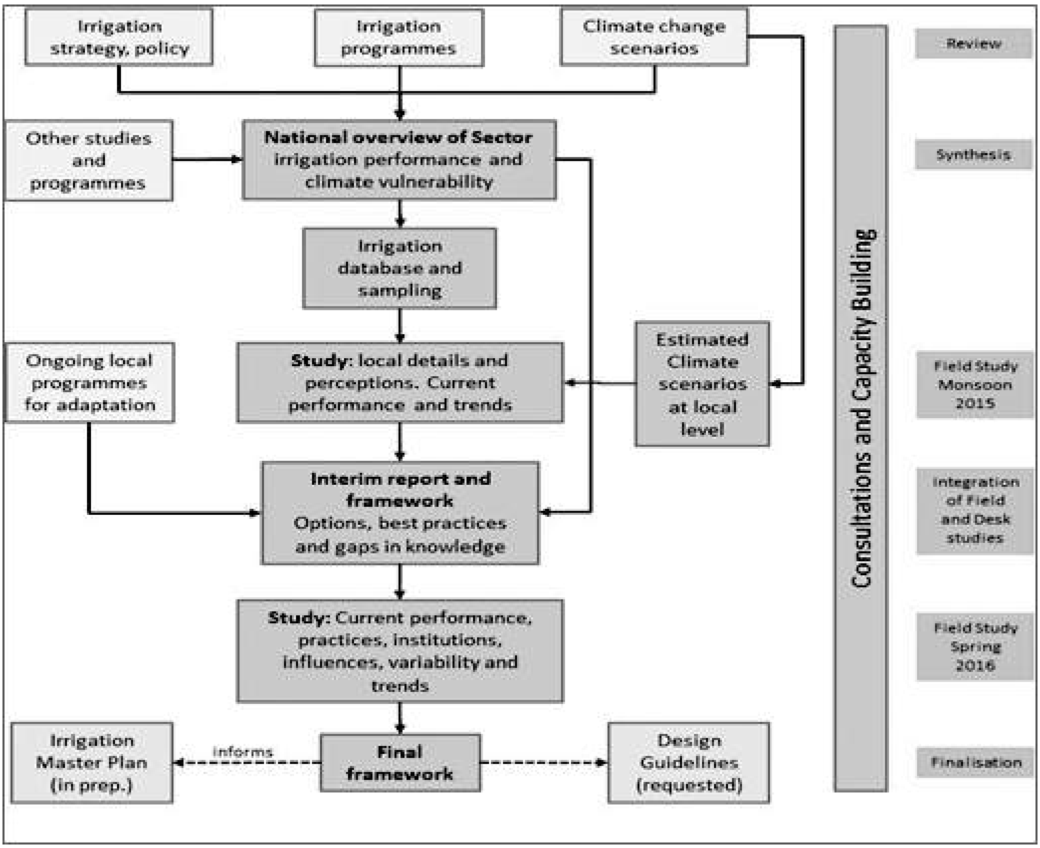

Figure 1: Framework for Study of Climate Change and Impact on Irrigation Sector

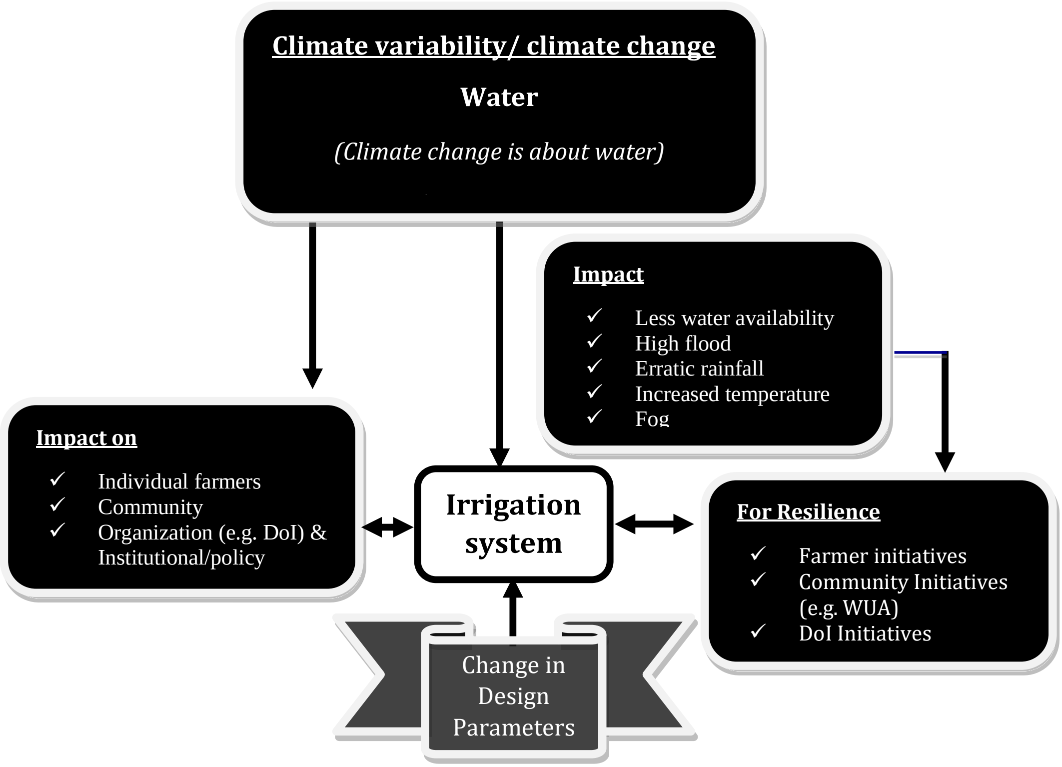

Figure 2: Effects of Climate Change in Water Resources and Irrigation System

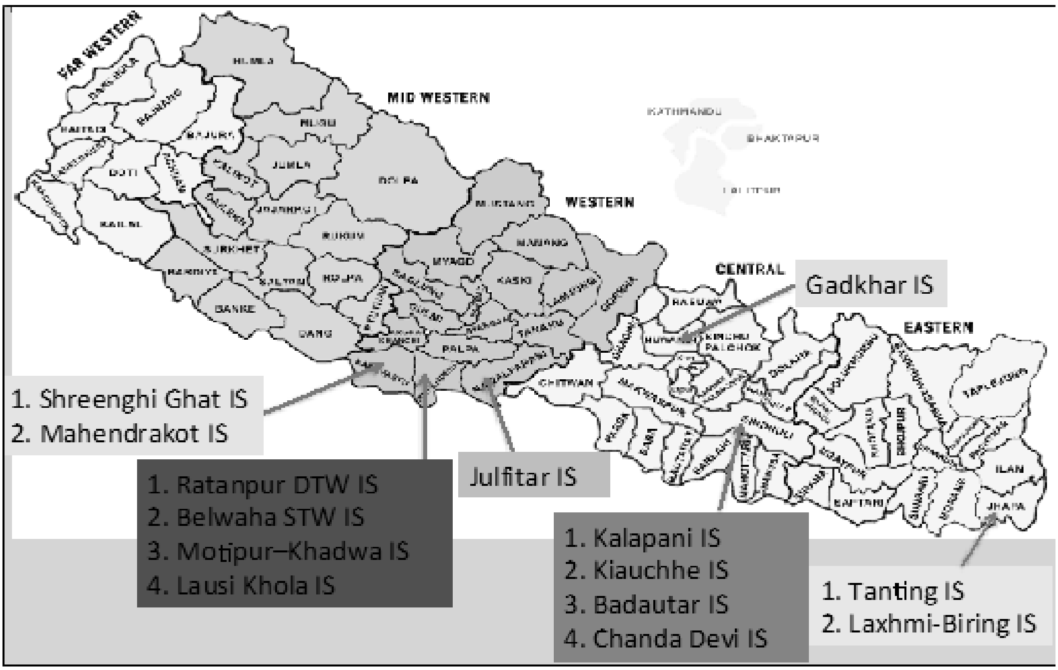

Figure 3: Location of Irrigation System Visited

4. Methodology of detail case study of two systems

Based on reconnaissance, two small water basins were selected. They are Banganga River basin of Kapilbastu and Girwari River basin of Nawalparashi. The irrigation systems selected for detail study are: Shreengeghat of Banganga River basin and Julfetar of Girwari River basin.

The methodology of detail study includes

Qualitative Information collection

- Focus Group Discussion (FGD) at 11 locations for farmers perception
- Senior citizens interview for timeline information of change

Quantitative Data collection

- Household survey
- Daily collection of hydrology and meteorology and river flow data collection (temperature, rainfall and river and system level water flow)

In order to ensure quality data collection, information of climate at HH level of different category was collected . 7 branches of 2 systems are selected for household survey (H, M, T)

- List of beneficiaries of these branches were received from WUAs
- Clustering was done and at least 30 beneficiaries from each group were selected for interview. Total of 221 hhs out of 1518 were selected.
- General information regarding perceptions of climate change and impact on agriculture were included.

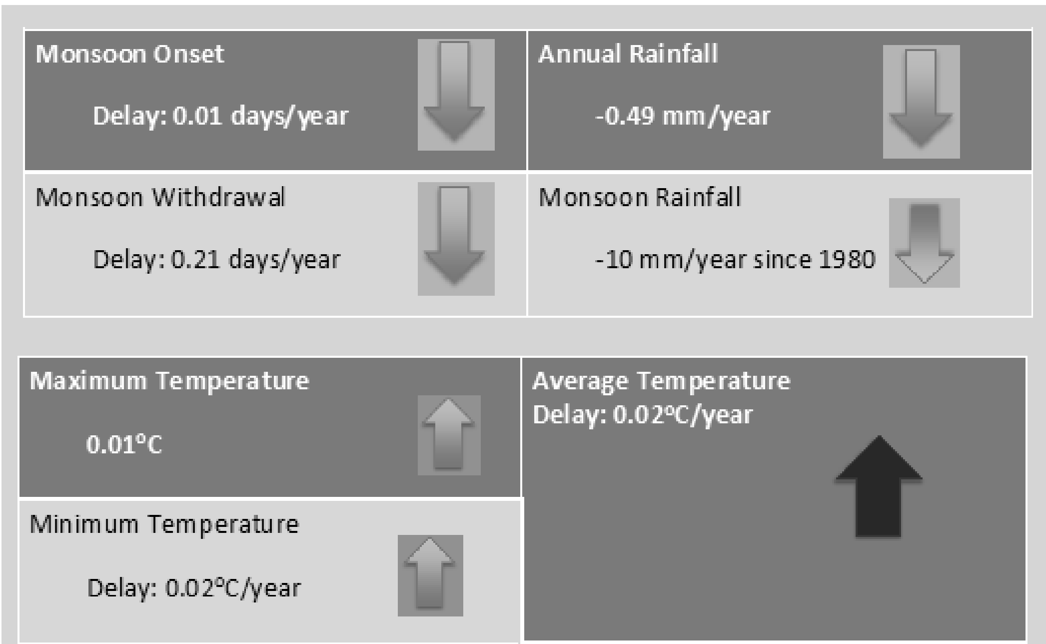

Figure 4: Climate Trends in Bhairahawa

5. Climate Change Effects

Some climate changes have already been observed through the farmers perception and local stations data

- ➢ Winters are getting warmer
- ➢ Rainfall is more erratic, intense but intermittent during the monsoon

Dry season flows appear to have reduced. Sediment transport has changed

There is evidence of increasing peak flood flows in rivers. Irrigation systems with declining water availability seem to be operating under deficit irrigation,

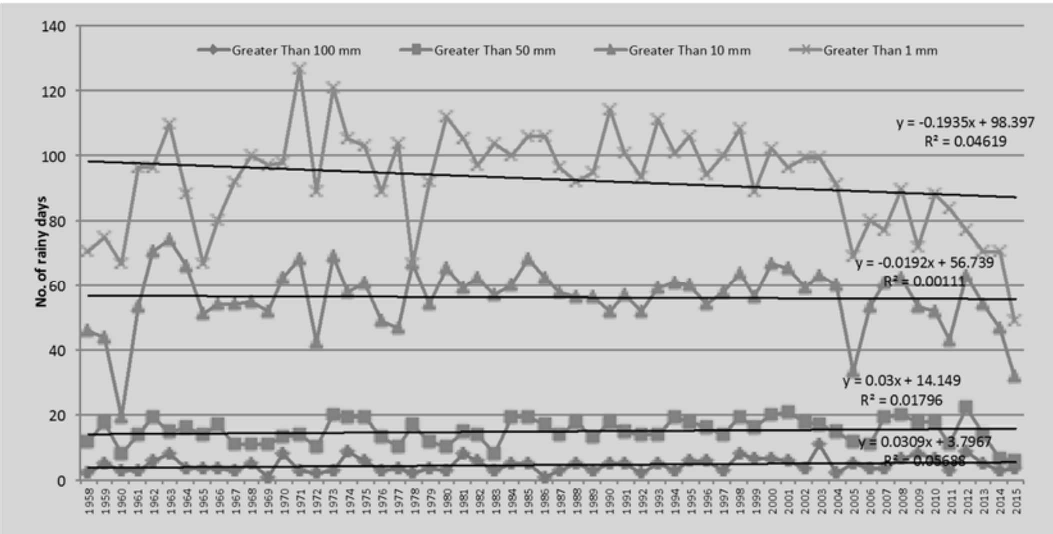

Figure 5: Climate Change Effects

5.1 Climate Change stimulated mitigation measures

Changes in irrigation and agricultural practice have been observed. They are basically in;

- ➢ Change in cropping calendar
- ➢ Short duration / early repining varieties to match with water supply

It is observed that the farmers made efforts for improved coordination among systems along a single river leading to river basin based management of irrigation.

Diversification of water sources including the DTW and STW installations in the irrigation command area. Farmers have been active for improved infrastructure for better control of water. They have witnessed that where they have good water control system, they have felt less climate change effects. It is also observed the increased tendency of merging intakes of two or more systems for climate resilient development coupled with management of scarce labor resources for periodic O&M. Previously, farmers were very particular about water right issue among the systems. Now, they have gone for collective effort to meet the challenges of climate change in water resources management. There is now increased tendency of taking risks by adapting deficit irrigation. Yield response to water is about ± 25%.

5.2 Implications of Climate Change on Irrigation Planning and Design

Following suggestions are given in order for improving irrigation planning and design from CC perspective:

- Approach to enhance irrigation supply in the areas through infrastructural intervention
- Approach to minimize irrigation demands
- Revisit hydrological design parameters: return periods, flood flows, low flows, available flows, and crop water requirements

5.3 Making Climate Resilient Irrigation Systems

The climate resilient irrigation systems are to be considered at three levels. They are at farmers level, at Water Users Association (WUA) of community level and at national institutional level like at Ministry of Irrigation and Department of Irrigation.

A. Farmers level

Climate change has impact on the livelihood of farmers, hence they can adapt different measures for increasing resilience to climate change impacts.

- Change in cropping pattern
- Seeking off-farm employment
- On farm water management, water saving devices, conjunctive use of ground water in both study systems
- Timely climate and agriculture information utilization
- Awareness campaign to the farmers

B. Community level

Management improvement measures by WUA (community)
Measures for water augmentation
Demand suppression for water management
Basin approach in water management (Giriwari / Shreengeghat)
Inter-system cooperation
Strengthening of WUA to respond changes

C. At the national level

Institutional capacity building for

- Disseminating information on hydrology & meteorology
- Monitoring of water resources at community level

Design system rehabilitation in cluster at basin / watershed level
Establish basin level organization (RBO) for water resources management in order to promote water basin approach. It is no longer so effective only to consider individual irrigation system rehabilitation and improvements.

Promote and institutionalize Integrated Water Resources Management (IWRM) policy.

There is need of a strong agency and research cell to look for water saving irrigation alternative technologies and their applications at farmers field. Effort is to be made to promote farm mechanization with commercialized agriculture. In order to better utilize decreasing availability of irrigation water, laser leveling of farmers field is also to be considered.

Climate change effects along with socio-economic changes in the village life have to be taken into consideration for planning of future irrigation systems.

Farmer Managed Irrigation System and Gender Participation
(A case study of sorah-chhattis mauja irrigation system, Rupandehi)

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Abstract

Irrigation contributes to national economy by increasing agricultural production. Farmer managed irrigation system covers larger area in Nepal than the government managed. But, the efficiency in irrigation management, particularly among indigenous communities in Terai region is hindered by low women participation. With that background in mind this research is aimed to identifying the potential of improving women participation in irrigation management systems as a means to increase their access to agricultural resources and benefit from irrigated agriculture.

The study employs both secondary and primary data obtained from random sample of 100 households from five maujas of the irrigation system. Descriptive method is used to analyze the data.

The study reveals decreasing participation in the irrigation system due to increased education, income and off farm employment and use of alternative means of irrigation. This study also identifies the factors constraining women participation.

The female participation in all aspects of irrigation management activities is very low mainly caused by *Parda* system, traditional culture, and lack of awareness and low level of female literacy. Awareness and training on irrigation management can increase women participation in irrigation system increasing their farm productivity.

1. NTRODUCTION

There are varieties of indigenous knowledge system to manage natural resources in Nepal viz-a-viz forestry management, biodiversity management, soil management and so on and so forth. Among them managing water resource by farmer through indigenous ways is a well-known knowledge system.

Farmers of Nepal have been developing and managing irrigation since time immemorial that appears to have been contemporaneous with agriculture. Although Nepal has a long history of irrigated agriculture, the importance of irrigation has been realized only in the recent years with the advancement in the irrigated agriculture technology a substantial portion of lowland throughout the country. There is large discrepancy in the total area reported under Farmer Managed Irrigation System (FMIS), probably due to lack of information on number and size of FMIS. A report indicates 17,700 units of FMIS existing in the country that accounts for roughly 75 percent of the total irrigation development (Poudel, 1993).

The role of gender in irrigation has become a global agenda for development practitioners. It is believed that equal participation of both sexes in irrigation enhances the performance of the irrigation (Gautam, 2000)

Women are involved in most of the activities related to use of water for agriculture and household purposes but not in decision-making. They have specific concerns related to the availability of water for domestic use such as kitchen gardening, livestock, fodder etc (Luintel, 2002).

Although women are engaged in a wide range of farming activities, there has been observed a tendency of overlooking women’s contribution to agriculture sector because of the society’s perception of regarding men only as farmers (Zwarteveen and Neupane, 1995). As a consequence, the failure to integrate women in irrigation activities and access their participation has made the development efforts less effective in Nepal.

The overall development of a country is only possible when everybody participates in the development process. In Nepal, this condition is not met. Even though, the constitution provides for equal opportunity regardless of sex, females who make up more than half of the population, is often denied this opportunity. Their participation is very low (Chaudhary, 2004).

Despite the growing recognition of the different needs of women irrigators, their participation in community water management associations is limited or lower than men's for a variety of social and institutional reasons. Formal membership is often restricted to those who legally own irrigated land, or are household-heads, or sometimes a combination of both factors. Since these categories largely apply to men, women farmers are not considered eligible for membership although in many cases they are cultivating and managing land in the absence of men who have migrated (www.genderandwater. org).

However, prevailing beliefs about appropriate male and female behavior, for example Taboos in talking in public meetings in front of male elders restricts active female participation in much of south Asian agrarian context. In the SCMIS in Nepal women claimed that they never attained meetings of the WUAs because they were not able to raise their concerns and needs. Many of these women found it easier to 'steal water' (free-riders) than participate in the formal structures (Zwarteveen and Neupane, 1996).

It is observed that the *kulahra* (workers) participation in the *mauja* (command village) level is decreasing day by day. The main reasons behind it are foreign employment, higher opportunity cost than of participation, using other means of irrigation, increasing level of education and income, etc. And it is observed that there is low women participation in Sorah-Chhattis Mauja Irrigation System (SCMIS). But, if we can get involve to the women in the SCMIS as a *kulahra* the trend of decreasing participation can be reverted.

With these broad perspectives, this study is conducted to find out Gender Participation in the context of SCMIS. Considering the above mentioned issues, this study focused on the following research objectives.

1. To examine the trend of *Kulahra* participation in Farmer Managed Irrigation System with special reference to Sorah-Chhattis Mauja Irrigation System.
2. To analyze the roles of women in irrigation management.
3. To find out the factors those constrain or facilitate the participation of women in irrigation activities.

2. RESEARCH METHODOLOGY

This chapter describes the method adopted for data collection, analysis and presentation of the study. This includes hypothesis, rational for selecting study area, research design, and sampling procedure, method of data collection etc.

2.1 Hypothesis of the study

The hypotheses tested for the study are:

i. The number of farmers (kulahras) at the mauja (village) level is decreasing over the years.
ii. There is negative association between education and participation in irrigation management.

iii. Higher is the household income, lower be the participation in irrigation management.

2.2 Selection of the study area

Sorah- Chhattis Mauja Irrigation System (SCMIS) is a biggest irrigation system in Rupandehi district. According to Uprety (2006) it is four tier-based irrigation systems. He further reported that, the head office of the joint system is located at Butwal and Sorha mauja's office is at Anandban-7 and the office of Chhattis mauja is located at Shankar Nagar VDC (Premnagar). It is serving 33 and 59 maujas respectively with about 10,000 households providing water for more than 13,500 hectare of command area for irrigation purpose.

2.3 Research design

The research is descriptive in nature, where trend analysis and association analysis are used to show the prevalent condition of participation/women participation in that particular irrigation system command area in relation to their work pattern. With a view to develop a better understanding of women's participation at different level and to develop an action plan for enhancing their participation at various level and related person were interviewed.

i) Trend Analysis

When the data are collected at intervals spread over a period of time, it is called a trend analysis. This types of research samples different groups of people at different points in time from the same population. So, the time series data are collected at intervals spread over a period of five years from Sorah and Chhattis mauja irrigation system and analyzed.

ii) Association Analysis

Association analysis has been used in this research which is used to ascertain the extent to which two variables are related e.g. association between education and participation on irrigation system, income and participation.

2.4 Nature and sources of data

Qualitative and quantitative information were collected. Primary data were collected from the field by interviews, personal interviews, key informants interviews and focus group discussions with the executive members, Mukhiya/ Mukhtiyar/ Badhghars of each mauja. In addition, the secondary data were collected by reviewing - previous studies, published book, journals, case studies, news, articles, document and constitution of the SCMIS under the secondary sources and use both formal and informal methods for the collections of both quantitative and qualitative data.

2.5 Universe and sampling

The total of the Water Users' Associations (WUAs) from the 92 maujas constitutes the sample universe of the study, in which I have taken 2 maujas of Sorah and 3 mauja of Chhattis mauja as sample unit as per their water sharing proportion (i.e. 40:60) within the sample mauja from Chhattis there is constituted 7 regional committee among them a mauja has been selected from each of the regional committee (from 2, 4 and 6 region). Similarly, from the Sorah mauja it has been taken one head reach mauja and one of tail reach mauja. From each mauja 20 of sample are taken by lottery system, random sampling methods.

2.6 Data collection technique

Several data collection methods and tools are used for study such as observation, key informant interviews, focus group discussion, field observation and direct observation. Secondary sources and existing records are also used for clarification of collected and supplemented data. Secondary sources including attendance rosters, meeting minutes and notice and collected data were used.

i) **Participant Observation:** Close observation on the life-style of the people especially women with regard to water use, decision-making in water user's association, meeting, work pattern of women, opportunities available to the women and the changes in the lives of the women are observed. Direct observation is carried out to garner the information and data on the physical location of the study area, social infrastructures, topography, hydrological systems, natural resources, settlement patterns, agricultural practices, canal maintenance practices, control structure activities design, construction, water acquisition and drainage.

ii) **Key Informant Interview:** KII held with, officers of these system, local leaders (Mukhiya/ Mukhtiyar/ Badhghar), sepoy (Cahukidar), farmers, women group (mothers' association), who were directly or indirectly involved in the irrigation system.

iii) **Focus Group Discussion:** The focus group discussion was conducted with the official members and executive members of both Sorah and Chhattis mauja by paying some amount as per their rule, Joint Committee, Village level committee, WUAs, Mother groups.

3. RESULTS AND DISCUSSION

The irrigation tasks are inevitably related to agriculture activities. It does not exclude agriculture and household tasks while studying the role of women in irrigation. Therefore, there is need to explore the involvement by gender in different activities to understand whether or not the women have enough time for participating in irrigation system.

3.1 Trend analysis of participation

Data were collected at intervals spread over a period of time of five years from both of the Sorah and Chhattis mauja separately. The data include *Kulahra* participation from the Sorah and Chhattis mauja irrigation system and mauja level participation. From which it was found that mauja level *kulahra* participation is decreasing than of Sorah-Chhattis Mauja Irrigation System. Figure 1 shows that the trend of Kulara participation from Sorah mauja is increasing due to the increasing of command village or mauja. Initially it was only 16 mauja but it has increased its command villages/maujas by 17 so that, the participation is increasing. But in the context of Chhattis mauja the participation is consistently decreasing from the past 10 years but now in 2010/11 the participation is drastically increased, due to increasing of command village now it is 59 (it is 59 mauja).

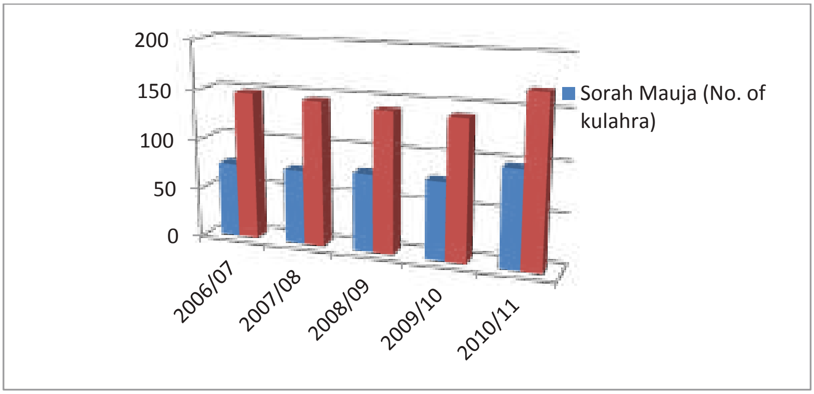

Figure 1: Trend of *Kulara* Participation of Sorah and Chhattis Mauja
Source: Field Survey, 2011

Another reason for this, the canal lining is in progress. The lining of canal increases the command maujas because the service is getting increased and the labor needed is getting lower. So, most of the mauja of tail end were hopeful for getting the water from the canal of SCMIS.

Similarly, the data from each of the sample mauja area shows that the mauja level of *Kulahra* participation is consistently low. Increased of off-farm employment opportunities is reducing the *Kulahra* participation. Initially, the *Kulahi* (work of Irrigation) was compulsory for each landholders but now it is not so. People prefer off- farm employment instead of involving in *Kulahi*. Because, by doing so they are better-off, they earn more than the *Khara* they have to pay for *Kulahi*.

3.2 Level of education and kulahara participation by gender

Education is the backbone for the development of a country. To access the association between the increasing level of education and participation in the *kulahi* system it was found that there is negative association between these two variables, because an increase in education level decreases the *kulahra* participation. Here, the assumption is that, educated people means the person who have passed the higher secondary level and above. Similarly, persons having less than 10 classes of formal education are taken as literate only not educated (Pangeni, 2004).

Following the assumption it is found that, when the level of education is increasing in both male and female the number of *kulahra* is decreasing. From the sample household (i.e100 households) there were 478 people. In which there are 236 male and 192 female.

The number of literate population of 14^+ male are 209, among them the person who have got only primary level education is 83, their participation in irrigation system is higher which comprises 52 were usually participate, 24 were always and only 7 are never participating. Similarly, at the higher level education (higher, graduate, post graduate) there were 16 males in which, only 4 male were usually participated, and merely 1 participated always and the rest were never participated in irrigation system.

Likewise, from the total female population of 192, the literate females were 138 only. Among them 76 female have got primary education, and the usual participation of female having primary education is 13 following to merely one female always participate. It seems that the large volume of women were not participates in irrigation system rather they stay at home by doing their household chores. Similarly, at the higher level education (including higher, graduate, post graduate) there were 7 female but they have never been participated in the irrigation system. Here the assumption, only above 14 years of people used to go for *kulahi* so the level of education presented in the table 5.6 is only of 14^+ age group. Hence, it is clear that there is negative association between the increasing level of education and participation in irrigation system management. Because when the level of education increases that creates off-farm employment opportunities. So the educated people prefer white collar job or off-farm employment and they do not want to participate in the irrigation system. Likewise, mostly the educated people earn more rather than literate and illiterate person. So they tend to pay user fee because they earn more per day in other occupation than the user fee of one day.

3.3 Relationship between income and participation

Income is also a variable which determines the participation in the irrigation system. If someone has greater income they hesitate to go for *kulahi* rather they prefer to pay *Panikat* (annual water user fee) and or *Khara* (Penalty for absentee). This is because they earn more than what they pay as user fee.

The research shows negative relation between the income and *kulahra* participation. Because it indicated that higher the income lower the physical participation. Mainly the sources of the income of the sample households are agricultural production and remittances. And the other sources of income are rents by transportation and houses, wage labors, jobs, etc.

3.4 Gender participation in irrigation related task

Without proper irrigation facilities, good production is impossible. An irrigation system could be viewed as technical, organizational and social elements as it includes construction and management of different activities through interactions of people.

Canal design and construction: In most cases men are involved in discussing and finalizing the design of structures with technicians. In 84 percent of the cases men are involved in this activity.

Operation and maintenance (O&M): Operation and Maintenance is an integral activity in any irrigation system. Usually men are involved in operation and maintenance (O&M) of the canal. Men do 90 percent of O&M related works.

Water acquisition, allocation and distribution: There is low women involvement in these tasks too. Men do 86 percent works related to water acquisition, allocation and distribution. Low women involvement in this task is due to low literacy level of women in the study area, old age practices and tradition that women should not go out of home and work together with men. There is not a single women operator in the study area.

Applying irrigation: The task of irrigating field is important for good crop production. In 66 percent of cases men are involved in applying irrigation. Women's involvement in this task is low.

Decision-making: The participation of women in the meeting is negligible. During meeting, 80 percent participants are men. In cases when women attend the meeting, this does not mean that they have any influence upon the decision being made or the topics discussed in the meetings.

Communication flow: In SCMIS, Water Users' Association (WUA) has appointed "Watchman", or "Sepoy", locally called *Chaukidar,* who communicate information to all the farmers about general meeting and dates for maintenance work. In this case also 92 percent *Chukidar* are men.

Resource mobilization: There is low participation of women in resource mobilization. It is because of male dominant society that women should not go to others yard to collect fees.

Conflict management: The role of women in conflict management is almost negligible. It is mainly because of the tradition of men dominant society.

3.5 Factors Constraining women's participation in irrigation

In SCMIS study area, both male and female work together in the field round the year. The male and female members of the household are engaged in agricultural activities from early morning till late in the evening during the peak agricultural season. But, even though, females are not considered as trustworthy farmers as male. So their participation in irrigation related task is very nominal. There are many factors that constrain the women participation in SCMIS they are described below.

i) Lack of recognition of women as a *kulahra*
ii) *Parda* system
iii) Low socio-economic condition of women
iv) System rules and regulations on women participation
v) Other constraining factors are: Male dominated society, Poverty creates barrier to the women to move freely, Illiteracy is also a major factor which makes hesitation in women to speak, Traditionally assigned household chores have created over load on women, Considering women as hewers of wood; drawers of water and bearers of children and their maternal responsibility which cut them off from participation, Less activeness of women, Non Co-operation from men and family, Lack of self-confidence among women, Men rarely listens voices of women when women speak; men think women should not be over smart, Men do not like women to come in front, they dislike smart women, Men nature not to obey women leadership, Women are hesitant, Maximum household chores..

3.6 Some way-outs to increase the female participation

As there is nominal level of female participation in irrigation works, where they neither have got vital post nor do they have decisive role. Similarly, they hardly recognized as *kulahara* because their works and support never been praised. Thus, after the KII, participants' observation and FGDs researcher come to a solution to increase their participation. They are as follows:

a. They should be recognize as Kulahara, for this the bidhan (constitution) should be amended
b. There should be reservation quota system where at least 33 percent of female should be nominated in the executive board as the constitution of Nepal also has ensure the 33 percent participation of women in every sector.
c. They should be positioned as Sepoy
d. They should be appointed as water allocation and distributer (canal operator)
e. They can work as water drawer
f. They could be called during lower level (traditionally known as dhule/dhuriya) kulahi.
g. They can work during leveling the mud and dust while the male work to digging the canal.

4. Conclusions

The study shows that both male and female work together in the field around the year. The male members take the decision regarding utilization of land and irrigation. The involvement of women is found as agriculture labor, but their role is almost negligible in decision making. It simply implies that the total contribution of men is higher than that of women in the various activities related to irrigation activities.

In the SCMIS, the gender participation is unbalanced. The ratio of men participation is higher than the women participation in each and every section of management and organizational system of the irrigation system management. Though, most of the respondents like women participation in the *kulahi* but it is not practiced in the reality.

It is revealed from the study that women's low participation in *Kulahi* is due to both internal and external factors. Due to illiteracy and other social prejudices women have been oppressed since long. This has been continuing and will continue if they are not given an opportunity to come out of the old age household drudgery.

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Operational Dynamic of an Irrigation System-Performance Assessment: A Case Study of Sunsari Morang Irrigation System (SMIS)

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Abstracts: It was observed that all the offtakes to the corresponding Watercourse Canal receive inequitably deficient water, due to structural limitations in the design. This is critical in the SS9F canal. Moreover, reliability of water delivery considering management performance coupled with delivery schedule is least in the downstream section. The reason is that the response time of actual supply to the steady state is not in line with the start time of intended supply into respective offtakes under design conditions.

In actual operation condition, actual supply is less then intended (calculated using CROPWAT of existing cropping pattern) during the season and discharge is fluctuating day by day. The indicators adequacy and efficiency have small deviation from design case but the spatial and temporal variation coefficient are poor then design value due to structural limitation and frequency of supply are concentrated in January month. Inadequate supply of water in SS9F has only 45% adequacy and reliability is decreasing from head to tail.

Key words: Adequacy, efficiency, reliability, equity, modernization.

1. INTRODUCTION

Background: Approximately 6,000 rivers and rivulets, with a total drainage area of about 194,441 km2, flow through Nepal; of which 46% of this drainage area is contained within Nepal (Water and Energy Commission Secretariat, 2004). Water is an important natural resource of Nepal. The huge quantity of water available in the country and its potentiality to irrigate significant percentage of the total agricultural land, provide us the opportunity of overcoming the barriers of economic development in this beautiful Himalayan country. The major rivers of the country are the Koshi, Gandaki, Karnali and Mahakai, which are all major tributaries of the river Ganges. Most of the irrigation systems in Nepal divert water from a river by diversion head works or side intakes. The river carries very high discharges during the rainy season and little or no flow in some cases during the dry season.

Agriculture accounted for 40% of gross domestic product (GDP) in 1994 and, despite falling to 33% by 2004, remains by far the largest sector of the economy. It employed 81% of the population in 1994, a figure that fell to 41% by 2004. The contribution of the sector to per capita GDP was only around half that of other sectors, illustrating low productivity. Agricultural growth rates averaged 3.3% during the Ninth Plan

(1994–2001) but only 2.64% during the Tenth Plan (2002–2004). Both of these figures are above the population growth rate of 2.1% per annum, but with huge year-on-year variation, the range being 5% in 2003 to 1% in 2004. This variation reflects high weather dependence and an underdeveloped sector (ADB, 2009). The different research shows that irrigation is major input for enhance the agricultural production, there for the role of irrigation becomes very crucial for the country like Nepal.

Most of the large-scale irrigation projects appear to perform below expectation. Due to increasing water demands, accurate control of the water flow in the irrigation system is becoming more and more important, but in practice control of water flow in irrigation systems is still rather poor. This implies an inefficient, unreliable and/or inequitable water distribution, which may occur in main canal systems as well as in the minor canal systems (Schuurmans, 1991).

The present scenario of large irrigation system of Nepal is operation and maintenance cost are increasing and the irrigated area is decreasing year by year, the one of the reason is due to unavailability of water in to source which cause inadequate and unreliable supply onto irrigation system result very low collection of irrigation service fee in the meantime the government policy bound that farmers must share the operation and maintenance cost. That is why a question is arises for sustainability of irrigation project.

Hence, in order to sustain the irrigation system the performance should improve with the limited available water to be served through the delivery system requires accurate control and management that competes with intended supply at respective offtakes serving the user groups in a dual managed irrigation system. This creates unsteady flow in the canal network while adjusting the control structure and managing discharge for the user groups served by the main system. Consequently, timing of actual supply discharge would be different from intended discharge at the outlet to the users group. Hence, accurate adjustment of gates as well as timing of actual supply discharge, among others, is a vital contribution to improving operation performance of the water delivery system. Further, careful design, implementation and maintenance of physical facilities including channels, control structures and offtakes, role of water user perform a vital role in improving the operation of the water delivery system.

1.2 Objective: The success of a water delivery system can be measured by how well it meets the objectives of delivering an adequate, while not excessive, and dependable supply of water in an equitable manner to users served by the system. Hence, there is need for performance measures, in a quantitative manner, which is associated with the evaluation, planning and design of water delivery system.

The study will focus on the operation performance of a system S9 of SMIS for design and actual operation condition of winter season (1-December, 2013 to 31-March, 2014). The one- dimensional (I-D) hydrodynamic model DUFLOW will be applied as a tool to analyze the physical and mathematical characteristics of the water flow under controlled conditions in order to assess and predict the system operation performance. Main objectives and associated methodologies of the research will be to:

- Assess the operation performance of a system of SMIS by using quantitative performance measures for both design and operation case;
- Analyze and evaluate the system water operation performance for both case;
- Compare the operation performance between design and operation case.
- Recommendation for enhancing the operation performance of SMIS.

3. METHODOLOGY

3.1. General

The methodology of the study is shown in Figure 3.1. Numerous past studies have addressed performance assessment for irrigation water delivery systems among these the idea proposed by Molden and Gate (1990) for performance assessment of water delivery system is used as fundamental principal for this study. To assessment water delivery performance S9 canal of SMIS, design and actual water delivery system in S9 system are reviewed from design report (1984) and IWRMP unit office of SMIP respectively. Hydraulic dimension of the canal are collected from As Built of SMIS and the gate openings height of actual operation from IWRMP unit office of SMIP for physical and mathematical simulation of S9 canal in DUFLOW model. After calibration and validation, model outputs are used for performance calculation using performance indicators and analyzing and evaluating of result for both case which helps in concluding the study and recommendation for better performance.

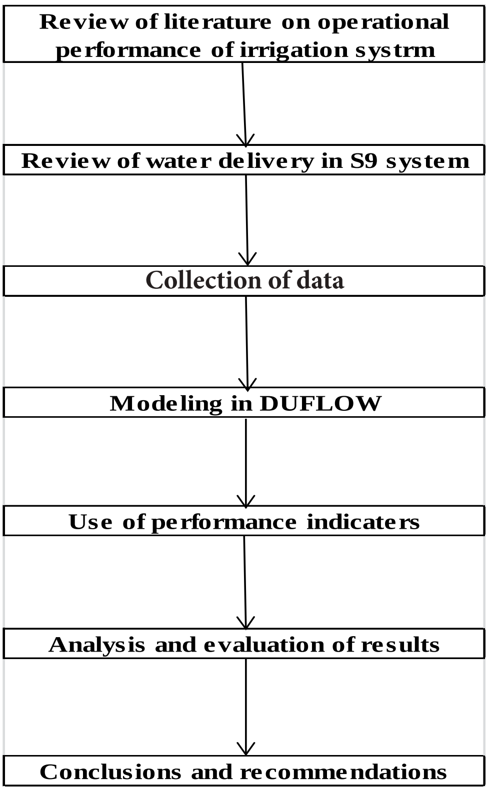


Figure 3-1: Methodology Flow Diagram

3.2. Selection of canal

The performance measures discussed in the Section 5, as a result of literature review, is applied to a system S9 of SMIS. S9 canal is one of the secondary units off taking from CMC. Three sub-secondary units, viz, SS9B at head reach, SS9F at middle reach and SS9J at tail reach, off taking from the secondary unit is selected as representative canals in the study. Use of the performance measures is made at off takes in the network of sub-secondary units until the head of tertiary units and head of watercourse unit off taking from sub-secondary units. Performance simulation is made under design condition considering full flow condition and operation condition of winter irrigation season, 2014.

3.3. Methods

Design Case

Estimating the values of performance measures for the selected delivery points require the determination of the temporal and spatial distribution of the values of the variables Qa, Qi, and Qe for the time period of interest, given the required amount Qr.

The computation in DUFLOW starts with the operation of Group A. The time period of operation for Group A taken under study (i.e., SS9B and SS9F canal) is from 180th hour to 252nd hour (i.e., 4th day to 10.5th day). While, the time period of operation for Group B taken for SS9J canal is from 84th hour to 180th hour (i.e., 3.5th day to 4th day). First 3.5th day has been excluded for study because the model shows irregular waves un-associated with real state of flow in the canal networks during initial flow computation.

The procedures to obtain the sample values of the variables in canal system S9 under study are as follows:

- Application of DUFLOW as a means of estimation is made to obtain value of Qe for the contribution of structure and management components in operational performance at respective offtakes of the water delivery system. The parameters and boundary conditions of the model is specified in accordance with the given structural characteristics and assuming that the operational rules for given water delivery schedule are perfectly followed. The model is then used to predict the water deliveries for the locations and time period of interest. These calculated water delivery is taken as sample values for Qe. That is, the predicted value from the model would represent estimates of the amounts that the system would deliver if the management perfectly followed the given delivery schedule and operational rules.
- The start time of Qe at respective offtakes under study is the point of time when

Qa at the same offtake becomes steady. End time of Qe is from the time when the turn of other Group starts to operate.

- The value of Qa is similarly obtained from the result of the model for respective offtakes under the period of operation.
- Values of Qr and Qi are collected from information surveys of the irrigation agency. The start time of Qi at respective offtakes under study is the point of time when Qa begins to operate. The end time of Qi corresponds to start time of Qa for the next group under operation.
- Application of the indicators (Adequacy, efficiency, Reliability &Equity) are used to study the performance of water delivery at respective offtakes of SS9B, SS9F and SS9J canals.

Actual Operation case

Since the measurement was taken only at HR of sub-secondary canal so model output is use to find the actual supply in to the offtakes from sub-secondary canal. The daily fluctuation of actual supply discharge in S9 limits calculation of effective (Qe) discharge because it also changes day by day. That is way I directly calculate the operation performance.

- The value of Qa is obtained from the result of the model for respective offtakes under the period of operation. Since the operation period is long (120 day) and actual measurement are on daily basis, so model output are also taken in daily basis.
- The winter season have four month and CWR depends on different stage of crop growth there for performance calculation critical period i.e. January and February are breakdown into 15 day and non-critical period December and March on monthly basis.
- The CLIMWAT and CROPWAT software of FAO is use for crop water requirement (CWR) of existing cropping pattern of sub-secondary canal (taken from SMIP) in monthly basis as shown in ANNEX A4. The climatic data is taken for Biratnagar airport and other stander data from different literature for soil and crop (ANNEX A8). The CROPWAT output are multiply with actual crop area and divided with canal efficiency gives the intended discharge (Qi) at canal head.
- Application of the indicators discussed in Section 5 is used to find the operation and overall delivery performance of water delivery at respective offtakes of SS9B, SS9F and SS9J canals.

And finally, the overall delivery performance of actual operation case is compare with that of design case.

3.4. Water Delivery Performance

Delivery performance ratio is the product of delivery-schedule performance and operational performance of water-delivery system. Further decomposition of operational performance into two components results in: first as structural performance and second as management performance of water delivery system. These are presented in Table 3-1 and Figure 3-2.

Additionally, parameters of delivery performance and operational performance that relate to system objectives in matrix form are presented in Table 3-2 below.

Table 3-1: Overall Delivery performance

Delivery performance, P_D	$= V_a/V_r$
Schedule performance, P_{SC}	$= V_I/V_R$
Operational performance, P_{SM}	$= V_A/V_I$
Structural performance, P_S	$= V_E/V_I$
Management performance, P_M	$= V_A/V_E$
Hence, $P_D = P_{SC} \times P_{SM} = P_{SC} \times (P_S \times P_M)$	$= V_I/V_R \times V_A/V_I = V_I/V_R \times (V_E/V_I \times V_A/V_E)$

Table 3-2: Matrix of water delivery system performance relative to its objectives

System objective	Delivery performance	Operational performance	
		Structural	Management
Adequacy	$P_A = \frac{1}{T}\sum_T\left(\frac{1}{R}\sum_R p_A\right)$	$P_{AS} = \frac{1}{T}\sum_T\left(\frac{1}{R}\sum_R p_{AS}\right)$	$P_{AM} = \frac{1}{T}\sum_T\left(\frac{1}{R}\sum_R p_{AM}\right)$
Efficiency	$P_F = \frac{1}{T}\sum_T\left(\frac{1}{R}\sum_R p_F\right)$	$P_{FS} = \frac{1}{T}\sum_T\left(\frac{1}{R}\sum_R p_{FS}\right)$	$P_{FM} = \frac{1}{T}\sum_T\left(\frac{1}{R}\sum_R p_{FM}\right)$
Equity	$P_E = \frac{1}{T}\sum_T CV_R\left(\frac{Q_a}{Q_r}\right)$	$P_{ES} = \frac{1}{T}\sum_T CV_R\left(\frac{Q_e}{Q_i}\right)$	$P_{EM} = \frac{1}{T}\sum_T CV_R\left(\frac{Q_a}{Q_e}\right)$
Reliability	$P_R = \frac{1}{R}\sum_R CV_T\left(\frac{Q_a}{Q_r}\right)$	$P_{RS} = \frac{1}{R}\sum_R CV_T\left(\frac{Q_e}{Q_i}\right)$	$P_{RM} = \frac{1}{R}\sum_R CV_T\left(\frac{Q_a}{Q_e}\right)$

Source: Molden and Gates,1990

The summations in Table 3-2 indicate an average of discrete functions of ratios in comparison of sate variables over a hydraulic level or a region or sub-region, R, served by the delivery system for a time period T.

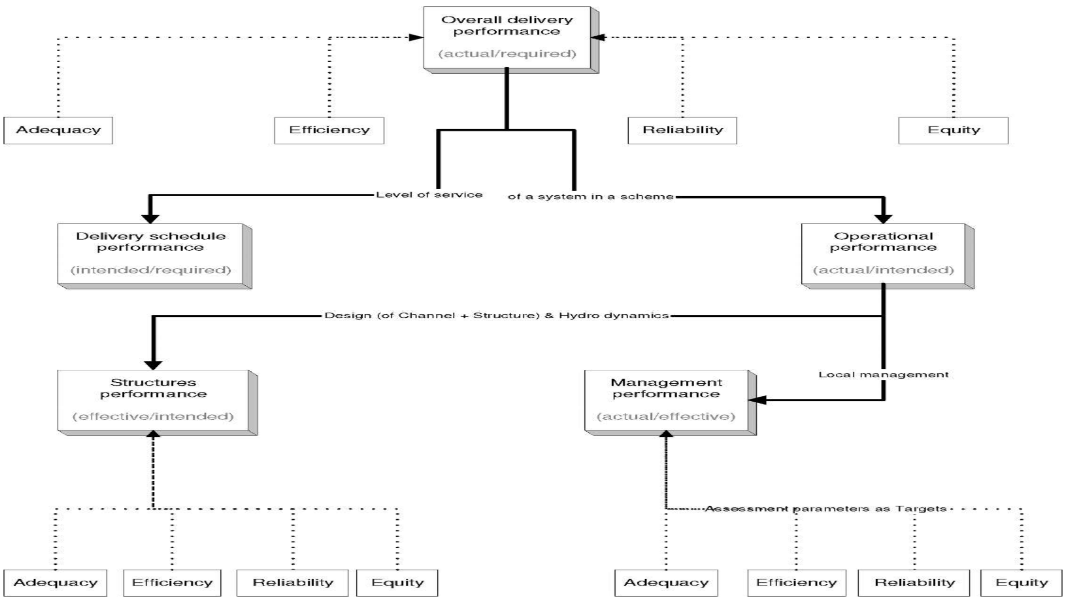


Figure 3-2: Performance diagram of system components

Table 3-3: Performance Standard

Measure	Performance Classes		
	Good	Fair	Poor
P_A	0.90-1.00	0.80-0.89	<0.80
P_F	0.85-1.00	0.40-0.84	<0.40
P_E	0.00-0.10	0.11-0.25	>0.25
P_D	0.00-0.10	0.11-0.20	>0.20

Source: Molden and Gates, 1990

4. RESULTS AND EVALUATION

4.1. Performance of S9 canal system in design condition

4.1.1 General

The results from DUFLOW model of S9 canal network under design condition is compiled with respect to performance measures (adequacy, efficiency, reliability and equity) for different components of water delivery system of irrigation canal.

The period of water delivery under study is taken as 3.5 days for each Group. This is because the S9 canal can continuously irrigate only 50% of its command area. Thus, group A and group B so formed to irrigate command area of S9 canal is operated in turn for 3.5 days. Contribution of rainfall to water delivery and field irrigation is sacrificed in the study.

The description of performance measures is discussed in section 3. The boundary of actual delivery period of water to respective offtake under the study is taken from the beginning of actual supply (i.e., when offtake gate is open to receive delivery) to the end of intended time of supply. The reason for this is the residual volume of actual water supply, however less, into the offatke after the end of intended supply will not contribute effectively to all offtakes of lower order canal.

Further, the boundary of effective period of water delivery through structure at an offatke is taken from the point of time when actually supplied water realizes steady state to the point of end time of intended supply into off-take. The reason for this to avoid accounting irrespective fluctuations of discharge until the offatke respond to steady state, and the time gone before response of offtake is merely used to fill the canal reach upstream of the offtake to its desired level. The residual volume of water supply into the offtake after the end of intended time is not considered effective because of obvious reason. Nevertheless, the residual volume of water supply is effective in actuality to the downstream while considering water balance within the command area.

4.1.3. Delivery schedule performance

The delivery schedule performance, i.e., the ratio of intended delivery of water by the agency to the required delivery of water by the crop or by the farmer, of S9 canal network under study is evidently 0.5, as only 50% of command area is served with continuous irrigation supply. That is, the required amount of water supply is 2 times of continuously available (in our case it is intended) supply to its respective offtake. This is the delivery schedule performance at all offtakes over the period (i.e., start time and end time) of intended supply with respect to required supply.

4.1.4. Performance of design case of SS9J canal network

4.1.4.1. Operational performance

Adequacy and efficiency parameter

Operational performance at an off-take is contributed both by performance of structure (Figure 4-3) and by performance of management (Figure 4-2) to water delivery. The operational performance of SS9J canal, in average, considering all of its offtakes in terms of adequacy and efficiency is optimal over the period of study as in Figure 4-1, meaning that amount of actually supplied water to its offtakes is what is intended to be.

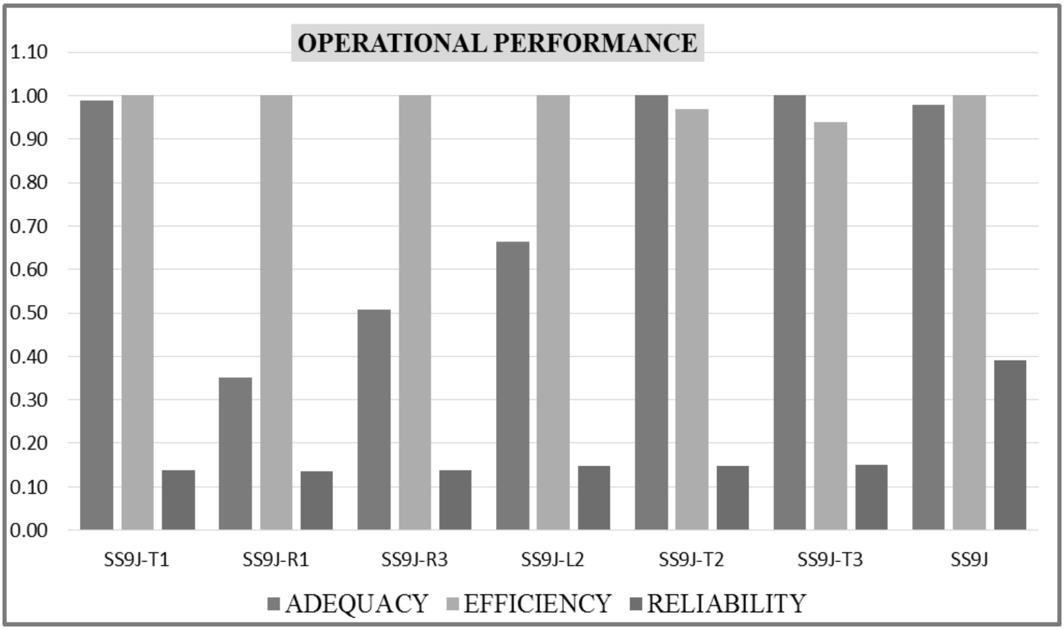


Figure 4-1: Design operational performance of SS9J canal network

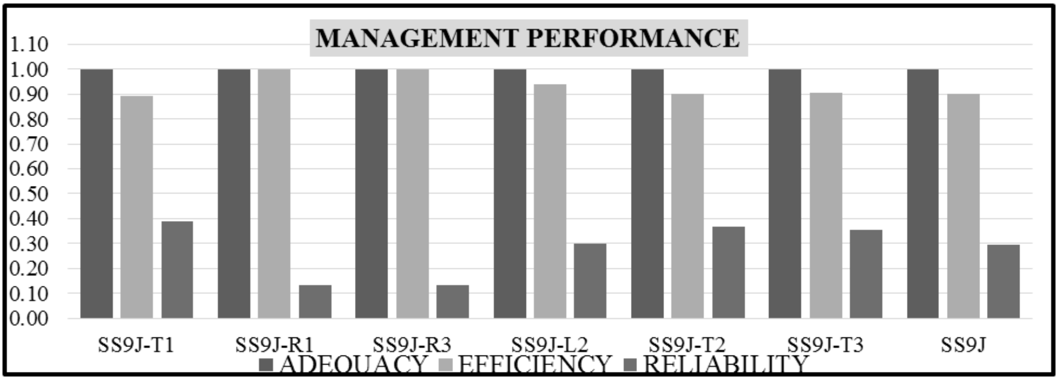


Figure 4-2: Design management performance of SS9J canal network

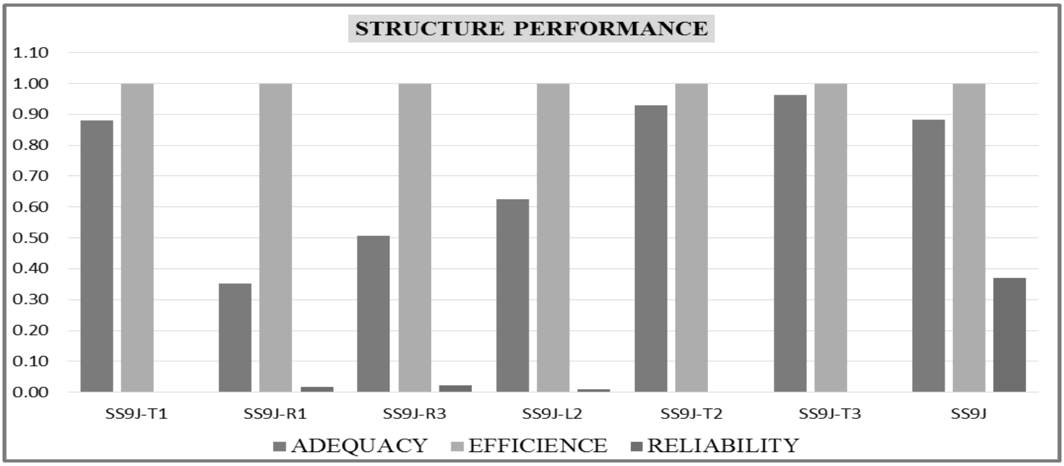


Figure 4-3: Designed structure performance of SS9J canal network

It is observed that actual delivery of water to offtake SS9J-R1 is least in the order of adequate followed by SS9J-R3, SS9J-L2, SS9J-T1, SS9J-T2 and SS9J-T3 with respect to intended delivery (Figure 4-1) given the highest possible use of water delivery by operation performance relative to efficiency, only 35% of water is actually supplied into SS9J-R1; whereas SS9J-T2 and SS9J-T3 actually receive more delivery than intended. That is, offtake SS9J-R1 has been seriously underused by actual delivery of water. In contrast, SS9J-T2 and SS9J-T3 have moderately been overused by the actual delivery of water, showing efficiency less than 100%.

This means actual supply into the offtakes is constrained either by the performance of structure or by the performance of management responsible to water delivery preset by delivery schedule.

Most optimum state of operational performance in terms of adequacy is only at SS9J-T1. The reason for this is:

- Offtake receives more water than is effective due to its designed level of crest (Figure 4-3). and
- What is effective through the structure is less than intended supply due to response time (Figure 4-4).

Thus the combination of above makes operational performance of SS9J-T1 apparently optimum.

Under use and overuse of actually delivered water, either in isolation or in combination of contribution of water management and capacity contribution of structure, through an offtake under study is realised respectively by adequacy and efficiency measure of performance less than one (or 100%). This is considered as state of alarm for the measure of performance in water delivery. In other words, water balance at an offtake and between the offtakes over the period of study can be judged through adequacy and efficiency measures.

Reliability parameter

However, there is significant departure from reliable delivery, i.e., Coefficient of variation (CV) in time of the ratio of the actual delivery to the intended delivery, is observed at offtakes of SS9J canal under time points of study. The statistical limit for CV is 10%. This obviously and only means timing of actual supply to the offtakes is not in line with intended time of delivery into respective offtakes. There can be two reasons for this as:

- Either management personal responsible for actual supply into offatke is violating operational schedule. This is, however, not possible in the design case of study, as the gate at sub-secondary canal is opened at scheduled time

- Or, the operational schedule needs revision so that it maintains beginning of supply time just after the response time of the system. This is true in our case as start time of intended delivery at offtakes is same as start time of actual supply.

Equity parameter

Further, operation performance of SS9J to spatial uniformity described by CV in space of the ratio of the actually supplied to the intended supply of water into the offtakes is non-uniform to the amount of 36%, which is significant. This focuses on the offtake/s being overused by actual supply and some being underused actual supply from its right to receive the intended water. There can be two possibilities for the spatial non-uniformity as:

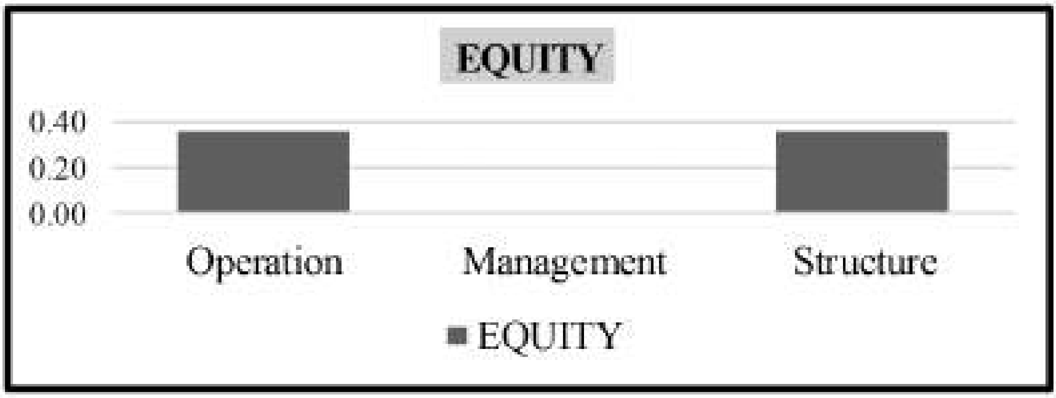


Figure 4-4: Design equity measure of SS9J canal network

- Actually delivered water by the management personal into the respective off take is not effectively used in average or,
- Effectively used water in average through the off take structures are not what is intended to be

It is clear from Figure 4-2: that spatial non-uniformity to the operational performance is contributed only by structure performance. This means some off taking structures along SS9J canal are designed to receive more water than intended. In other words, some structures are designed to a level that denies the intended share of water.

Further, the structure performance is embodied with response time of actual supply to be effective. The response time is coupled with start time of actual supply to match with intended supply. Hence, if start time of actual supply is unequal with intended supply at off take, then the capacity value of structure can be under/overestimated. Therefore, the actual contribution of structure relative to adequacy in steady state (i.e., effective) discharge at offtakes of SS9J, i.e., water balance, can be observed and compared from Table 4-1 and Figure 4-4.

Hence, from above it is clear that timing of delivery schedule set by the operational rule should be judged from response time to steady state before evaluating individual contribution of management and structure to the performance measures.
Water balance

The water balances along SS9J are presented in Table 4-1. The offtake SS9J-R1, SS9J-R3 and SS9J-L2 receives lesser discharge then intended. Therefor the withdraw capacity of these offtake must be increase by decreasing the crest level of offtake or increasing the gate width or increasing the water level in sub-secondary canal or combination of these option suitable to actual field condition.

Table 4 1: Water balance along SS9J canal network

Offtake	Discharge, m3/s		Effect/Intended	Remarks
	Effective	Intended		
SS9J-T1	0.51	0.50	1.01	
SS9J-R1	0.01	0.03	0.36	Needs revision
SS9J-R3	0.02	0.04	0.52	Needs revision
SS9J-L2	0.03	0.04	0.68	Needs revision
SS9J-T2	0.50	0.48	1.05	
SS9J-T3	0.26	0.24	1.09	
SS9J	1.33	1.33	1.00	

4.1.5. Performance of design case of SS9F canal network

4.1.5.1. Operational performance

Adequacy and efficiency parameter

Operational performance of SS9F canal, in average, is characterized by inadequate supply of water into offtakes with efficiency of water use relative to intended supply as 88% in Figure 4-5: This implies that

- Some offtakes are being overused by water, barring other offtakes from intended share, due to substandard design.
- Response time is different with the start time of intended supply

The operational performance of SS9F-R4 is the worst, where there is no supply of water due to high crest level design of structure.

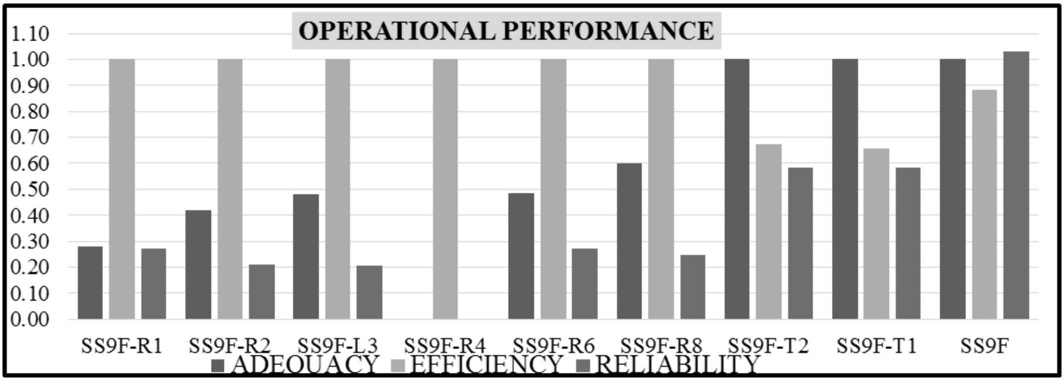


Figure 4-5: Design operational performance of SS9F canal network

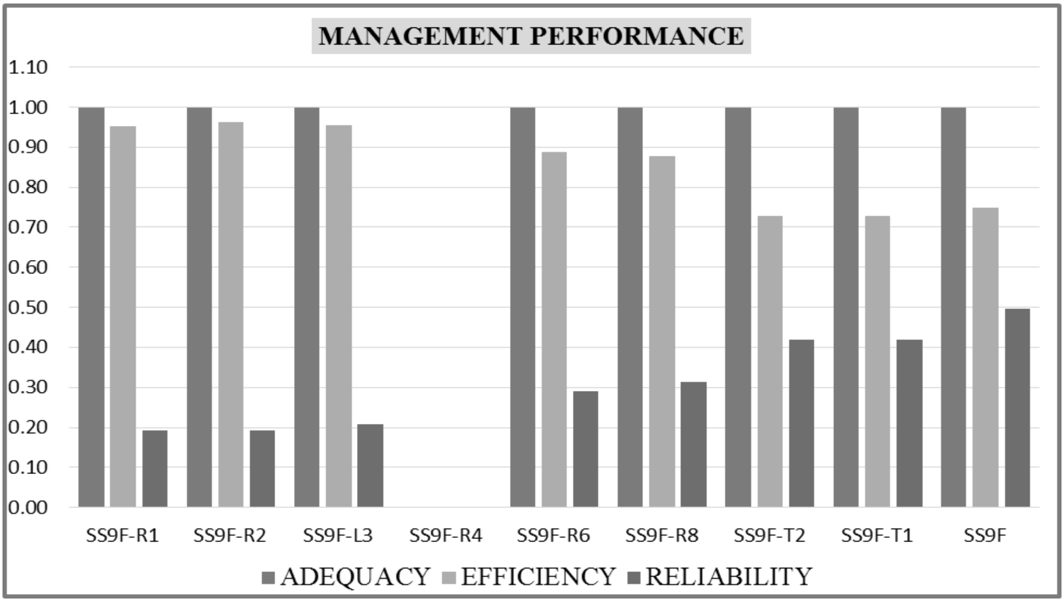


Figure 4-6: Design management performance in SS9F canal network

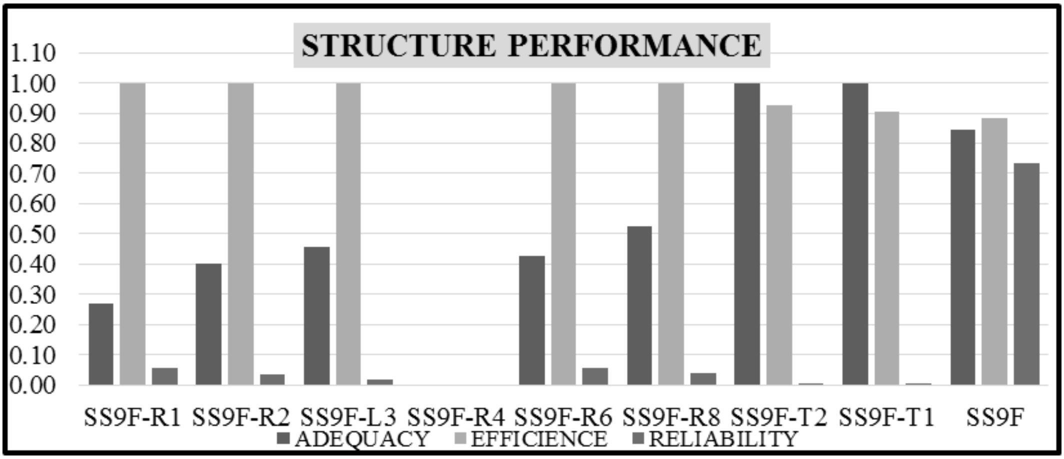


Figure 4-7: Design structure performance in SS9F canal network

Reliability parameter

The reliability measure is characterized by coefficient of time variation of the ratio of actual supply over intended. It is statistically affected by extreme values, in this SS9F-R4, SS9F-T1 and SS9F-T2. This is the reason why operational reliability of SS9F is worsened by 1.03, apart from the response time as shown in Figure 4-5:

Equity parameter

The spatial non-uniformity of operational performance is significantly high due to the effect of structure performance.

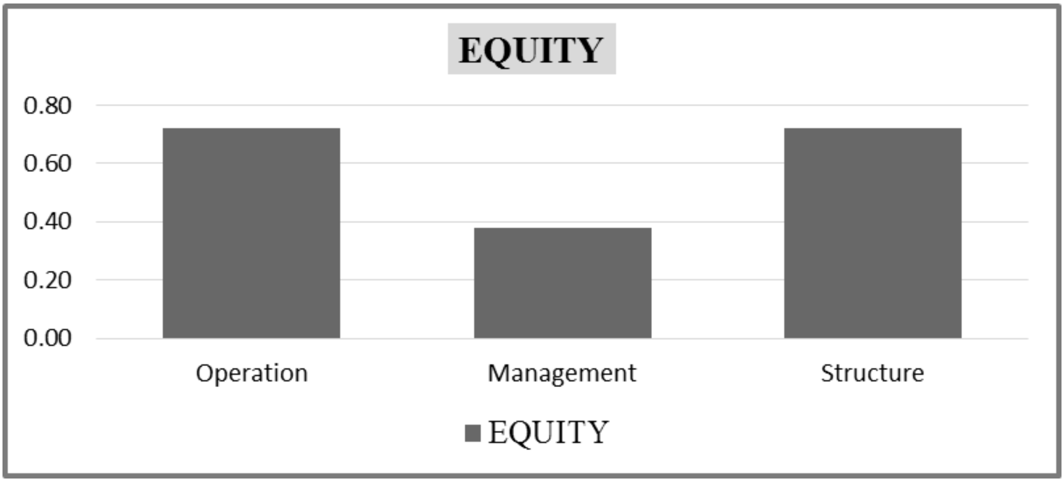


Figure 4-8: Design equity measure of SS9F canal network

This is statistically affected by number of offtakes in a canal receiving fair share of water. Irrespective of uniformity in capacity, more offtakes receiving unfair share of water directs to inequitable supply. In SS9F canal, there are 6 offtakes, viz, SS9F-R1, SS9F-R2, SS9F-L3, SS9F-R4, SS9F-R6 and SS9F-R8 against 2 offtakes SS9F-T1 and SS9F-T2, which receives inadequate supply of water. The operational inequity of SS9F canal for this reason is as high as 42% (Figure 4-8).

Water balance

The water balances along SS9F are presented in Table 4-2. The offtake SS9F-R1, SS9F-R2, SS9F-L3, SS9J-R6 and SS9F-R8 receives lesser discharge then intended and SS9F-R4 has no effective discharge. Therefor the withdraw capacity of these offtake must be increase by decreasing the crest level of offtake or increasing the gate width or increasing the water level in sub-secondary canal or combination of above option suitable to actual field condition.

Table 4-2: Water balance along SS9F canal network

Offtake	Discharge, m3/s		Effect/Intend	Remarks
	Effective	Intended		
SS9F-R1	0.01	0.03	0.28	Needs revision
SS9F-R2	0.02	0.04	0.42	Needs revision
SS9F-L3	0.02	0.04	0.48	Needs revision
SS9F-R4	0.00	0.04	0.00	Needs revision
SS9F-R6	0.02	0.04	0.46	Needs revision
SS9F-R8	0.02	0.03	0.54	Needs revision
SS9F-T2	0.30	0.23	1.24	
SS9F-T1	0.31	0.24	1.30	
SS9F	0.68	0.40	0.98	

4.1.6. Performance of design case of SS9B canal network

4.1.6.1. Operational Performance

Adequacy and efficiency parameter

Adequacy in operational performance of SS9B, in average, is close to 100%. This means actual supply is what is intended, due to shorter response time to steady state. However, SS9B-T4 is overusing actual supply, which is shown by lower efficiency, 49% (Figure 4-9).

The reason for this is the existence of submerged overflow in the canal SS9B-T3 at the same location. Further SS9B-T1 and SS9B-T2 receive inadequate supply. This means crest level is high enough to have design head over these structures.
Reliability parameter

The reliability measure of operational performance is 32%, which is high due to variable response time at offtakes of SS9B canal to steady state. As can be observed in Figure 4-9 that coefficient of time variability at offtakes SS9B-T2, SS9B-T4, SS9B-T1 and SS9B-T3 is different. This makes value of standard deviation large that results are high coefficient of time variation.

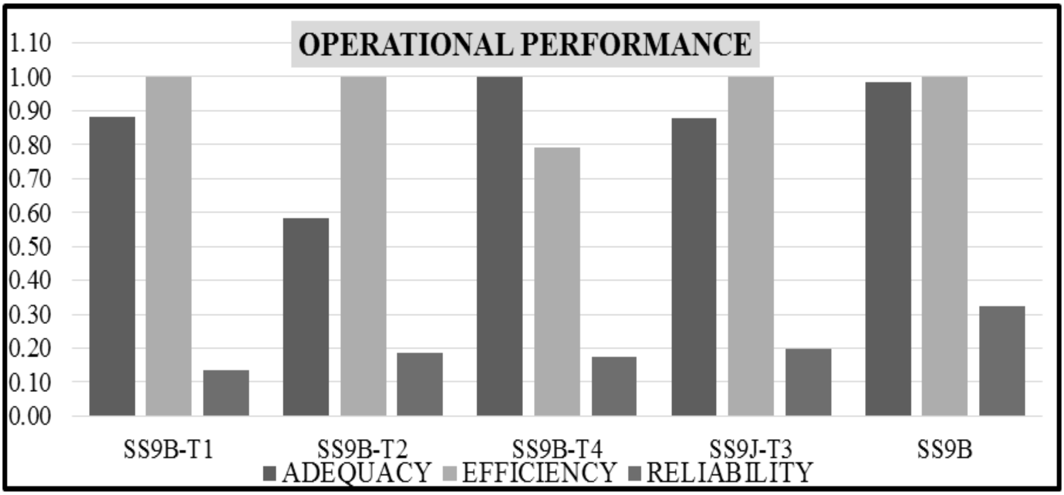


Figure 4-9: Design operational performance of SS9B canal network

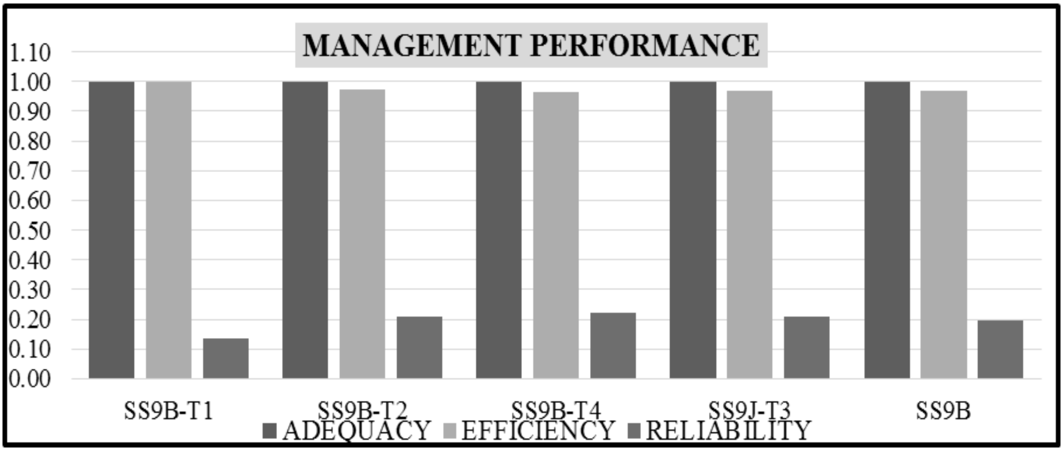


Figure 4-10: Design management performance of SS9B canal network

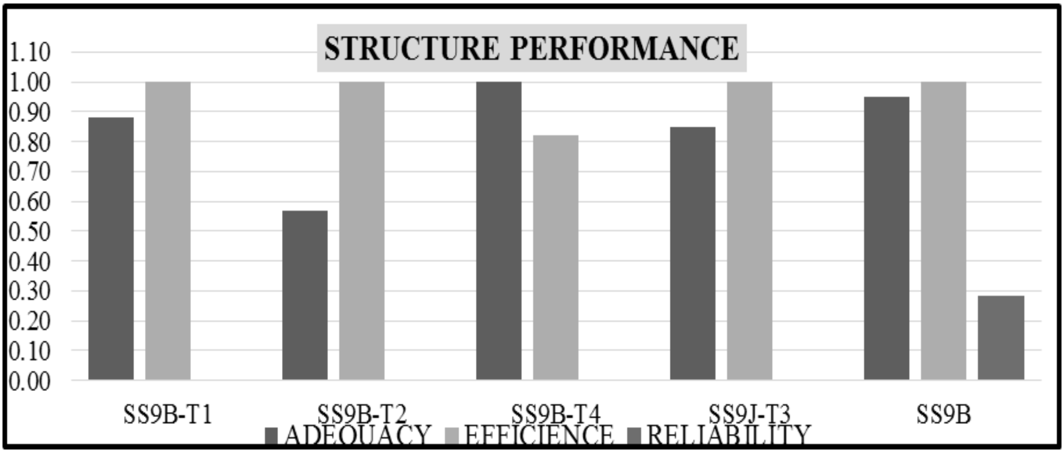


Figure 4-11: Design structure performance of SS9B canal

Equity parameter

Equity measure of operational performance is 24%, indicating that some offtakes receive more water than intended and the rest receive less (Table 4-3).

Table 4-3: Design equity measure of SS9F canal network.

Performance	Equity
Operational	0.24
Management	0.00
Structure	0.24

Water balance

The water balances along SS9B are presented in Table 4-4.The offtake SS9B-T2, receives significant lesser discharge then intended. Therefor the withdraw capacity of these offtake must be increase by decreasing the crest level of offtake or increasing the gate width or increasing the water level in sub-secondary canal suitable to actual field condition.

Table 4 4: Water balance along SS9B canal network

Offtake	Discharge, m3/s		Effect/Intend	Remarks
	Effective	Intended		
SS9B-T1	0.10	0.12	0.90	
SS9B-T2	0.18	0.31	0.59	Needs revision
SS9B-T4	0.44	0.58	1.28	
SS9J-T3	0.24	0.24	0.89	
SS9B	1.24	1.24	1.00	

4.1.4. Overall delivery performance of design case of S9 canal network

Evaluation of delivery performance of SS9B, SS9F and SS9J canal that cover head, middle and tail reach respectively of S9 canal and comparison among them to represent S9 canal as a result of the study is presented below.

Adequacy and efficiency parameter

Adequacy and efficiency measure to delivery performance of S9 canal is close to100% as shown in Figure 4-13. However, SS9F receives 13 % more water, shown by lower efficiency to 88%. The reason is that derivation of the parameter is based on the operational performance, which is coupled with management performance and structure performance of SS9F canal. Management performance is affected only because of response time to steady state in design case, which comes from delivery schedule performance. And, the structure performance is affected due to substandard design of offtake and/or upstream channel that convey flow (i.e., discharge and water level). So, if the efficiency of management and/or structure performance is low, then the efficiency of overall delivery performance becomes low, as the case is (Figure 4-12).

Coefficient of time variation of S9 canal is the lowest 1% in Figure 4-13. The reason is that, the model formulated in DUFLOW for S9 canal network is such a way, it supply design discharge to all its offtake.

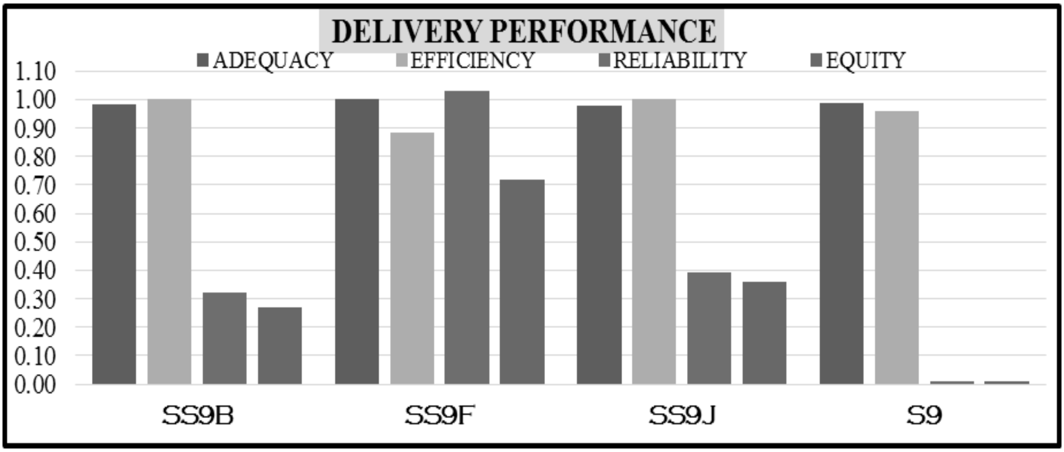


Figure 4-12: Design delivery performance of S9 canal network Reliability parameter

In contrast, offtakes SS9B, SS9F and SS9J have larger coefficient of time variability, as in Figure 4-13. The reason is water manager of S9 canal evaluates the merit of the personnel responsible for operational performance at individual sub-secondary canal irrespective of number of offtakes in a sub-secondary canal. So, the objective is different. This is bounded with logic that the method is less sensitive to extreme value/s. For example, at SS9F-R4, SS9F-R1, SS9F-R2, SS9F-L3, SS9F-R6, and SS9F-R8 there is no/less supply of water into the structure due to its limitation. However, operation performance is shown by lower efficiency to 88%, indicating more supply with respect to intended, as in SS9F-T1 and SS9F-T2. Hence, if operation performance of SS9F canal per unit offtake were considered, then the result would be much lower.

Equity parameter

Coefficient of space variation of S9 canal is 1% as in Figure 4-13. The reason is as mentioned in previous section. This means management personals is equitably distributing supply into respective offtakes in comparison to each other.

4.1.8. Response time to steady state

The response time to steady state of the canal network in study is shown in Table 4.5. It is observed that SS9B canal network in study takes 4 hours to come to steady state, whereas SS9F canal requires 12.5 hours and SS9J canal needs 11 hours to achieve steady state. This means considering the greatest time required reaching steady state, the supply from the parent canal S9 should be ahead of this response time to fully meet the balance of actual supply with intended and effective through the offtake.

Table 4 5: Response time at offtakes

Canal	Location*	Hours	Canal	Location	Hours
SS9B	360	2.00	SS9F-R6	2200	6.50
SS9B-T1	20	1.50	SS9F-R8	3534	4.50
SS9B-T2	1126	3.50	SS9F-T1	3890	12.50
SS9B-T3	1900	3.50	SS9F-T2	3890	12.50
SS9B-T4	1900	4.00	SS9J	14200	11.00
SS9F	4066	5.00	SS9J-T1	459	10.50
SS9F-R1	420	3.00	SS9J-R1	480	1.50
SS9F-R2	868	3.00	SS9J-R3	1109	1.50
SS9F-L3	1125	3.50	SS9J-L2	1124	4.00
SS9F-R4	1900	4.00	SS9J-T2	1666	10.00
			SS9J-T3	1666	10.00
* location in meter from respective parent canal					

4.2 Performance of S9 canal system in actual operation condition (winter season, 2014)

4.2.1 General

The results from DUFLOW model of S9 canal network under operation condition is compiled with respect to performance measures (adequacy, efficiency, reliability and equity) for different components of water delivery system of irrigation canal.

The period of water delivery under study is taken as 120 days (1-December, 2013 to 31 May 2014) for winter season. The SMIS was taken the complete set of operation data for that season i.e. the gate opening of S9 HR,CR1 to CR4 and all fourteen offtake HR every three time a day at 8am,12 pm and 4pm .The SMIP plan to irrigate the S9 irrigation system command area in Six dose of irrigation. The each dose discharges are design for four day continuous irrigation of each group at interval of 22 day for this winter season.

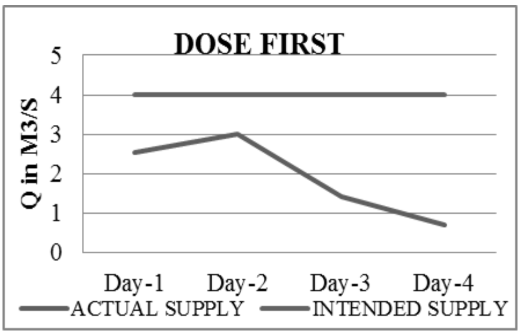
After analyzing the operation data the S9 system was run in six dose for this winter season i.e first dose from December-25 to Dec-28,Second dose from Dec-31 to Jan-6, third dose from Jan-12 to Jan-18, fourth dose Jan-24 to Jan-24, fifth dose from Feb-6 to Feb-18, and sixth dose from March-8 to March-14.The planed assumption for irrigation in winter season is not match in all dose in actual operation condition. The measured data shows that, the gap of first dose is 24 day, first to second are two day, second to third six day, third to four are five day and four to five are nine day and five to six are 24 day. Probably these variation are may be due the CMC has no operational plan, it run on historical experience of WUA and SMIP office as well as unavailability of water in CMC.

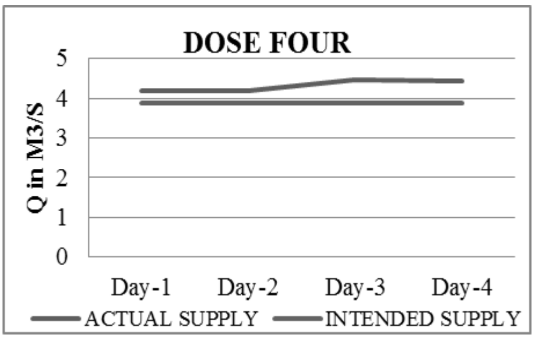
The daily average height of each gate opening for 120 day is set at trigger series in the validated model formed in DUFLO for S9 network and Run the model for 120 day and the output is taken in form of discharge (m3/s) for SS9B, SS9F and SS9J canal network at HR of each oftake from these sub-secondary canal which gives the actual water supply from sub-secondary canal network.

The CLIMWAT and CROPWAT software of FAO is used for crop water requirement (CWR) of existing cropping pattern of sub-secondary canal (taken from SMIP) in monthly basis shown in Annex-A4.The climatic data are taken for Biratnagar airport and other stander data from different literature for soil and crop (ANNEX-A8). These CWR is multiply with actual crop area and divided with canal efficiency gives the intended discharge at canal head.

4.2.2 Actual operation Flow condition in S9 canal network.

The daily discharge hydrograph of at ch. 0+000 of S9 canal for winter season of different dose of irrigation as shown in Figure 4.14;





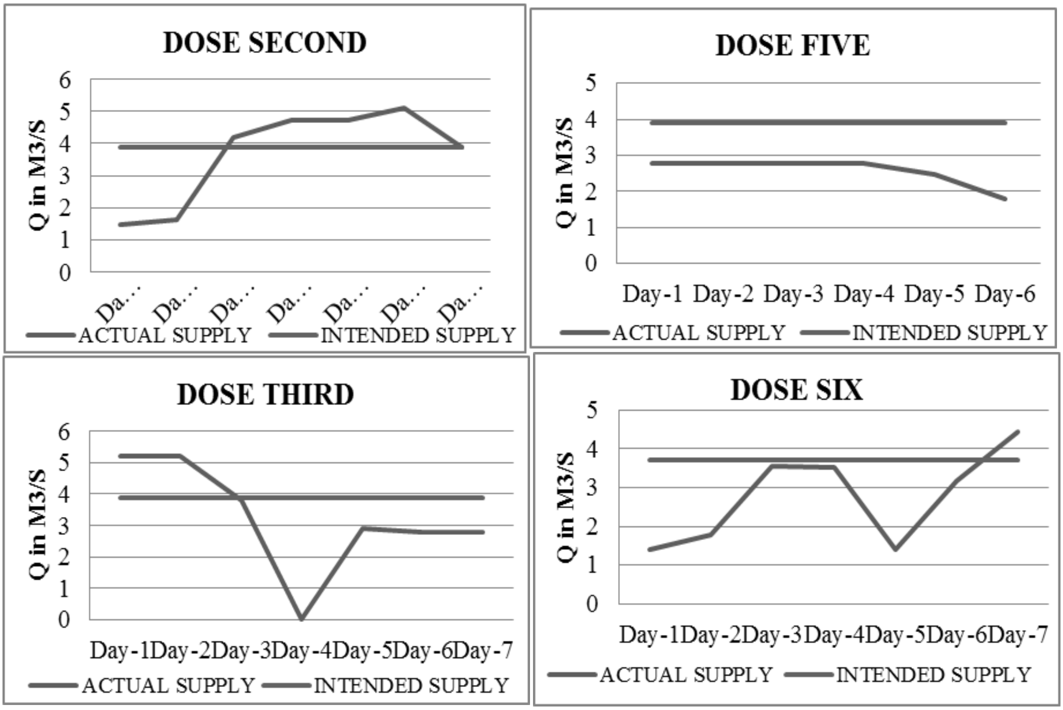


Figure 4-13: Model output discharge in S9 at ch 0+000

The figure 4-13 shows the relation of actual and intended supply as well as variation of discharge on daily basis. The situation is that the actual supply is less than intended supply as well as high fluctuation of discharge throughout the season. According to design case output if we supply constant full supply discharge in S9 canal, then after 12 hour the canal network becomes steady but in actual operation condition discharge is changes day to day so each day have different hour response time and effective discharge there for the 12 hour response time may increases in actual operation condition due to less supply then intended. The figure also shows that, S9 canal system not run in steady condition in operation case more than half of day(which is maximum) during this winter season cause unable to calculate effective discharge pass through S9 network due to varies of effective discharge day by day. The situations are worst in case of individual offtake i.e. at SS9J, SS9F & SS9B. That is why the structure and management performance cannot calculate separately because these parameters have relation with effective supply. So I directly calculate the operational performance of under study taken sub-secondary canal.

4.2.3. Delivery schedule performance

The delivery schedule performance, i.e., the ratio of intended delivery of water by the agency to the required delivery of water by the crop or by the farmer, of S9 canal network under study is evidently 0.5, as only 50% of command area is served with continuous irrigation supply, which is follow in actual operation condition. That is, the required amount of water supply is two times of continuously available (in our case it is intended) supply to its respective offtake. This is the delivery schedule performance at all offtakes over the period (i.e., start time and end time) of intended supply with respect to required supply.

4.2.4. Performance of operation case of SS9J canal network

4.2.4.1. Operational performance

Adequacy and efficiency parameter

Operational performance at an off-take is contributed both by performance of structure and by performance of management to water delivery. The operational performance of SS9J canal, in average, considering all of its offtakes in terms of adequacy is good and efficiency is poor over the period of study as in Figure 4-14 meaning that amount of actually supplied water to its offtakes is what is intended to be is more.

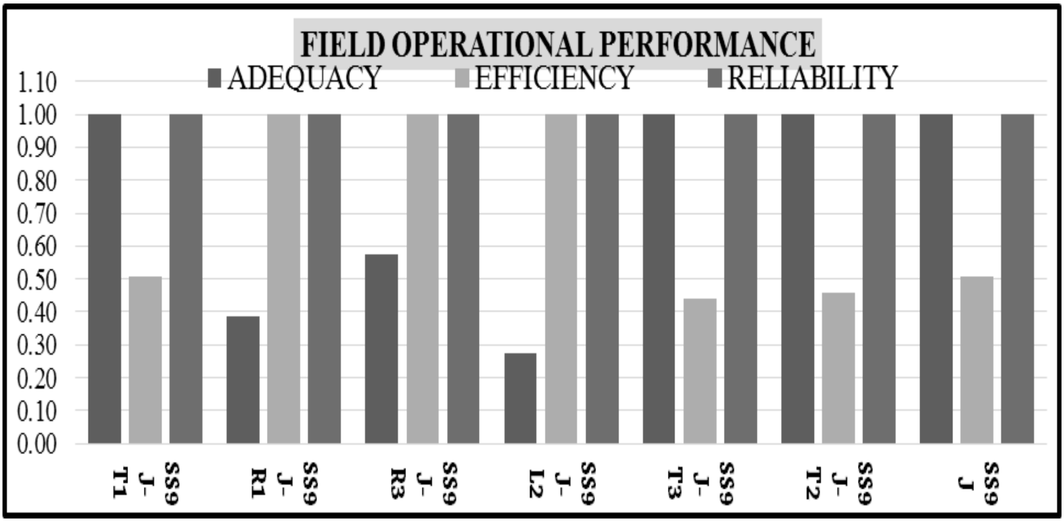


Figure 4-14: Actual condition operational performance of SS9J canal network.

It is observed that actual delivery of water to offtake SS9J-L2 is least in the order of adequate followed by SS9J-R1, SS9J-L3, SS9J-T1, SS9J-T2 and SS9J-T3 with respect to intended delivery (Figure 4-14). Given the highest possible use of water delivery by operation performance relative to efficiency, only 28% of water is actually supplied into SS9J-L2; whereas SS9J-T2, SS9J-T3 and SS9J-T1 actually receive more delivery than intended. That is, offtake SS9J-L1 has been seriously underused by actual delivery of water. In contrast, SS9J-T2, SS9J-T3 and SS9J-T1 have been around two times overused by the actual delivery of water, showing efficiency 46%, 44% and 51% respectively.

This means actual supply into the offtakes is constrained either by the performance of structure or by the performance of management responsible to water delivery preset by delivery schedule.

No any offtake has optimum state of operational performance in terms of adequacy. The reason for this is:

- Some offtake receives more water than is intended and some receives less due to its designed level of crest (Figure 4-14) which are discus in design case, and
- The supply discharge is lower than intended which decrease the opportunity time for high crest level oftake.

Under use and overuse of actually delivered water, either in isolation or in combination of contribution of water management and capacity contribution of structure, through an offtake under study is realized respectively by adequacy and efficiency measure of performance more than one (or 100%) and less than one respectively. This is considered as state of alarm for the measure of performance in water delivery.

Reliability parameter

The reliability shows the temporal variation of discharge over the given time period. The operational performance of SS9J canal, in average, considering all of its offtakes in terms of reliability is poor over the period of study as in Figure 4-14, meaning that timing of actual supply to the offtakes is not in line with intended time of delivery into respective offtakes. There can be two reasons for this as:

- The module output result shows that around one day time required to reach the water at tail end of S9 after the opening of S9 HR, probable which cause the violating operational schedule by management personal responsible for actual supply into offatke.
- Or, the operational schedule needs revision including such time.

Equity parameter

Further, operation performance of SS9J to spatial uniformity described by CV in space of the ratio of the actually supplied to the intended supply of water into the offtakes is non-uniform to the amount of 45%, which is significant high. There can be possibilities for the spatial non- uniformity as:

- Actually diverted flow is less then intended flows which cause decrease water depth into sub secondary canal SS9J which cause not sufficient head for the offtake like SS9J-R1, SS9J-R3 and SS9J-L2 having high crest level due to structural limitation. This cause the non-uniform distribution of delivered water.

4.2.5. Performance of operation case of SS9F canal network

4.2.5.1. Operational performance

Adequacy and efficiency parameter

The operational performance of SS9F canal, in average, considering all of its offtakes in terms of adequacy and efficiency is poor over the period of study as in Figure 4-18. The SS9F canal gate only 51% of intended discharge during this season, this is due to following reason;

- All offtake of SS9F canal receive inadequate discharge below 40% in this season as shown in Figure 4.18. The SS9F-R4 has worse adequacy because it has no supply throughout the study period and the SS9F-R1 have only 3% adequacy.
- The diverted flow is very small compare to intended flow but most of the offtake have high crest level due to design limitation cause low water supply in canal network.

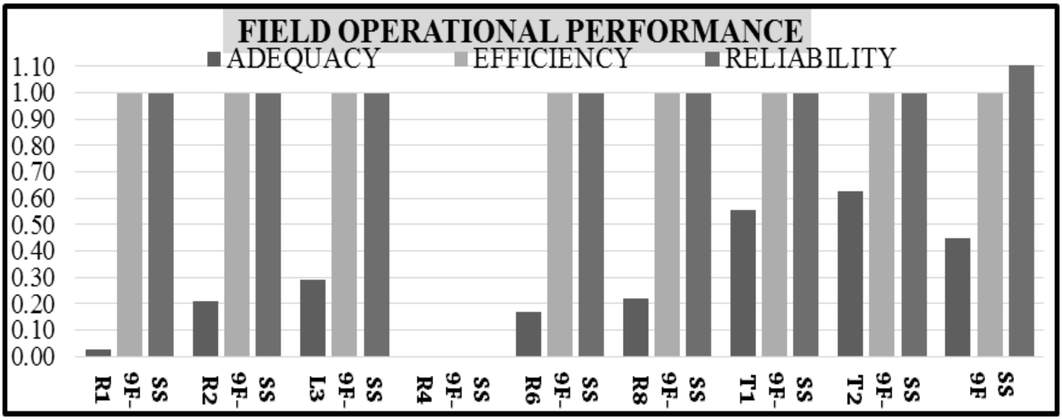


Figure 4-15: Actual condition operational performance of SS9F canal network

Reliability parameter

The reliability measure is characterized by coefficient of time variation of the ratio of actual supply over intended. The statically value of reliability of all SS9F offtake are in between 1.2 to 1.35 whereas 1.08 for SS9F, which are significant value and fall in poor categories but better than SS9J (Figure 4-15).

Equity parameter

Inequity in operational performance of SS9F is observed as 86%.This spatial non-uniformity of operational performance is significantly high due to the;

- Effect of structure design limitation.
- Or the actual diverted flow is very small then intended flow as well as fluctuation of discharge is high.

- Or Small discharge supply longer time which causes unequal opportunity of time at different offtake i.e. more time for lower crest level offtake and less time for higher crest level offtake.

Due to one or combination of above reason cause unfair share distribution of water at SS9F offtakes. In SS9F canal, there are two offtakes, viz, SS9F-T1, SS9F-T2 have more than 50% adequacy , four oftake, viz, SS9F-R2, SS9F-L3, SS9F-R6 and SS9F-R8 have below 30% adequacy and two oftake , viz, SS9F-R4, SS9F-R1have 0-3% adequacy see in Figure 4-15.This fluctuation of adequacy cause unequal distribution of share water in SS9F.

4.2.6. Performance of operation case of SS9B canal network

4.2.6.1. Operational performance

Adequacy and efficiency parameter

Adequacy in operational performance of SS9B in an average taking account of it all offtake is 98%. This means actual supply is what is intended due to longer day of irrigation in most of doses even the actual flow not match with intended flow. There for efficiency is also close to 100% as in Figure 4-16.

The offtake SS9B-T4 supply is free flow condition whereas supply of oftake SS9B-T3 is submerged condition at constant U/S head there for SS9B-T4 receive more water having adequacy more than 100% and efficiency 64 % due to over irrigation whereas SS9B-T3 receive less water having adequacy 46%. SS9B-T2 has 39% adequacy due to high crest level.

Reliability parameter

Reliability measure of operational performance of SS9B canal (Figure 4-16) is high more than 100%.Relability of all offtake are individually also more than 100% except SS9B-T4 having 99%.this means over the time period of actual supply with respect to intended is not match.

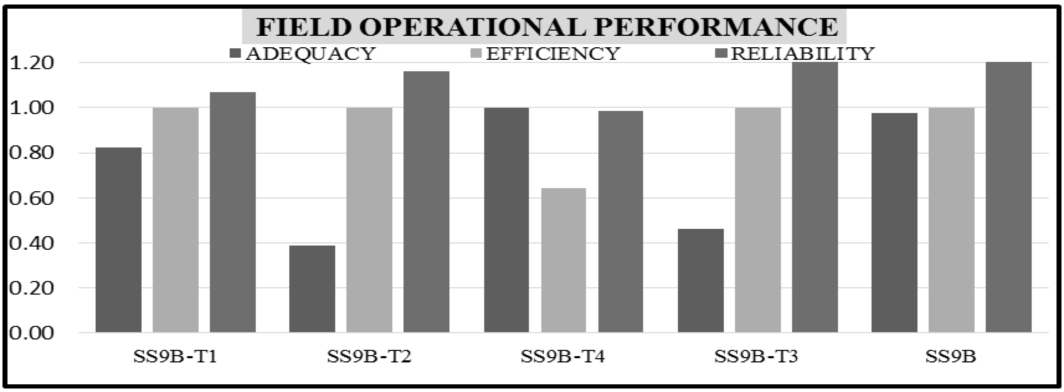


Figure 4-16: Actual condition operational performance of SS9B canal network

Equity parameter

The spatial discharge variation in SS9B canal over the winter season is 58%, which is better than SS9F and SS9J. The equity value is high due to either one reason or combination of both;

- Design limitation of SS9T3 and SS9T4 having different flow condition at same U/S head.
- Or actual flow is less than intended flow which provides longer opportunity time for low crest offtake and vice versa.

4.2.4. Overall delivery performance of operational case of S9 canal network

Similar to design case, Evaluation of delivery performance of SS9B, SS9F and SS9J canal that cover head, middle and tail reach respectively of S9 canal and relationship among them to represent S9 canal as a result of the study in operation case is presented below.

Adequacy and Efficiency parameter

Adequacy and efficiency measure to delivery performance of S9 canal is 81% and 84% as shown in Figure 4-21:

However, SS9J receives more water, shown by lower efficiency to 52%. The reason is that the management responsible person supply longer duration in some dose then intended duration as well as some dose has high actual discharge then intended. Whereas the SS9F has 45% adequacy cause 100% efficiency due to structural limitation. And SS9B has optimum adequacy and efficiency as in Figure 4-17.

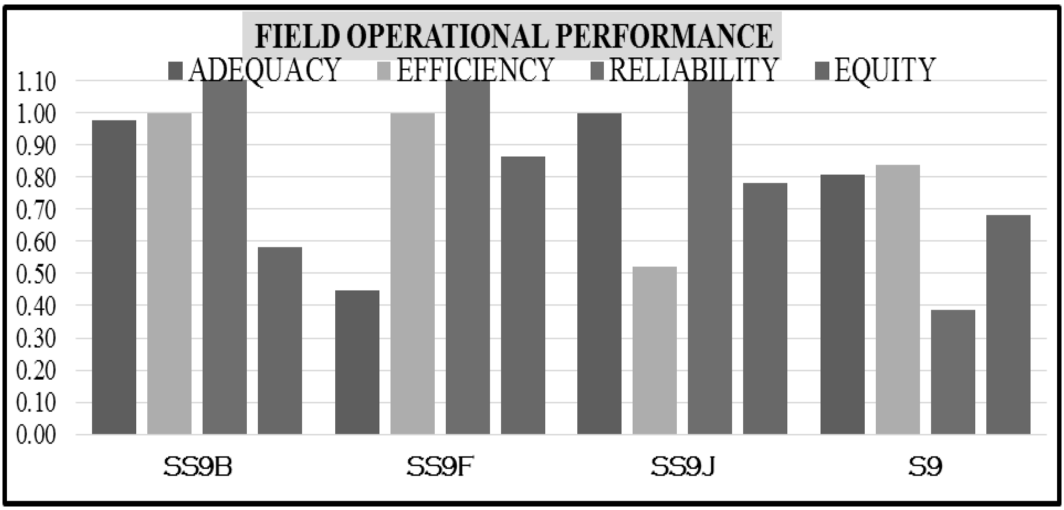


Figure 4-17: Actual condition delivery performance of S9 canal network

Reliability parameter

Coefficient of time variation of S9 canal is 0.39 which is significant value because the limit value of CV is 0.1 where as these value for SS9B,SS9F and SS9J have 1.28,1.64 and 1.44 respectively as in Figure 4-17 and Table 4-6. This numerical value of CV clear shows that the head reach of S9 canal have reliable supply of water and decreases to tail reach which reflect the actual operation condition of irrigation system in Nepal also. The reason behind it is due to one or combinations of all are;

- After analyzing the tail reach hydrograph, only the arrival time of water from S9 to tail part is about one day in complete dry canal which is shown in clearly in first and six irrigation doses.
- The actual supply flow is smaller than intended flow which reduce the water depth in canal, these cause violating of operation schedule by water user as well as no flow or small flow in high crest level offtake like SS9F-R4 and SS9F-R1.
- Probably due to fluctuation of water level in CMC; Even at constant opening, S9 HR unable to supply constant discharge in S9 network which cause unsteady flow in S9 canal network. The model output of different section of S9 canal shows S9 never run in steady state up to one day during this season except small part of head reach.

There for a small steady flow may cause reliable supply then large unsteady flow.

Equity parameter

Coefficient of space variation of S9 canal is 68% which is significantly high value as in Table 4-6. The reason is as mentioned in previous section. This means management personals is unable to distributing equitable supply into respective offtakes in comparison to each other.

Table 4-6: Measure of water delivery in S9 canal at operation condition

Performance	Canal	Adequacy	Efficiency	Reliability	Equity
Delivery	SS9B	0.98	1.00	1.28	0.58
	SS9F	0.45	1.00	1.64	0.86
	SS9J	1.00	0.52	1.44	0.48
	S9	0.81	0.84	0.39	0.68

4.2.8 Comparison of overall deliver performance

The numerical comparison of all four indicators (Adequacy, efficiency, Reliability and Equity) of delivery performance for both cases i.e. design and operation case are presented in figure 4-18.The figure shows that all four indicator value is batter in design case then operational case. The numerical value of adequacy, efficiency, reliability and equity indicator for design case are 0.99, 0. 96, 0.01 and 0 .01where as for operational case are 0.81, 0.84, 0.39 and 0.68 respectively. The indicators adequacy and efficiency have deviation from design case due to SS9F having 45% adequacy only. But the spatial and temporal variation coefficients are poor then design case due to structural limitation and frequency of supply are concentrated in January month. The other reasons are mentioned in previous section.

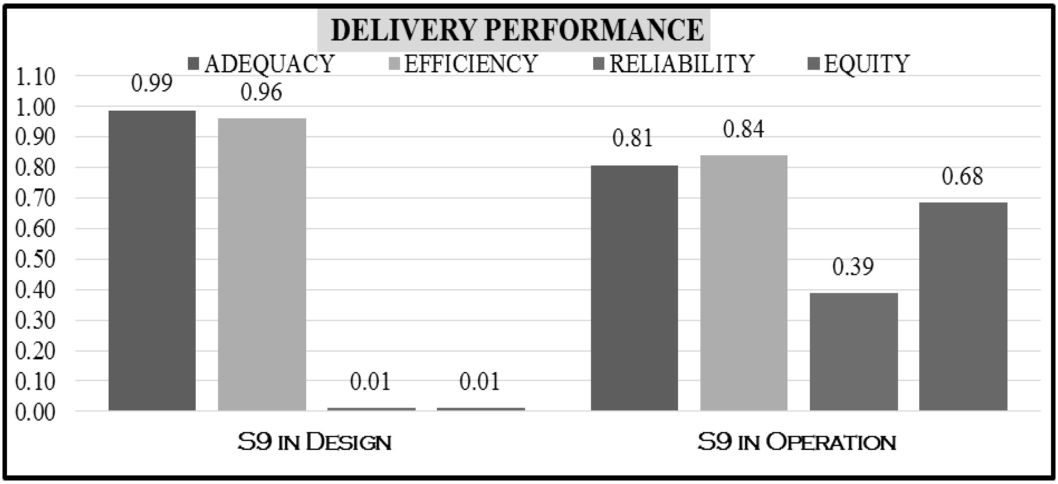


Figure 4-18: Design &Actual condition delivery performance of S9 canal network

5. CONCLUSIONS AND RECOMMENDATIONS

Flow in S9 canal is continuous and lower order canal runs in 1:2 mode of operation during peak demand. Hence, strict follow up of operation procedure is required to obtain high performance of water delivery.

The dimension of the sections of secondary canal S9 shows departure in discharge, based on which channel section is designed, from continuity equation by an average of 14%. The discharge calculated from steady state continuity equation is higher than the designed section discharge. This means discharge capacity of the section is more than design discharge. Hence, for a given section with design discharge water depth is less, as flow velocity would be less along secondary canal S9. Thus, water level or head loss across the offtakes in S9 to command area is over-estimated. Therefore, revision of gate settings for the offtakes along S9 canal is more economical than revising channel section.

Offtake S9-T1, S9-T2, SS9F, S9-T4 and SS9H require use of cross water level regulator downstream of it to match with full supply intended discharge through respective offtakes. However, during design flow in the canal use of cross regulator should be absent to minimize loss of water due to negative hydrodynamic storage. This is more noticeable at offtake for S9-T4 and SS9G, as the distance between cross regulator and the offtake is 300 m and 950 m respectively. Response time to steady state is significant if there is cross regulation of water level along parent canal downstream of offtake aiming to meet target level for intended discharge through the offtake. Hence, inclusion of a new cross regulator along S9 canal downstream of the offtake is recommended as change in bed level of existing S9 canal section or shifting offtake location in upstream would be uneconomical.

Start of intended delivery at an offtake should be right after the response time through canal network to steady state, otherwise depth of irrigation application for a given area would be ineffective by an amount of supply within repose time. This means start of actual delivery at the head of canal level must be scheduled prior to the response time, for an offtake downstream, of actual supply to steady state. Hence, the schedule of delivery preset by operational rule of organization of irrigation scheme should consider response time to steady state to make performance of structure and management at its highest, as the coefficient of time variation in all sub-secondary canals is high. Greatest response time, considering remote location of the offtake from S9 head, the source of water supply, of 12 hour should be adopted in operating gates of respective sub-secondary canal of S9 to match with the start time of intended delivery and start time of effective supply through offtake structures, especially in the tail reach.

Design of all watercourse structures along Sub-secondary canal is substandard, with significantly high crest design at SS9F-R4 where water level in parent canal is below 0.69 m from the crest of offtake. Hence, sufficient time must be given to the careful design of irrigation network with physical facility. The design of control structures should be in line with intended supply, resulting in high performance of structure in design case.

At tail location of SS9B canal, performance of structures of same type behaves hydraulically different for a constant head upstream. Such offtakes as in SS9B-T3 has submerged overflow and in SS9B-T4 with free overflow. This is means flow distribution is not fully proportional because of non-modular flow in SS9B-T3 offtake and modular flow in SS9B-T4 offtake. The non-modular flow is on account of high tail water level led by the bed level in design case. Hence, limiting bed level downstream of structure that ensures modular flow over the offtake can modify this discrepancy, as there is 0.6 m bed drop at 100 m downstream of SS9B-T3 canal with no offtake structure along this length.

As long as structures are not designed to the best of its performance, management contribution is difficult to separate; for example, in SS9J canal the efficiency of management performance is less due to structural limitation under design condition of study.

The irrigation requirement for winter season is divided into six doses each dose of duration four day and irrigation interval twenty two day. The hydrograph of six doses at different section of S9 canal shows that, the actual flow supply is smaller than intended due to unavailability of water in CMC as well as the CMC has no operation plan. But duration is more than four days in some dose for an individual offtake which are tried to meet CWR in volumetric basis. There for the CMC has must run according to logical operation plan.

The smaller actual supply than intended supply reduce the water depth in canal, these cause violating of operation schedule by water user as well as no flow or small flow in high crest level offtake like SS9F-R4 and SS9F-R1 that is why SS9F has 45% adequacy and S9 has 84%. For higher performance canal must be run with intended supply.

Probably due to fluctuation of water level or unavailability water in CMC; Even at constant opening, S9 HR unable to supply constant discharge in S9 network which cause unsteady flow in S9 canal network. The model output of different section of S9 canal shows S9 never run in steady state up to one day during this season except small part of head reach which limit the extent of effect of management and structure performance separately in operational performance for actual operation condition.

According to tail part hydrograph; only the arrival time of water from S9 HR to tail is around one day in dry canal, which is clearly shown in first and six dose of irrigation and out of six dose three dose of irrigation concentrated in January only. This cause unreliable and non-equitable supply, the reliability and equity indicator for S9 are 0.39 and 0.66 respectively which are significant high and the situation for SS9B, SS9F and SS9J are also very poor. There for intended schedule must be follow i.e. four day continuous irrigation at 22 day interval.

Coefficient of time variation of S9 canal is 0.39 which is significant value because the limit value of CV is 0.1 where as these values for SS9B, SS9F and SS9J have 1.28, 1.64 and 1.44 respectively. This numerical value of CV clear shows that the head reach of S9 canal have relatively reliable supply of water and decreases to tail reach which reflect the actual operation condition of irrigation system in Nepal also.

Thus, Using the performance indicators with hydrodynamic model, for example, DUFLOW and crop water requirements model, say, CROPWAT in isolation takes quality time and energy to a manager to come to a quick decision as to the adjustment of water allocation in canals according to the availability and the crop need. Hence, a model that couples performance indicators, canal hydrodynamics and crop water requirements in one is required to be adopted to support short term and log term decision-making procedures in water management of irrigation system.

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Assessment of Water Resources and Irrigation Potential in Nepal

Case Study: Sunsari, Saptari and Dhanusha Districts
By : Birendra Kumar Yadav
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Abstract

Water Resource assessment is the estimation of available water resources and its use for effective planning, sustainable development and management of water resources. Irrigation potential is the area that can be irrigated with the available water resources based on irrigation requirement in soil types, cropping pattern and climate. In this study, available water resources for dry season was estimated based on the groundwater recharge and storage volumes in the ponds for dry season irrigation in of Rabi crops of Sunsari, Saptari and Dhanusha districts in Terai region of Nepal. For groundwater assessment, estimation of recharge is the pre-requisite for management of groundwater resources. Since, recharge computation helps to compute the water that can be potentially used from the groundwater aquifers. In this study, Surfer (golden software) and Water Table Fluctuation method has been used for recharge estimation. Surfer is computational software which creates grid based map using XYZ data file and from created grid file contour map is produced. In Surfer, annual storage volume was computed from plotted contour of maximum and minimum water table depth of May and September annually for study period and then subsequently annual recharge and discharge rate was obtained from storage volume. Also to have more confirmation on result of Surfer, Water Table Fluctuation method was applied to know the seasonal groundwater table fluctuations and to estimate the annual groundwater recharge in the study period. In addition to it, water table data was plotted in the Surfer to have understanding about the spatial and temporal distribution of groundwater table in study districts. Furthermore, annual and monthly fluctuation of water table contours and graph reveals that there is spatial and seasonal fluctuation of water table in study districts. Average annual recharge of 138, 165 and 126 mm/yr was estimated for Sunsari, Saptari and Dhanusha districts respectively which were found 6, 9 and 8 % of annual rainfall in respective districts. Monsoon precipitation was found to be the main source of recharge and about 85 % rainfall occurrence from May to September and June to September appears as major recharge period as well as water source for ponds in study area.

In addition, for pond water, pond volume was computed from the area of the pond obtained using GIS and depth was collected from sample ponds during field visit.

Finally, annual pond storage volume was calculated and it was found to be1.54, 6.99 and 4.81 MCM Sunsari, Saptari and Dhanusha districts respectively. By summing up estimated groundwater and pond water volume, total annual water volume available for potential use was computed as 159, 209 and 148 MCM for Sunsari, Saptari and Dhanusha districts respectively. Furthermore, total water demand was estimated by calculation of the water use in different sectors like agriculture, domestic, cattle and industry. Agriculture demand of water is obtained by calculating the gross irrigation requirement of common crops growing in study area. Agricultural water demand was computed based on the gross irrigation requirement and non irrigated area in existing cropping pattern. However, for other uses secondary data was used for calculation consequently; total water demand was computed as 131, 239 and 282 MCM in Sunsari, Saptari and Dhanusha districts respectively. By comparing the water availability and its demand it was identified that estimated available water was found to be higher than demand for Sunsari district however lower for Saptari and Dhanusha districts. In Saptari and Dhanusha districts it could meet the total demand of winter and spring seasons crops however for summer season available water can meet only about 85 % and 11% of non irrigated area in Saptari and Dhanusha district respectively. This indicates there is sufficient water availability to meet the demand of dry season cropping in all three districts, which reflects that there is potential to irrigate all rainfed land in winter and spring season and most of the lands in summer season of study area which will finally raise the agricultural production and productivity in the study area and indeed helps in income generation of subsistence farmers and reduction of poverty in study area.

Keywords: Water Resources, Assessment, Recharge, Terai, Groundwater, Pond, irrigation, Water demand

1 INTRODUCTION

1.1. Background

Assessment of water resources and irrigation potential is the estimation of available water resources with the water balance, extensive use and the projection of available water in future for the planning and management. Water resource assessment study is basic component for sustainable water related development like irrigation, water supply and use of available water resources (World Meteorological, 2012). It helps in evaluating temporal and spatial variation of the available water and sustainable levels of irrigation for crops and demand. Similarly, Irrigation potential is the area that can be irrigated with the available water resources depending on the type of soil, irrigation requirement and climate (Frenken and Faurès, 1997).This study concentrates on three districts of the Nepal Terai region (Sunsari, Saptari and Dhanusha) to explore water resources and viable irrigation potential. In this study, groundwater and pond water is evaluated for the dry season irrigation of Rabi crops. Irrigation is one of the crucial input for the sustainable agricultural production (Singh, et al., 2012).Water is the key component for sustainable and economic development (World Meteorological, 2012) especially in a country like Nepal where it can acts as the catalyst for all round development and economic growth of the country (Thapa, 2007).

Although in 1995, agricultural perspective plan identifies that for agricultural growth and poverty reduction year round irrigation is the prerequisite for intensification of Nepalese agriculture (Shrestha, et al., 2015). Only about 33 % of irrigated area has got winter season irrigation till date. Due to seasonal and spatial variability of rainfall and surface source, agriculture sector demands for the reliable source of groundwater. Even in study area only less than 35% of irrigated area has winter irrigation facility which is based on the irrigation provided by department of irrigation however, there may be some part of agriculture irrigated by individual tube wells of the farmers. Recently, Nepal government formulated new irrigation policy to provide year round irrigation using conjunctive use of available groundwater and surface water sources. Hence, this assessment of water availability and demand estimation will help in formulation of year round irrigation facility in study districts. It is in these perspectives that this study has been taken-up to evaluate the water sources and irrigation potential of the study area based on study of the groundwater and pond water use and its further potential to use of existing resource for the sustainable irrigation development in the three districts of Nepal.

1.2. Problem Statement

In Nepal, majority of the population lives in rural area and 80 percent of rural livelihoods dependent on subsistence farming (Pariyar, 2003). Most of the farmers, who depend upon rain-fed agriculture for their livelihoods to produce food and generate income, are severely affected by fluctuations in water resources, fluctuation in precipitation and climatic variation (Duncan and Biggs, 2012). Nepalese agriculture contributes 32 % in total GDP and provides employment to 66% of the economically active population (Haefele, et al., 2014). Poor utilization of the available water resources followed by the small, fragmented landholdings and poverty, are the major constraint which reduces the productivity of various agricultural produce in the study area (Rajmohan and Prathapar, 2013). Most of the farmers, who depend upon rain-fed agriculture for their livelihoods, are severely affected by fluctuations of water resources (Duncan and Biggs, 2012). Although Nepal is the second largest water resource rich country following Brazil, the people of study area have been suffering from consequences of drought. Furthermore, According to Department of Hydrology and Meteorology, in Nepal, the data shows the frequency of the drought is increasing in recent years.

In the past decades, the country has faced several dry spells in 1972, 1977, 1982, 1992, 2002, 2004, 2005, and 2006 in both dry and wet monsoon. However, some of these droughts have been followed by the floods and heavy rainfall (Miyan, 2014). According to the Department of Hydrology and Meteorology, the winter drought in 2008 - 2009 was the worst on record when country received less than 50% of average precipitation during the period November 2008 to February 2009. The past records indicate that the frequency of the droughts is in increasing and causing problems in the livelihood. It has caused on crop loss in rainfed farming and has had severe implications on household food security (Miyan, 2014). Due to not having reliable irrigation facility in study area, every year significant parts of the agricultural land remain uncultivated in study area.

Rainfed farming in Terai suffers from frequent and often prolonged, drought due to poor rainwater management during monsoon season (Miyan, 2014). Often these lands remain fallow in winter season due to scanty rainfall and lack of assured irrigation facilities (Synnott, 2012). In order to meet the food demand of the growing population at the current growth rate, the productivity of rain-fed farming in the study area has to be raised from the present level. The Problem is going to be still worse for those areas where possibility of developing conventional irrigation facility, mainly run-of-the-river and groundwater irrigation are limited. The fate of millions of rainfed farms in the region can be greatly improved by adopting the effective utilization of the groundwater (Shrestha, et al., 2013) and rainwater harvesting, conservation and management practices (Sharma and De Datta, 1994). In the view of dwindling water supplies in the study districts, greater emphasis has to be placed in groundwater and pond water and then using it as conjunctive use for supplemental irrigation to crops. Thus, to cope with the frequent drought viable alternative solution is pre-requisite for the study. This study has therefore been conceived to assess the water resources and irrigation potential in Sunsari, Saptari and Dhanusha Districts of eastern Terai region to utilise the available water resources for the agricultural area intensification and crop production to convert the subsistence farming to commercial farming in study area.

1.3. Objectives of the Study

The overall objective of this study is to evaluate the temporal and spatial variation of water availability and sustainable levels of irrigation of Rabi crops for the expansion and intensification of irrigated agriculture in study area of the country. The specific objectives the study is as under:

- To assess the potential of groundwater and pond water within each district.
- To determine crop water requirements of common crops grown within each district.
- To project the irrigation area based on the water assessment and irrigation potential.
- To determine sustainable levels of rabi crop irrigation for each district.

1.4. Study Justification

Proper assessment and understanding of available water resources is crucial for informed irrigation development in Nepal, where majority of the population live in rural areas and 80 percent of rural livelihoods dependent on subsistence farming (Pariyar, 2003). In the Terai region, FAO reported that additional assessment of ground water is necessary (Rajmohan and Prathapar, 2013). It is in this context, this study has been conducted at district level to assess the seasonal variability available resources and irrigation potential. Availability of irrigation has been established to be a major constraint to enhancing agricultural productivity in the Terai region.

The agricultural data claims most of the potential arable land is already used for cultivation. The rapid increase in population forcing for stable and improved productivity from cropping systems for the food security (Sherchan and Karki, 2006). The productivity of the irrigated agriculture shows the sustainable irrigation is necessary to meet the growing food demand. Hence, proper planning and use of the available water will enhance the land productivity, and will help in reducing poverty and ensuring food security.

The means of further intensification of irrigated agriculture in Terai is expansion of area under groundwater based irrigation schemes because the most of the large potential sites for run-of-the-river type schemes have already been used. Now the development of ground water irrigation appears as potentially feasible option for further development of irrigation in the study districts. The need for the increased food production and heightened awareness of intensive agriculture has led to assess the unutilized potential water sources. Due to spatial and temporal variation of the surface water source, it is not enough to meet the water demand during dry season. The significant seasonal variation in irrigation indicates that there is a need of utilization of other water sources in winter and spring season along with the use of surface water sources to raise the agricultural production and productivity in study area. Utilization of groundwater and pond water will certainly help in enhancement of yield in rainfed farming of study area. As groundwater is sensitive, it would be better to evaluate the present water availability for effective development and management of the groundwater resources. Groundwater information shows that the groundwater assessment was carried more than 20 years ago which suggests the long study gap. Also, in this period land use, weather pattern and discharge in the rivers have changed remarkably due to increase in population and change in climatic condition. This seeks for the present study prior to groundwater use in study area. If groundwater and pond irrigation is used with proper planning and management then it will enhance the use of land and water resources, resulting in increased crop production with reduction in poverty (Rajmohan and Prathapar, 2013). Although conjunctive use of surface and groundwater is already been in practise of the limited farmers in the study area; hence, before boosting the uses of groundwater, sustainability issues need to be addressed through recharge evaluation of the study area (Sapkota, et al., 2013).

2. DATASETS AND METHODOLOGY

To fulfil the objectives of the study, field study was conducted as a part of the primary and secondary data collection. Based on the data requirement, location and situation face to face interviews, telephone conversation, emailing was mainly used for the data collection.

2.1 Summary of Methodology

Methodology adopted to fulfil the objectives briefly mentioned in Table 2.1.

Table 2.1 Brief Summary of Methodology

Research Questions	Methodology	Data Used	Outputs
Assessment of pond water source.	Analysis of the primary data collected during ground during ground truthing of ponds. Estimation of average depth from pond from collected data. Estimation of Pond area from shape file prepared by IWMI using NDWI.	Depth of Ponds collected during ground truthing of ponds. Secondary data from IWMI, GIS shape file prepared by IWMI	Availability of seasonal storage water in the ponds. Volume of Water in the ponds before and after the monsoon period. Volume of water available in pond for irrigation.
Assessment of Ground water source.	Use of monitoring well data in Surfer to estimate seasonal groundwater storage. In Surfer, by using monitoring well co-ordinates and water table depth, it plotted water table contour and provides volume for wet and dry months. Difference of wet and dry month gives seasonal storage. Use of Water fluctuation method. Using difference water depth between May and September (Δh), specific yield (S_y) and area gives storage volume.	Monthly groundwater monitoring well data. Location co-ordinate of monitoring well stations. May and September water depth to calculate Δh. Specific yield values. Area of aquifer.	From Surfer, water table contour map and seasonal groundwater storage volume of each year. Based on storage volume estimation of recharge and discharge. Estimation of recharge also from Water Fluctuation Method.

Determination of the current extent of the irrigated cropping in the Rabi season	Secondary data of irrigation area was collected based on the study area information.	Irrigated and un-irrigated area of the study area. Surface and groundwater irrigated area.	Extent of irrigated cropping area in the Rabi season. Additional requirement of irrigation in different season.
Calculation of the crop water requirement.	Estimation of crop water use and net irrigation requirement. Estimation of gross crop water requirement for common crops.	Climate data, soil data, crop area in the districts. Secondary data of water uses in other sectors like domestic, industrial Cropping pattern and secondary soil data.	Seasonal Crop water demand. District wise irrigation water demand for rainfed farming.
Potential of irrigation and Rabi crops within each district.	Computation of gross irrigation requirement and water availability of districts.	Computed Irrigation water requirement. Assessed Water resource and its availability.	Projection of irrigable area based on the water availability.

3. Results Analysis

3.1 Water Resource Assessment

3.1.1 Pond Water Source

Large numbers of permanent and temporary ponds are available in study districts. Based on the remote sensed image information, altogether 1283, 2844 and 2858 number of permanent and temporary ponds are existed in Sunsari, Saptari and Dhanusha district respectively.

Storage area and Volume of Ponds

Table 3.1 Permanent Ponds Area and Potential Volumes for Use

District	*No. of Permanent ponds*	*Permanent Ponds Area (Ha)*	*Average wet season depth (m)*	*Average dry season depth (m)*	*Wet season volume (MCM)*	*Dry season volume (MCM)*	***Total volume (MCM)***	*Evaporation loss (MCM)*	*Seepage loss (MCM)*	***Potential Volume for use (MCM)***
Sunsari	707	137	2.34	1.21	3.20	1.65	**1.55**	0.7	0.3	**0.6**
Saptari	1848	426	3.03	1.39	12.92	5.93	**7.00**	2.1	0.9	**4.0**
Dhanusha	1956	473	2.75	1.73	13.02	8.20	**4.82**	2.3	1.0	**1.5**

Source: IWMI Ponds Map

Number of permanent ponds indicates that there is large number of existing ponds which can be used for supplemental irrigation in study area. Altogether 13 MCM volume of water was found as pond storage volume but by considering the evaporation and seepage losses only about 6 MCM volume was found for potential use of dry season crops in study area. Evaporation and seepage losses were determined by following the procedure adopted by FAO.

Although, ponds are mainly used for fishery purpose, it is found that most of the ponds are using for dry season irrigation depending on the availability of water in ponds. Especially, in the area where there is no surface and groundwater facility available pond is crucial for supplemental irrigation. Result shows that altogether 6.0 MCM of pond water volume is available for potential use in the study districts

3.1.2 Groundwater Source

Assessment of the change in groundwater storage involves periodic water level measurements, construction of water level change maps from water level measurements and computation of the volume change with time. Unless artificial abstraction disturbs the natural phenomena, the storage change of the aquifer reflects the seasonal change in precipitation and evapotranspiration. Monitoring well data explains the trend and fluctuation of the water table in the aquifer.These results cover general groundwater concepts and are the result of data collected for the assessment of groundwater and finally quantify groundwater availability in the districts.

In the Terai plain of Nepal, precipitation is the primary source of groundwater. As mentioned in the hydrogeology of the Terai plain, upper part of Terai is the Bhabar zone, is highly permeable. It is the principal recharge zone of the Terai groundwater. It recharges either by the direct rainfall infiltration or inflow from the rivers traversing it (Rajmohan and Prathapar, 2013) and (Dahal, 2014). Area covered by the Bhabar zone is 100, 200 and 140 Sq. km in Sunsari, Saptari and Dhanusha district respectively (Kanzler and Shrestha, 1989), (Echhya K, 1992b) and (Echhya K, 1992a).

3.1.2.1 Maximum Water Depth Fluctuation

Water depth fluctuation describes the spatial groundwater table trend in the study area during study period. It helps to analyse the variation in different location and reason of spatial water table change in different parts of district and finally it helps to understand the variation of the groundwater spatially in the districts. Maximum water depth fluctuation is the difference in deepest water depth in May (pre monsoon) and shallowest water depth September (post monsoon) for each station during study period. Maximum fluctuation water table contours of study area shows that the fluctuation is the maximum in Dhanusha and Saptari districts whereas it is not beyond 7m in Sunsari district. Maximum water depth fluctuation contour illustrates that water table fluctuation is spatially diverse in districts. Plot showed that fluctuation is lower in the region where river passes across it and higher in the city area except in Dhanusha district where table fluctuation more in northern part of district. In significant part of districts area, it appears as fluctuation is about 2 to 3 m which explains that there can be potential groundwater storage in most part of study area.

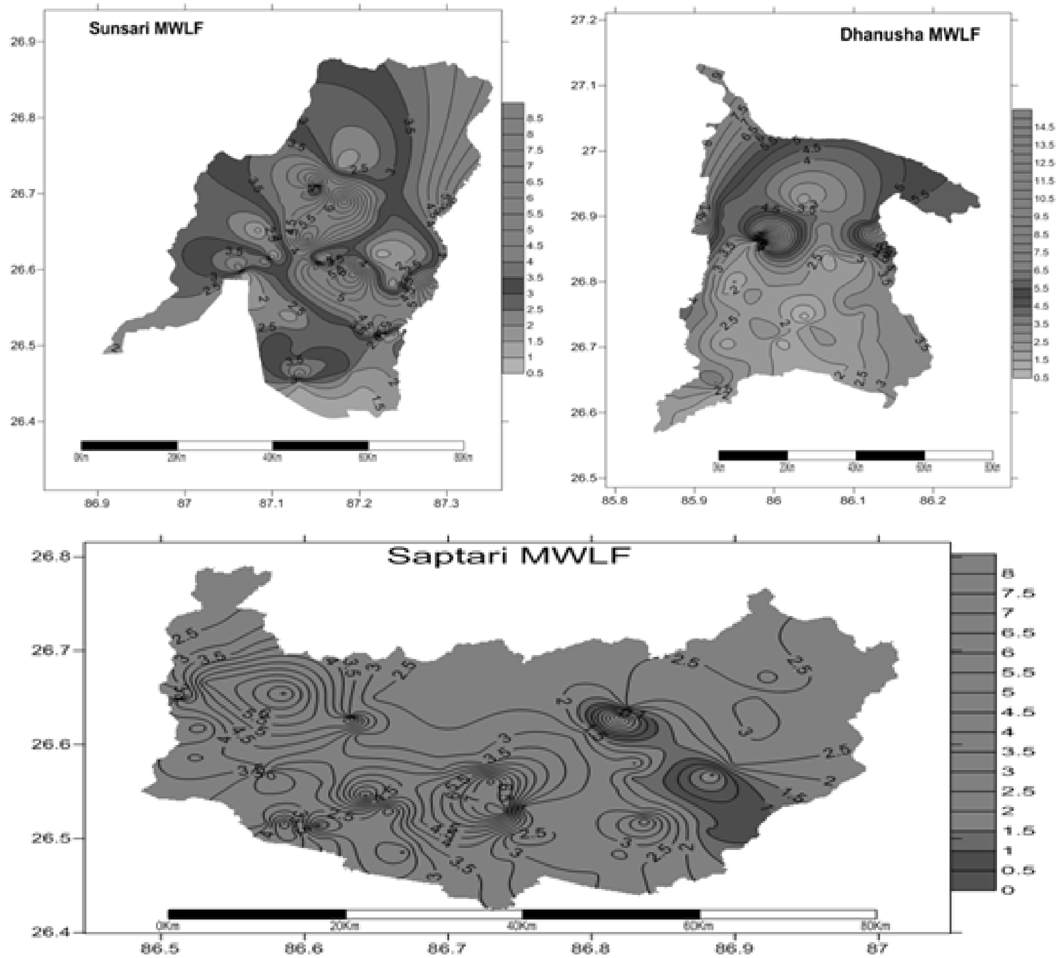


Figure: Maximum Water Depth Fluctuation in Study Districts (Source: Surfer Result)

3.1.2.2 Groundwater Storage

In order to quantify the groundwater storage, it is necessary to calculate Δh and specific yield (Sy) of the aquifer. Δh is calculated based on the monthly measurements of 24, 42 and 28 monitoring wells in the Sunsari, Saptari and Dhanusha district respectively. Though these numbers of stations were mentioned for the calculation but all these stations did not have the complete datasets of throughout the study period. Hence the number stations of vary in some years of the calculation.

The annual Δh was obtained from difference between maximum water depth in May and minimum water in September. Specific yield value was used based on the review of literature of similar geologic formation of India (Ambast, et al., 2006), as study area is also a part of the Gangetic basin. To be on the safe side it was assumed as 10% for whole study area although in India it is ranges from 10-18 percentages. However, (Machiwal and Jha, 2014) emphasized that in real world aquifer system Sy values are spatial and Sy value need to be determined for the different region of the aquifer. But, due to unavailability of the spatial data of Sy and limitation of time it was not possible to obtain specific field of study area. Thus, in this study specific value of Indo Gangetic Basin of India has been used as reference value.

The changes in storage volume in May and September reflect the recharge and discharge in the aquifer of the study area. In this study Surfer was used to compute the storage volume in May and September.

a) Annual Storage and Recharge Calculation based on Surfer

The average annual recharge was computed as 141 mm/yr, 161 mm/yr and 119 mm/yr Sunsari, Saptari and Dhanusha district respectively. Annual average recharge obtained from the Surfer is identical to the results of national groundwater recharge estimated by IGRAC. (Margat and Van der Gun, 2013) suggests groundwater produced internally as 142 mm/yr and diffuse natural groundwater recharge as 135 mm/yr for Nepal. Result obtained from the Surfer was found near to national recharge estimation. Hence it verified the result of Surfer. However, this result deviates from recharge estimated by UNDP in the Terai region of Nepal. UNDP claims annual recharge as 200 MCM/yr, 400 MCM/yr and 300 MCM/yr for Sunsari, Saptari and Dhanusha district respectively (Echhya K, 1992a, Echhya K, 1992b, Kanzler and Shrestha, 1989).

b) Annual Storage and Recharge Estimation Using Water Table Fluctuation (WTF)

It is the most commonly used method for the computation of the groundwater recharge (Healy and Cook, 2002). This method is based on the assumption that the fluctuation of the static water level in the unconfined aquifer is mainly due to the contribution of recharge to the water table (Healy and Cook, 2002). This method is suitable where groundwater monitoring data is available and in humid region like study area. The average water table was found deepest in the May and shallow in September. Summary of the annual recharge results indicates significant annual variation in recharge within district as well as among districts in study area. However, average annual recharge of study period found likely among the districts.

In summary, recharge value for each district was estimated as an average of the recharge rate computed from Surfer and Water Table Fluctuation method. Average of the evaluated recharge rate value is 138, 165 and 126 mm/yr and terms of total groundwater availability 158, 205 and 146 MCM/yr for Sunsari, Saptari and Dhanusha district respectively. If we look at study area average recharge is 143 mm/yr more closely to national internal ground water recharge of 145 mm/yr (Margat and Van der Gun, 2013). This indicates the good accuracy of the results.

Result Accuracy

The accuracy of the result calculated from the Surfer was checked with the result from the water fluctuation technique. The volumes estimated by using both methods are nearby and result deviates by only 4 %, 5 % and 10 % in Sunsari, Saptari and Dhanusha district respectively. This suggests that obtained result is good. In addition, calculated groundwater recharge value for the districts are near to internal annual groundwater recharge and diffuse natural groundwater recharge estimation 142 and 135 mm/yr respectively for Nepal by (Margat and Van der Gun, 2013). Hence, computed results are supported by the previous studies result and also in this study 11 years of groundwater data has been analysed which may give reasonable recharge estimates than (Kanzler and Shrestha, 1989) study in which only 3 years data were use and result was different than present estimation. To conclude, evaluated results for study area appears as suitable for future research and could be used for development as well as management of groundwater in study area.

Groundwater Recharge Estimates from Surfer and WTF

The recharge estimates include the total recharge contributed to raise the ground water table. It includes the precipitation, sub-surface inflow, and inflow from the river, return flow from irrigation and recharge from the ponds in the study area. Although there may be the part of the contribution from the sub-surface, river inflow and irrigation return flow; precipitation is the major source of recharge and cause of water table fluctuation. Groundwater recharge is estimated using Surfer and WTF method, using groundwater monitoring data from 2000 to 2010. Result obtained from the both method is meaningful because average annual results study period are close each other. Although recharge results illustrate, significant inter and intra annual variation likely to occur in study districts. The variation might be due to variation of rainfall, rainfall intensity in districts, different land use and difference in area of Bhabar Zone in districts. Generally, Bhabar zone acts as major recharge zone of districts due to having permeable formation of sand and gravel. It has been suggested that 32.5 % of rainfall in Bhabar zone for study area recharge to the aquifer. However, in Terai zone percolation vary in study districts. In Saptari district 21 % of rainfall percolates to the aquifer while for the same Terai region of Dhanusha percolation is only 15 % (Echhya K, 1992a). In present estimation, Saptari district has relatively higher recharge rate than Dhanusha and Sunsari district, might be due to having higher percolation in Saptari district in comparison to two other district. The recharge rate estimated for study districts in previous study is higher than present Surfer and WTF method computation mainly due to assumption of specific yield as 0.15 which is higher than the current assumption of 0.10 and partly might be due to different time of estimation. Previous estimation was carried more than 20 years ago, at that time land use type and precipitation might be different than the study period condition. Also, at that time May and September water table difference was assumed as 2.5 m which is significantly higher than present difference value of 1.35, 1.69 and 1.32 m in Sunsari, Saptari and Dhanusha districts respectively for the same. Hence, annual net recharge estimation provides the understanding of water table fluctuation and annual groundwater that can be potentially used in study area. Finally, it describes the annual groundwater availability to the district area. In Dhanusha, it shows negative recharge in the year 2009 and 2010 which means that water table in September is deeper than May for 2009 and 2010. It might be due to having low rainfall monsoon and high in spring season. Both recharge estimation from Surfer and WTF method indicate the close results of recharge in the districts. Average annual groundwater recharge and storage volume from estimations proves that there is availability groundwater source in study districts. Annual average recharge and rainfall need to be further analysed to know their consequences.

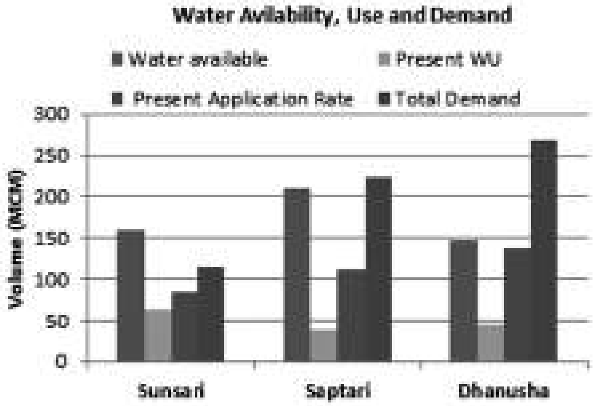
Rainfall and Recharge

Table : Annual Average Recharge and Rainfall

Name of Districts	*Surfer Annual Recharge (mm/yr)*	*WTF Annual Recharge (mm/yr)*	*Average Annual Recharge (mm/yr*	*Average Annual Rainfall (mm/yr)*	*Recharge as % of Rainfall*
Sunsari	141	135	138	2163	6%
Saptari	161	169	165	1749	9%
Dhanusha	119	132	126	1624	8%

Irrigation requirement of crops are affected by groundwater table depth in agricultural area. Especially, in case where groundwater table is shallow part of the crop water requirement contributed by capillary rise. (Mishra, et al., 1995) identified that it is not necessary to apply more than 120 to 180 mm irrigation in wheat where water table is (< 0.9 m) and (< 1.3 m) respectively in the Terai region of India.

1.6. Available Water, Use and Demand



Based on the water availability and water demand in current situation, all water demand can be possible to meet in the Sunsari district whereas for Saptari and Dhanusha districts water demand of only 20,500 and 3500 ha of paddy field can be meet during summer with respect to present demand and availability. However water demand in winter and spring season can easily meet the present availability in Dhanusha and Saptari too.

1.1. Limitations of the study

Following limitations were found during the study:

i. Lack of complete monitoring wells data. Monitoring wells data of all the months and all parts of the district were not available. Reliable spatial and regular monitoring well data is essential for good result.
ii. Unavailability of the surface water source river data make uncomfortable to make water balance of the study area.
iii. Assumption of specific yield value instead of having representative values of specific yield spatially in study area, as it was not possible to conduct pumping tests throughout district area due to limitation of time.
iv. Lack of runoff and rainfall intensity data in study area.
v. Lack of past study data in related research area. Due to which most of the infomation used for this study in terms of Terai region context.

A more comprehensive study on spatial specific yield, aquifer properties and economic study of groundwater use is recommended to arrive at guiding conclusive results.

1.2. Conclusion

There was wide spatial and temporal variation of precipitation in the study area. Occurrence of rainfall was excess during monsoon whereas deficit during the dry season with respect to ET demand. Available rainfall in dry season is insufficient to meet the crop water requirement of during dry season because more than 85% of precipitation occurs in from May to September and with significantly less rainfall in rest of the months. This annual and seasonal variation in rainfall has considerable affect in rainfed farming of Rabi crops and subsistence farming even more. Variation of the climatic condition indicates that it is important to shift from rainfed to irrigated agriculture to have better yield and profitable agriculture.

Based on the analysis of groundwater and pond water sources in the study area, potential annual water sources available for use are 159, 209 and 148 MCM, for Sunsari, Saptari and Dhanusha district respectively. Average annual groundwater recharge of 138, 165 and 126 mm was estimated using Surfer and Water Table Fluctuation method in study districts Sunsari, Saptari and Dhanusha districts respectively. The major contributor for the recharge is precipitation and was found 6, 7 and 8% of annual rainfall in Sunsari, Saptari and Dhanusha district respectively. Rainfall is Excess during monsoon and deficit from October to May far below than evapotranspiration demand. Based on the monitoring well data analysis and recharge estimation using different technique it can be concluded that there appears good prospects of groundwater in almost whole study area, except in the few northern part, at the foot hills where water table was recorded deeper than 10 m. In most part of the study area water table was appears near to the ground surface not below than 5 m, which indicates that water can be accessed easily and cheaply. Even a hand pump, treadle pump and centrifugal pump can be sufficient for the abstraction water which is relatively cheaper way achieving water than achieving water from deep depth with submersible pump or high capacity motors.

Existing groundwater and pond water in study districts can be the viable available water to meet the water requirement of the Rabi crops. As the most of the surface water source gets dry during dry season, available sources are pond water and groundwater. Groundwater table is near to the ground surface after monsoon season, which indicates that there is high potential to use groundwater for Rabi crops. The average monthly water table pattern shows that the water table depletes during the dry and recharged with the rain water during monsoon season. Since average annual groundwater recharge was found significantly higher than the current demand for dry season irrigation of winter and spring seasons hence it can be used for long term for irrigation in dry season for better yield in rainfed agriculture. In addition, use of ground water lowers the water table during dry season and makes more space for water to come in during dry season. This may helps to control the flood during high rainfall in monsoon season and also better aeration in the root zone where water table is near to the root zone during post monsoon season. Water availability shows that it can easily meet the irrigation requirement of dry season's crops.

Gross irrigation requirement of the crops based on the non irrigated area, existing cropping pattern and climatic conditions in Sunsari, Saptari and Dhanusha district was found 116, 224 and 268 MCM respectively which is below the available water in the Sunsari whereas higher for Saptari and Dhanusha districts. Hence for these two districts it is possible to irrigate only about 85 % and 11 % of non irrigated paddy field while for dry season crops it meets all the demand of water. Sufficient groundwater and pond water availability in dry season for Rabi crops indicate that by using these water sources agricultural production as well as productivity of Rabi crops can be increased in the study area. Water availability and demands of Rabi crop season confirms that Rabi crops can be irrigated sustainably for long term use since it requires only 50, 48 and 60 % of total water availability in Sunsari, Saptari and Dhanusha districts respectively. Hence, it concludes that there is good potential of groundwater to use as irrigation in dry season crops.

Finally, assessment of water resource is an important for good planning and sustainable development as well as management of available water resources. Especially, in the country like Nepal, where there is large spatial and temporal variation of water resources across the country.

1.3. Recommendations

- Specific to this study, based on the water availability and water demand in the study districts it would be good to use the groundwater and pond water sources as irrigation to raise the production and productivity in the study area. Study results shows that potential volume of water has not been used in agriculture hence effective utilization of the available water sources could be the wise decision in the study area to raise the production and productivity.
- It is recommended for conjunctive use of groundwater with surface water for economical and sustainable use. Also, enhancement of groundwater use through appropriate conveyance and irrigation methods to increase water use efficiency, which may help in control of pumping volume and costs.
- It would be good to recommend that as groundwater is common pool resources it would be better to make some policy for control use of groundwater. It would help in over abstraction as well as reduce the cost of pumping.
- Study shows that large number of permanent and temporary ponds spatially exists in the study districts with considerable volume of the pond water which can be the potential source for dry season irrigation which has not been taken in to account by government although it has long history of use.
- It is important to understand the rainfall intensity in order to relate rainfall and recharge, daily rainfall intensity data may provide better information for the

groundwater recharge consequences. As it is seen in the result analysis although rainfall had not varied in some years but recharge rate of the same years were found significantly. Hence, it would be better to know the rainfall intensity to compare the annual rainfall and recharge rate so that we can relate groundwater recharge variation with rainfall intensity. In this study only monthly rainfall data is considered for recharge.

- It is important to know base flow from the river to verify the groundwater balance in study area.
- It is recommended for the development and management of the existing temporary ponds. If existing large number of ponds get rehabilitated with depth, shape and size of the ponds so that it could store more water during monsoon season and which will finally help in dry season irrigation as well as recharge to the area.

Future Research

- A more comprehensive study on spatial specific yield and aquifer properties is recommended to arrive at guiding conclusive results.
- Although significant volume of water is available for use it would be better to account the economics of groundwater use for sustainable and profitable use of water resources.

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Understanding and managing spring systems for sustainable ground water development in mountain regions: Experiences from Doti and Baitadi Districts

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Abstract

Springs as the major source of drinking and irrigation water in the hills and lower mountain regions of Nepal is the expression of groundwater systems in these areas. However, natural and anthropogenic processes are leading to the drying of these important water sources. The result has been increased pressure for the migration of people and the abandonment of agricultural activities.

Despite the appreciation of springs as a livelihood driver for hill and mountain communities the complexity inherent in their understanding has so far not been comprehensively done. This complexity derives from the interactions of the surface and groundwater streams that requires significant detailed assessments and that is not normally not easy to accurately extrapolate across large areas.

A study is thus underway to try to provide a detailed understanding of these interactions and especially answer the questions: what is the source of the springs? How and from where are the springs recharged? What is the lag time in the recharge process of the springs? What is the lag time between rainfall and spring discharge response? This study is being implemented in the Far West region of Nepal using both biophysical and environmental tracer methods on two spring-sheds of Doti and Baitadi Districts. The assessment aims to develop a flow mass balance, describing the different contributions to spring flow over time and space. This information will aid in the quantification of spring sources, recharge areas, and recharge time and the responses to interventions to promote the health of these springs. The information obtained would be a significant contribution to the water management planning process aimed at assuring sustainability of these water systems through reliable determination of water availability for the communities. It will also support development plans that aim to promote agricultural production in these regions through a holistic system that supports the maintenance and/rejuvenation of spring sources.

In this report, we present provisional results indicating the dependence of the communities within the study areas to spring water. The communities perceived and acknowledged spring sources as the key determinant of their livelihood in an environment where natural resources are the sole source for economic and social development. We also

highlight the increased dependency on remittance and labor service for economic survival of the communities, a development that is both maintaining the community system despite reductions in traditional production systems (agriculture) while also impounding the negative impacts to the environment as less resources are devoted to the management of these resources.

Keywords: *Springs, groundwater, recharge area, environmental isotopes, remittance, migration*

Introduction

Springs are the major water source for most of communities located in the mountainous Himalayan regions, especially in Nepal. However, there is a lack of comprehensive studies on spring hydrology (which is the major water source for upland people) linked with surface and groundwater resources. Lack of physical data and undermining spring recharge potential in watershed management plans has led to negligence in understanding spring hydrology and subsequent omission in watershed planning activities. Furthermore, conceptual models (based on field observations), analytical models (based on laws of physics and derived equations) and digital models (such as computer modeling platforms) have not been extensively applied to address spring or mountain hydrologic phenomena, especially for the Nepal region.

Several studies have indicated that mountain springs are drying up, a fact that is being attributed to climate change. However, so far, there is no scientific evidence to back this up. Much of the statements on the status and trends in watersheds in Nepal are anecdotal, not supported by data from long term monitoring studies. Therefore, it will be very important to understand the type and origin of springs and their connection with the local as well as the regional aquifer systems. The existing springs as well as the spring source zones can be mapped and the concept of spring-shed areas can then be introduced for sustainable management of the springs (Government of Sikkim 2014; Mahamuni and Kulkarni 2012).

Studies like CHIRAG (2012) and Government of Sikkim (2014) highly recommend field monitoring of hydroclimate data to understand spring behavior to introduction of watershed interventions. Worthington (1999) also indicates the need for quality field measurements of climate and discharge to estimate the potential of watershed interventions on increasing reliability of springs discharge. On the same note, Negi (2002) in a review on micro scale and meso-scale studies conducted in the Himalayan basin urges the need for systematic and physical measurement based studies to aid in soil and water conservation in the Himalayan region. Kresic and Bonacci (2010) stated that any workable, realistic plan drawn for the management of springs must fulfill the following prerequisites: a) Hydrogeologic and hydrologic characterization of the spring type, drainage (discharge) and recharge area, and recharge and discharge parameters, such as water quality and quantity. b) Reliable predictive modeling of spring discharge and water quality, achieved by collecting discharge and quality data of springs.

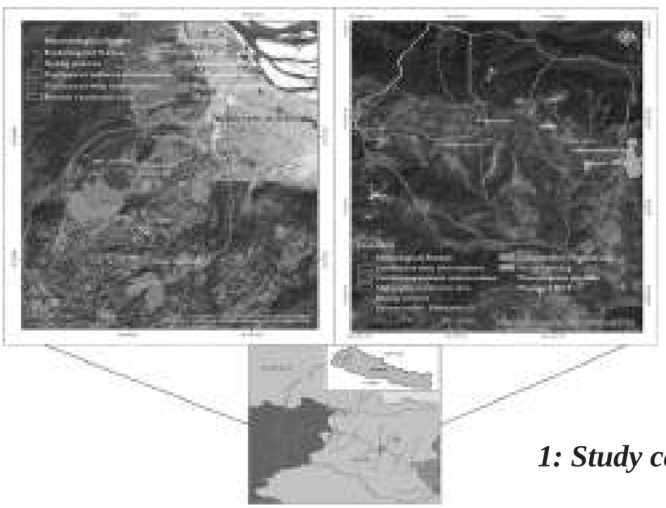
The objective of this study is understanding and managing spring systems for sustainable groundwater development in mountain regions through high resolution field monitoring, hydrogeological and hydrologic characterization of spring type, recharge and discharge parameters and recharge area.

Study area

The studied catchment lie in Shikharpur VDC of Baitadi district and Banlek VDC of Doti district of Far-western region of Nepal (Figure 1 below).

The studied catchment in Shikharpur VDC has four springs of two different typologies, seepage and flowing. The catchment covers an area of 3.74 sq.km. and extend in an altitudinal range of 1812 to 2470 m. The catchment lies in rugged mountain terrain with steep feature with slope ranging from 0.8 to 62%. The major land use/ cover types present are forest, grassland, cultivated land, earthen road, rock outcrop and barren land. About 75 HHs are dependent on these two sources for drinking purposes, these sources have multiple uses from drinking, irrigation to electricity generation.

The studied catchment in Banlek VDC has four springs all located in a gully named Badekhola, it covers an area of 1.74 sq.km and extend in an altitudinal range of 770 to 1215 m. The catchment lies in an old landslide zone with slope ranging from 5.8 to 48.4%. The major land use/ covet types present in the catchment are Sal and mixed forest, newly constructed earthen road, barren land, settlement and cultivated land. All the spring sources in this catchment are used primarily for domestic purposes, and irrigation if excess water is available. There are two well-defined channels in the catchment area.



1: Study catchments

Preliminary results

Baseline socio-economic Information

The study incorporated soft data collection through discussions with individuals, household surveys and transect walkthroughs. The data collected highlighted the high dependency of the communities to the natural resources. The increased economic pressure arising from low agricultural productivity and limited natural resources has led to increaesd out migration, especially by the men, in search of paid labor. This has resulted in increased reliance on remmittance by the family members left behind, especially the women, children and old people. Despite the dependency on foreign remmitances, there is still quite a strong interest in agriculture and the use of other natural resources such as forests for daily supplies.

Land degradation and increased fallowing have become major concerns over the last few years. This has been attributed to the out-migration on one hand, where the male members who traditionally provided labor for ploughing are missing and their skills to carry out major water and land conservation is lacking. On the other hand, changes in rainfall patterns, compounded by the lack of labor to have fields cropped have resulted in increased fallowing, reduced recharge and more erosion.

Despite lack of a structured water user mangement arrangements, the common-good interest has driven the community members to provide ad hoc arrangements around spring sources that has helped maintain them in fairly good state. It was noted that the driving force on this is the value at both individual and community level towards access to basic needs. On the other hand, forest management was noted to have a formal management committee, possibly due to government policy for formalised forest registration.

Women engagement in natural resource management is on the rise as they awake to the reality that in the absence of their male counterparts it is to them that this responsibility now falls, being the immediate beneficiaries of resources obtained from the same.

Hydrogeology

There are three springs and one seepage in the Shikharpur springshed: two springs at Paharpani Mul area, and the third one about 1 km west of Paharpani Mul. Around 90 Households are using these spring sources for domestic use, livestock, and irrigation for vegetables, as well as to power a micro-hydro. The water is sufficient for the daily requirement of the community, although residents say that water discharge is decreasing. Geologically, all of these three springs are located near the contact of underlying quartzite and phyllite, and upper-lying limestone, meaning they are contact springs.

This upper-lying limestone is sloped towards the south, has various joint sets and caves, and forms the aquifer system for springs. Vegetation cover on the uphill side also favors infiltration of rainfall. For all three springs, infiltrating water flows along the SW inclination of the rock and emerges as a spring when contacting the phyllite and the karstic limestone. The springs are located between 1900m to 2500m amsl. The area experiences heavy rainfall and springs are located on the upper half of the slope. The ground slope at the spring locations is steep, surface runoff is high, and permeability is low. Although it is difficult to predict exactly where the recharge zone is located, it is likely that recharge point can be a considerable distance from the spring emergent point.

There are 4 springs in the Banlek Springshed area. Around 70 Households use the four springs in the study site for drinking, bathing and washing clothes, and to a lesser extent livestock and agricultural practices. Mismanagement means that spring water does not meet the daily requirement of the community. Magarau Mul is a contact spring in the lower part of the catchment that originates at the left bank side of the stream from contact of colluvial soil and fractured quartzite. An abundance of colluvial soil and vegetation cover at the upper reaches of the area favors infiltration of rainfall. The slope aspect map shows a general eastward orientation (68-113o) with a 21-44o slope. The interconnected and irregular system of joints with resultant orientation of discontinuities towards 123 degrees also leads to the spring's emergence.

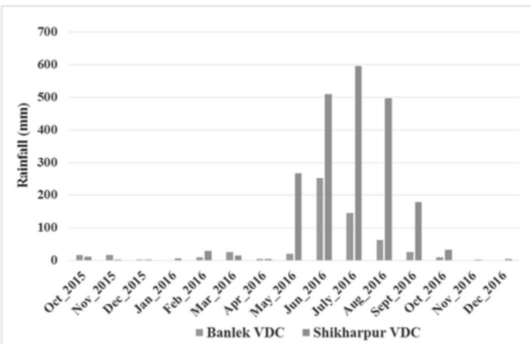
The Badekhola Naula is located at the lower end of the landslide-deposited colluvial soil. Two springs (Tallo and Mallo Badekhola) are located at the toe end of the colluviums and one (Badekhola Naula) at the further upstream side. The porous colluvial material permits infiltration, storage, and movement of water. The less porous bed rock behaves as an impervious layer and thus creates a contact spring. The slope faces NE with a slope of over 66o. This indicates that precipitation accumulated and flowed toward the colluvial body. Since the ground slope at the spring location is moderately steep and surface runoff is high, the recharge point may be far away from the emergence point, likely in the upper reach of the slope.

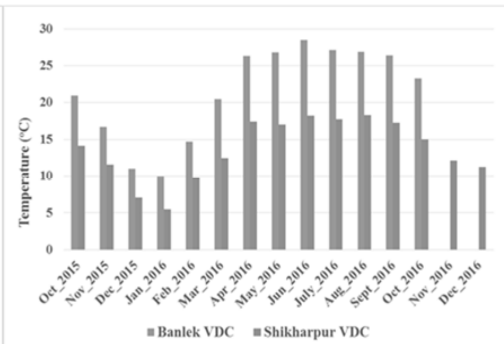
Hydro-climatic condition of West-Seti Watershed

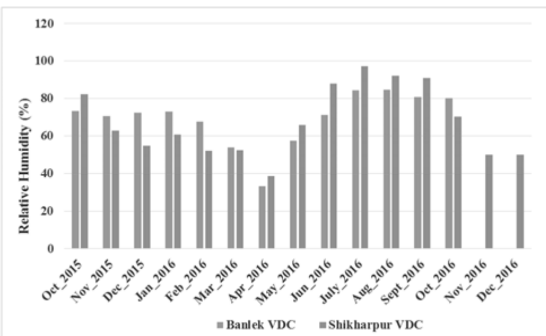
In the period of 1982 to 2013, the average annual rainfall (using station number 103, 218 from DHM) was 1921 mm whereas seasonal precipitation was 137 mm, 261 mm, 1449 mm and 74 mm in the winter, pre-monsoon, monsoon and post-monsoon seasons respectively. Therefore, in this sub-basin almost 75% of annual rainfall occurred during the monsoon season. It is to be noted that the higher altitude regions of the study area receive snowfall in winter. The mean monthly rainfall (from station number 218 from 1982 to 2013) indicate that the peak rainfall season starts from early June and ends in late October. July month has the peak rainfall ranging from 250 to 750 mm per month across the basin. Similarly the number of wet days high during the rainfall season, with July and August getting most of the rainy days (17 to 24 days). November and December have the lowest monthly mean rainfall (ranging from 0 to 20 mm per month). The West Seti is one of the most important source of water for the villagers in this region – for domestic as well as irrigation use. The Department of Hydrology and Metrology (DHM) - Nepal, monitors the stream discharge at five locations within the sub-basin. The average daily flow for the period of 2000 to 2008 monitored at the hydrological station 259.2 located in Seti River at GopaghatGaon close to Banlek catchment area is 203 m3/s. The maximum and minimum daily flow is 1880 and 32.7 m3/s. Likewise, the average daily flow for the period of 2000 to 2008 for hydrological station 258 located in Seti River at Dhung Gad, Bhasme downstream of Shikharpur catchment area is 5.10 m3/s, with the maximum and minimum daily flows of 81.5 and 0.5 m3/s respectively.

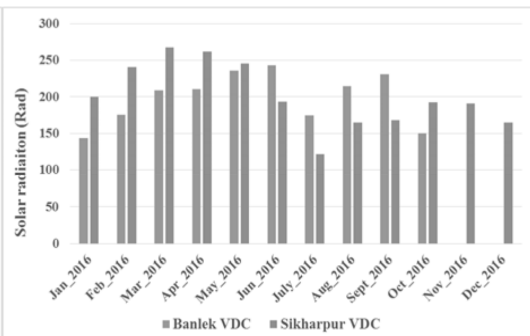
Hydro-climatic condition of study catchments

Two sets of hydro-climatic monitoring networks have been established in the two study catchments to closely assess the local hydro-climatic condition of study catchments as compared to larger landscape. One of the objectives of setting up hydro-climatic network is to generate local scale high-resolution information to accurately represent small catchments in hydrological modeling and studies and come up with accurate interpretation and recommendations.









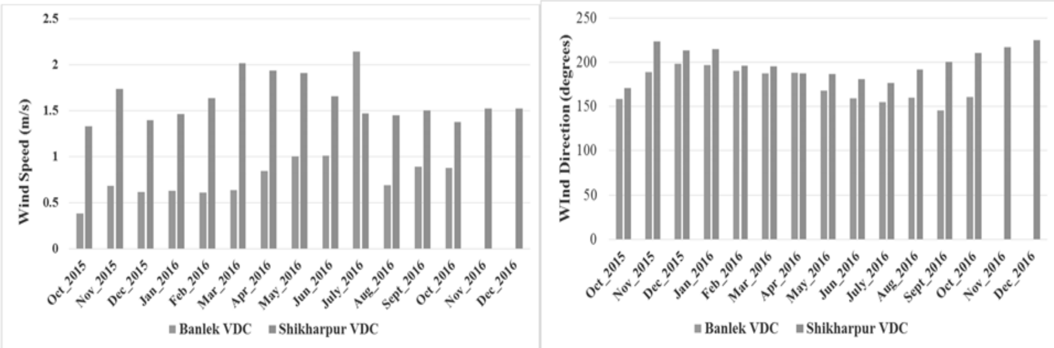


Figure 2: Comparison of climatic data (air temp., precipitation, relative humidity (%), solar radiation, wind speed and wind direction) between Shikharpur and Banlek VDCs

The data collected so far (Figure 2), shows that the total annual rainfall for 2016 was 580 and 2136mm for the Banlek and Shikharpur springsheds respectively. Banlek is comparatively warmer and drier than Shikharpur, which can be related to strong influence by elevation. The dry nature of Banlek springshed can be due to its north-facing slope. The annual average temperature for Banlek and Shikharpur springsheds are 21.5 and 14.33oC respectively. Relative humidity is higher in Banlek during post and pre-monsoon and humidity becomes higher during monsoon for Shikharpur as compared to Banlek springshed. Solar radiation follows an opposite trend to relative humidity. Wind speed values are higher in Shikharpur springshed than Banlek springshed except for the month of July, when Banlek gets very windy. Wind direction in Shikharpur springshed is mostly south-west whereas in Banlek it is mostly southeast, with slight south-west during post and pre-monsoon time (Figure 2 above).

The annual discharge volume for the four springs (Magarau mul, Mallo Badekhola, Upallo Badekhola and Badekhola Naula) in Banlek springshed are 2.60, 4.59, 5.08 and 1.66 million liters. Likewise, the annual volume for three springs (Paharpani tallomul, Paharpani mathillomul and Relapani mul) in Shikharpur springshed are 93.99, 67.39 and 39.04 million liters. The water availability within the study catchment in Shikharpur VDC is much higher than study catchment in Banlek. In both Shikharpur and Banlek VDCs, there is presence of two typologies of spring sources. One where discharge is highly affected by rain and the other has more steady flow throughout. Paharpani mathillo mul and Relapani mul of Shikharpur VDC are permanent spring sources with steady flow throughout the year. Whereas Paharpani tallo mul is highly influenced by rain events.

In Figure 2, there is slight temporal variability in the rainfall distributions in the two springsheds though the high monsoon rains are shown to occur between May and

September. In the Shikharpur springshed the Paharpani tallo mul shows high response to the monsoon precipitations. The increased flows are otherwise short-lived with a peak of about 600lpm. On the other hand, Mallo Badekhola and Upallo Badekhola within the Banlek springshed show similar response to monsoon precipitations but here there is a lag time in the peaking of discharge that extends well beyond the peak precipitation period likely suggesting a larger storage and flow buffering.

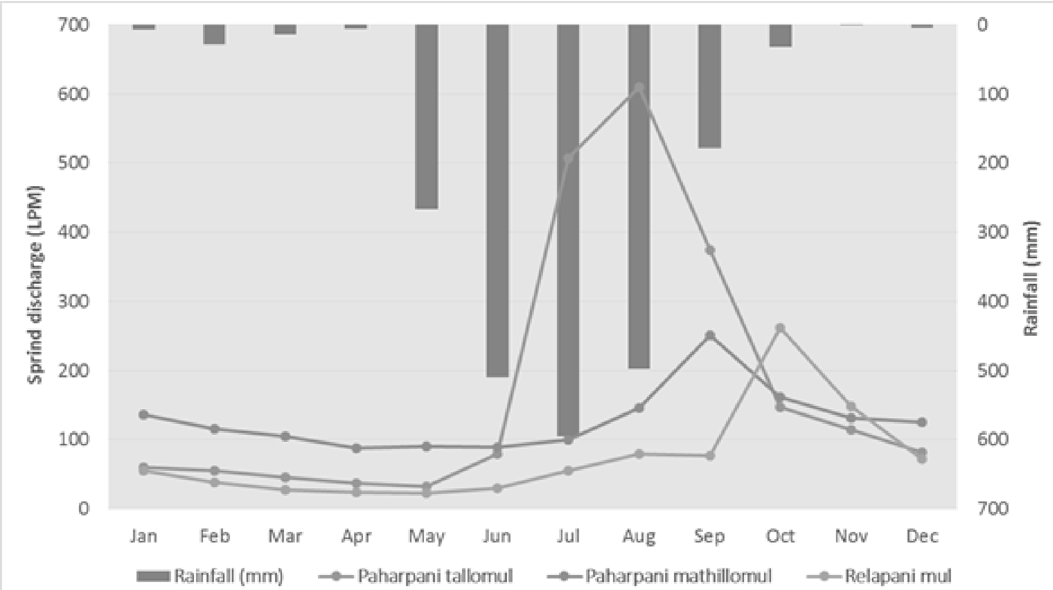


Figure 3: Monthly average spring discharge (LPM) of Shikharpur springshed

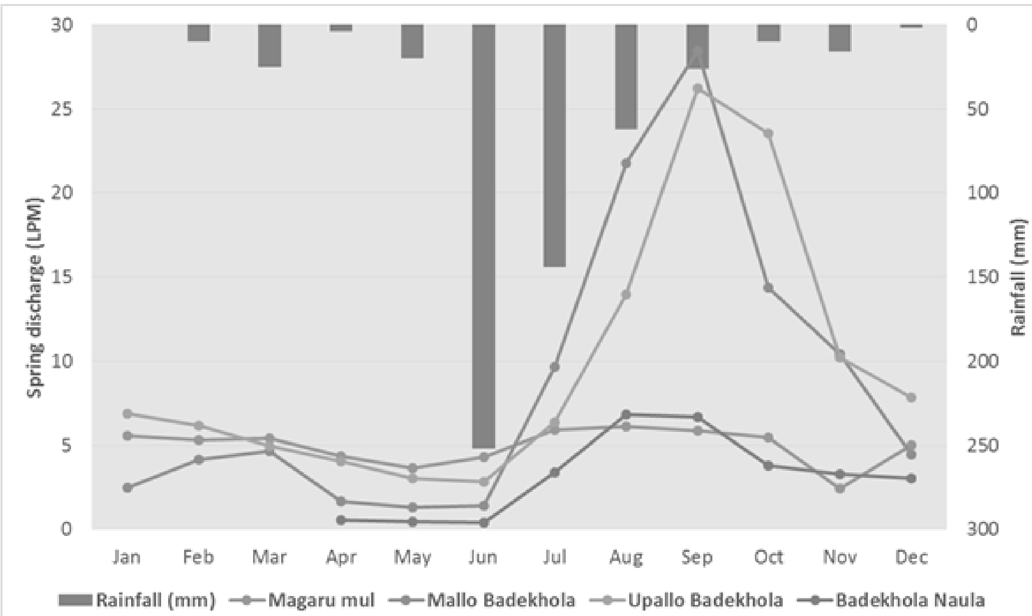


Figure 4: Monthly average spring discharge (LPM) of Banlek springshed

Isotope tracer analysis of study sites

Environmental isotope and hydrogeology techniques have been applied to scientifically understand the complexity of spring systems in order to reduce data uncertainty and fill in the existing knowledge gap. Springs in the Shikharpur springshed of Baitadi district are located between 1900 to 2500masl and they emerge at the contacts of phyllite and karstic limestone. Likewise, springs in Banlek springshed are located between 700 to 1100masl and they emerge at the contacts of colluvial soil and fractured quartzite. The stable isotopic variation in precipitation suggests that the altitude effect of -0.30% for δ18O and -1.73 % for δD, and -0.26 % for δ18O and -1.41 % for δD for Shikharpur and Banlek VDCs respectively. The local meteoric water line (LMWL), which is an equation that states the average relationship between hydrogen and oxygen isotope ratios in rain water samples of study catchments were generated. The LMWL generated for Shikharpur and Banlek springsheds are δD = 8.31δ18O + 13.41and δD = 7.81 * δ18O + 6.22, the slope and intercept for these equations suggest condensation effect in Shikharpur springshed and evaporation effect in Banlek springshed. The stable isotopic values of most springs in Shikharpur VDC lie above LMWL suggesting their source to be rain/ snow events at higher elevation with different source of moisture, wind speed and temperature. Whereas, stable isotopic values of springs in Banlek VDC lie closer and below LWML suggesting altitudinal effect.

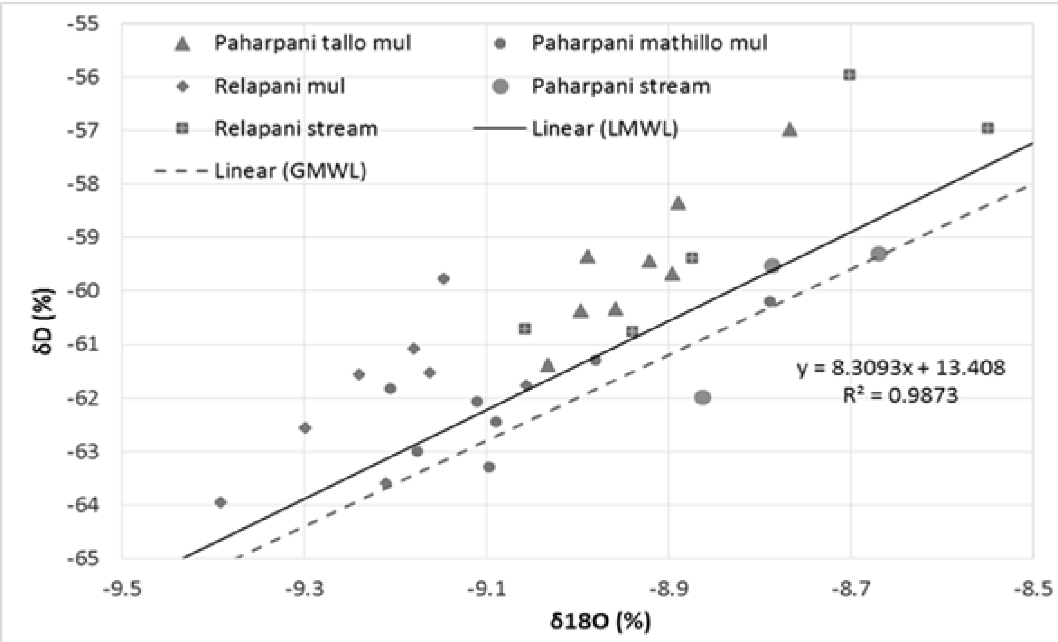


Figure 5: Plot of isotopic values of spring sources against Local Meteoric Water Line (LMWL)- Shikharpur VDC

Monthly average isotopic value of Paharpani tallo mul falls above LMWL indicating recharge from local rain events (moisture) and high elevation area with different wind speed and temperature. This supports the finding that it might be recharge by stream on the other side of the hill, which originates from higher elevation. Likewise, most monthly average isotopic values of Relapani mul follows the same principle as Paharpani tallo mul. Most monthly average isotopic value of Pahapani mathillo mul falls below LMWL, suggesting another source of precipitation i.e. monsoonal moisture, it also shows evaporation of rainwater before it enters into aquifers.

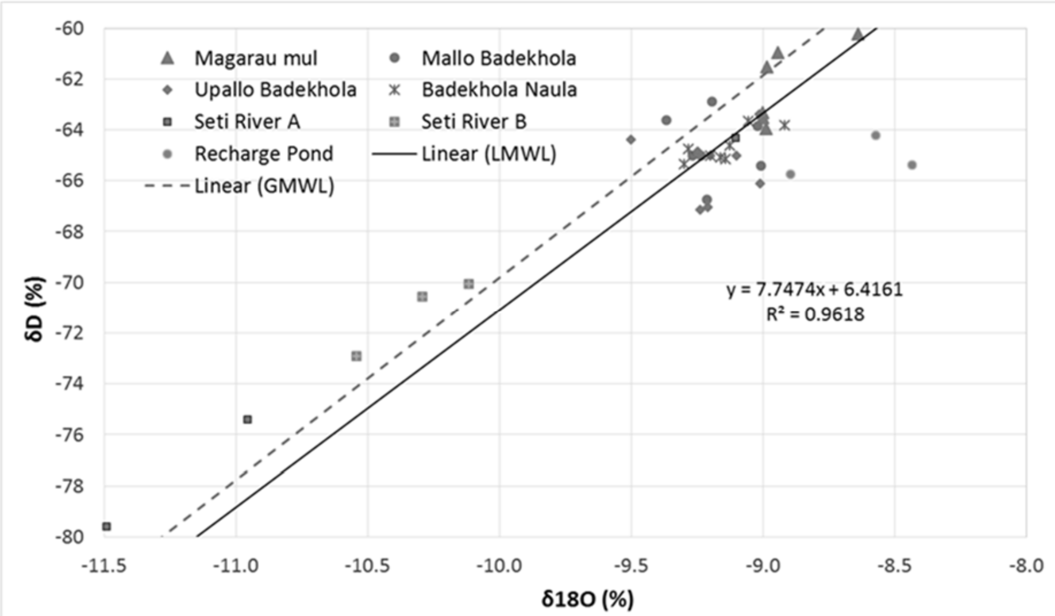


Figure 6: Plot of isotopic values of spring sources against Local Meteoric Water Line (LMWL)-Banlek VDC

Monthly average isotopic values of Badekhola Naula falls above LMWL and below GMWL indicating recharge from local rain events and high elevation area with different wind speed and temperature. Same explanation fits for Magarau mul except for the months of March and April, when source of moisture is probably westerlies wind. Monthly average isotopic values of Mallo and Upallo Badekhola suggest that recharge from monsoonal moisture during the month of July, August and September, from westerlies moisture during March and April and from local rain events (moisture) during May.

Discussion

The watershed hydrology impact monitoring research study being piloted in Banlek VDC of Doti district and Shikharpur VDC of Baitadi district is a five years study project. It consists of setting up hydro-climatic monitoring stations, isotope tracer analysis, hydro-geological and water resources assessment. The project is currently in its third years, where monitoring stations are well in place, isotope tracer analysis is undergoing and hydro-geological as well as water resources assessment are conducted. The preliminary results of the study as presented above are extremely promising towards understanding mountain spring systems.

The discharge measurements highlight the temporal and spatial characteristics of the springs that the communities use to inform access options and preferences of the spring sources. The results affirm that the low flow but stable springs are the preferred sources for domestic use due to their reliability whereas the highly fluctuating flows of the rainfall dependent springs are tapped as supplementary sources. Noting the seasonal flow variations even in the more stable springs it is likely that any annual weather changes such as droughts will significantly affect the discharges of these springs with the risk of severe livelihood challenges for the communities.

The isotope tracer analysis shows that sources of springs are both monsoonal and westerlies moisture. The springs are recharged by monsoonal rain during the months of July, August and September and westerlies rain during March and April. Based on local geological setting and isotopic information the recharge areas inferred for springs in Shikharpur are located at the altitude of 994 to 1100 masl, which is much lower than where rainwater samples are collected (1954 and 2362 masl). Likewise, the recharge areas inferred for springs in Banlek are located at the altitude of 631 to 715 masl and it is also lower than where the rainfall samples are collect (733 and 936 masl). These suggest higher proportion of earlier year precipitation in the spring recharge and streams lying on the opposite valley to be potential recharge areas for springs of both study sites.

The isotope tracer analysis is underway for the winter season as well as finding out lag time in the recharge process of the springs. The isotope tracer samples for intervention sites are being collected to analyze the effectiveness of interventions to address climatic and anthropogenic impacts on spring systems of mountain catchments.

The challenges facing the communities such as increased pressure on spring sources, land degradation, natural resource management needs though significant are also the motivation to turn things round. With increased social mobilization and capacity development that aims at a holistic management by stressing the interrelationships/dependency of different natural resources, a more sustainable development progress is achievable. By tapping into these local drivers of change and scaling up towards policy arrangements to support local initiatives and especially in empowering the women members, a more resilient springshed/watershed/basin environment is attainable.

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Multiple use of irrigation water: way towards sustainable irrigation management

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Abstract

The challenge of ensuring food security and modern energy is critical in the South Asian countries where about 51% of the population is food-energy deficient. Using irrigation water for both irrigation and micro-hydro purposes helps to make irrigation schemes sustainable and reduce energy deficit. This research is focused on multiple uses of irrigation water. The Chaud Irrigation Scheme lies in Sarmauli VDC of Darchula district, Far-western Development Region of Nepal is taken as the case study site. Food security is prime concern in this region. The primary data was collected using interview checklist, observation and interview with key informants during household survey. The irrigation scheme was rehabilitated in 2014 by Department of Irrigation under Irrigation and Water Resources Management Project. It is found that micro-hydro (11.5 KW) is in operation from the irrigation water with the financial aid of Poverty Alleviation Fund. It is distributed in 112 households of four villages where only 15 households had been using solar power for electricity. Farmers use water for irrigation during the daytime and for generating electricity in the evening. Food is now sufficient for 12 months as there was food deficit for 9 month before the rehabilitation of the irrigation scheme. They collect fees for electricity and use it in the canal maintenance. It is concluded that multiple use of irrigation water like generating electricity plays vital role for sustainable irrigation management.

Keywords: Multiple use of irrigation water, sustainable irrigation management, micro-hydro production, Chaud irrigation scheme, Far-western (Darchula)

1. Introduction

Government agencies are generally guided by sector-specific policies for development and management of infrastructures and they mainly focus on their own sector to utilize the natural resources rather than considering multiple uses. Public services are classified and fragmented with single mandates as directed by sector-specific policies and guide the related institutions accordingly (Rautanen et al, 2014). Irrigation schemes, water supply and sanitation schemes, micro-hydro schemes and hydropower schemes in Nepal are developed and managed by different ministries that follow sector-specific policies. In Nepal, Water Users Association of irrigation schemes or Drinking Water

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Supply Users Committee or Micro Hydro Users Functional Groups are expected not only to work exclusively for the given sector but also to operate within the sector-specific policies, standards and practices (Rautanen et al, 2014).

The concept of multiple-use water services has emerged since the early 2000s that seeks to overcome this sector-specific approach and enhance sustainability which is defined 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” (van Koppen et al., 2009).

Most of the schemes either irrigation or water supply and sanitation or micro-hydro schemes are single-use systems ‘by design’. However, many studies have shown that water services typically enable multiple uses although infrastructures were designed for a single purpose (Smits et al., 2010). Apart from using irrigation water for irrigating crop fields and gardens, it can also be used for:

- Domestic water (washing, hygiene and sanitation)
- Water for cattle
- Power generation
- Fishery
- Transportation
- Industry and business
- Recreation (Tourism)

Furthermore, it is also helpful in supporting biodiversity not only in plants but also in wildlife and birds. Due to increased demand for competing uses, freshwater is under growing stress and climate change is creating additional uncertainties (Eriksson et al., 2009).

The challenge of ensuring food security and modern energy is critical in the South Asian countries- Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri-Lanka-where more than 40% of the World’s population live and about 51% of the population is food-energy deficient (Ahmed et al., 2007). The per capita energy consumption in South Asia region is among the lowest in the World, only 300 kg of oil equivalent, which is just one-third of China’s 2001 per capita consumption (USAID, n.d.). This data shows that South Asia needs to focus on both food and energy. Ensuring enough water for growing food without losing hydro-power potential for energy security is prime concern in the context of increased water stress and water demand (Rasul, 2014).

The global population is estimated to increase to approximately 9 billion by 2050 and worldwide cereals demand has been projected to increase by 65% considering the population growth and rising incomes (de Fraiture et al.; 2007). In 2025, it is projected that there will be 2.2 billion people in South Asia and due to increased population the cereal demand will rise to 476 million tonnes as compared to 241 million tonnes in 2000 (FAO, 2012). If the higher incomes are considered, the cereal demand rises to 550 million tonnes (Dyson, 1999). In contrast, per capita agricultural land has been declining due to high population growth and industrial development, and the per capita arable land fell from 0.15 ha to 0.08 ha in Nepal between 1980 and 2010 (Kumar et al., 2012). 80 - 90% of the required increase in food production will have to be realized on existing cultivated land in coming decades (Schultz et al., 2009). Therefore, management of irrigation schemes should be carried out in a sustainable way to fulfill the projected food demands as well as energy demands up to some extent, for coming decades.

Using irrigation water for both irrigation and micro-hydro purposes helps to ensure food security as well as energy security. If micro-hydro schemes are merged with irrigation schemes, people get benefits of irrigation as well as energy. It is common tradition that people are ready to pay for the electricity and drinking water supply rather than the irrigation water supply. Collecting irrigation service fee has become a challenging task in irrigation sector of Nepal and it has challenged to sustainable irrigation management. So, multiple use of irrigation water can be a way towards sustainable irrigation management as Nepal has high potential of micro-hydro in Hill and Mountain regions. Beneficiaries are ready to pay the electricity service fee and this fee can be used for both irrigation and power systems. People regularly operate and maintain the canal system for electricity as it is a day to day demand rather than the seasonal demand like irrigation water. This helps to maintain the canal system functioning well. It makes irrigation schemes sustainable and reduce energy deficit as well.

2. Study site

2.1 Sarmauli VDC

The Chaud Irrigation Scheme is located at Sarmauli Village Development Committee (VDC) ward no. -7 in Darchula district, Far Western region of Nepal. Sarmauli VDC lies in the Southern part of Darchula district which is also the boarder VDC of Baitadi and Darchula districts. Geographically the scheme is confined at 29°38'0" N to 29°39'15" N and 80°29'0" E to 80°29'10" E. The project area is 55 Km far from district headquarter (Khalanga) along the Khalanga-Baitadi highway. The nearest road head from the project area is Salsena, 500 m far by foot trail and the nearest market is Goluleswor which is 9 km far from the command area. Location of Sarmauli VDC in the map of Darchula district is shown in Figure-1.

There are 24,618 households with 1,33,274 number of population in Darchula district (C.B.S., 2012). Total households in Sarmauli VDC are 812 and total population is 4348 including 2002 males and 2346 females. Most of the people in the Sharmauli VDC believe on Hinduism.

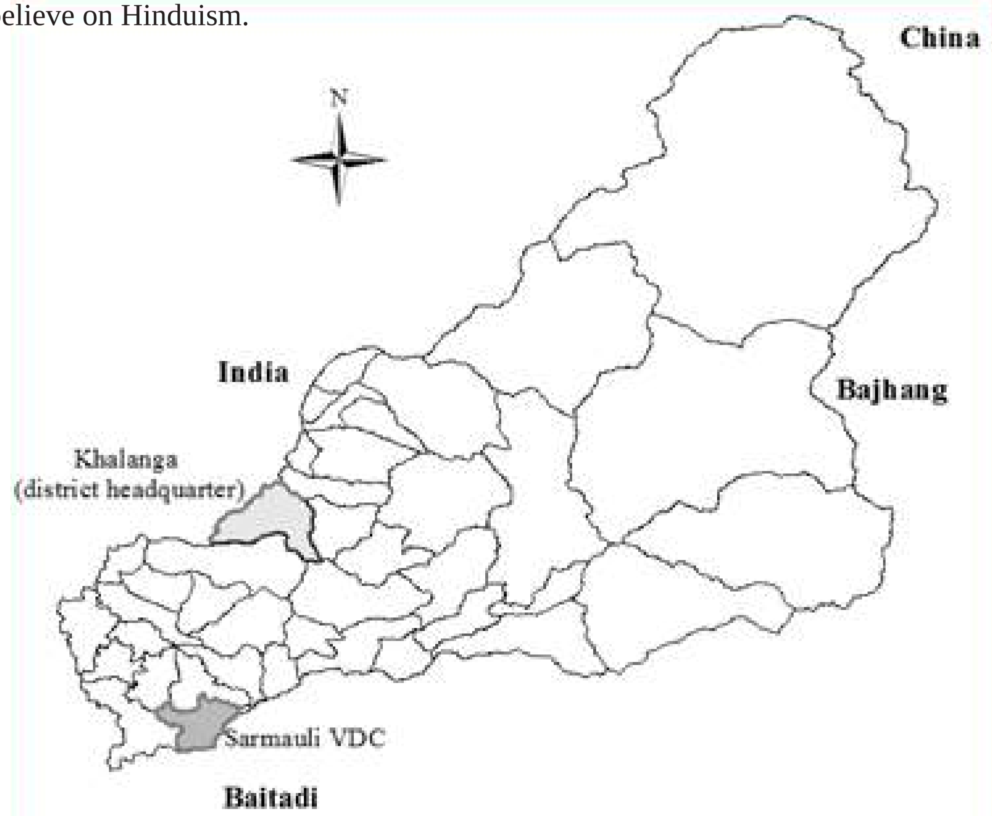

Figure 1: Location of Sarmauli VDC in the map of Darchula district

The average temperature of Darchula district ranges from 5°C to 34°C. The air temperature of the command area is suitable for cultivating paddy, winter vegetable, maize, wheat, potato, summer vegetable and soybean. The average annual rainfall is 1666 mm.

2.2 The Chaud Irrigation Scheme

The Chaud Irrigation Scheme was rehabilitated in 2014 under Irrigation and Water Resources Management Project (IWRMP) funded by World Bank and Government of Nepal. The Chaud irrigation scheme irrigates 60 hectares of 86 households. Almost half of the households (40 households) have now been migrated to Mahendranagar (city area) and only 46 households are now living nearby the command area. Altogether 328 numbers of 46 households are directly benefitted from this scheme. Out of 46 number of household, only 5 households belong to Joshi family and rest of the households are from Bhatta family.

The source of the Chaud irrigation scheme is Danogad river, a perennial source. It has catchment area of 8 sq. km. The Danogad river is a minor tributary of Chameliya river. The canal alignment lies on the left bank of the source. The command area is located between the left bank of Danogad river and right bank of Chamileya river.

About 83% of the households have farm size less than 0.5 ha (10 Ropani). In contrast, only 4% of the households have farm size more than 1 ha (20 Roapni). Rest of the households (13%) have farm size in between 0.5 ha to 1 ha. This shows that there is majority of low land holders.

The canal design discharge is 40 lps. The canal system consists of 1.8 km main canal. The total estimated project cost was 1,82,45,000. The expected cropping intensity after the rehabilitation of the project was 200%. (FWIDSD-2012).

Figure 2: Command area of Chaud irrigation scheme, Sarmauli, Darchula

2.3 The Danogad microhydro project

The Danogad microhydro project lies in sarmauli VDC of Darchula within the Chaud irrigation scheme. It has capacity of 11.5 KW. It was constructed in 2014. Total 112 households including 840 people are using electricity from this project.

Figure 3: The Danogad micro-hydro project, Sarmauli, Darchula

Poverty alleviation fund, Darchula provided NRs. 41,75,791.00 and user's participation was NRs. 5,91,643.00. Hence, the total project cost was NRs. 47,67,434.00. Rajakot Youth Club, Rapla, Darchula also helped during the construction of this project. People bought the land for powerhouse in NRs. 40000.00.

The design discharge is 35 lps, gross head available is 63.2 m, overall efficiency is taken as 0.55 and the designed output power is 11.5 kW. For this available head and design discharge, a pelton turrbine is used.

150 mm diameter, 3.0 mm thick and 109 m long MS penstock pipe is used. Total length of transmission and distribution line is 4.7 km.

3. Research Methodology

Primary as well as secondary data were collected for this research. The primary data collection was done during the field visit of the irrigation scheme. Extensive discussions were carried out with the local farmers, Water Users' Association (WUA) executive members, officials from Irrigation Sub-division Office, Darchula and other stakeholders of the micro-hydro projects. Similarly, secondary data were collected through different reports, publications and related websites.

Interview checklist, observation and interview with key informants were used for the primary data collection. Household survey was done in 43 households (50% of total households) of the Chaud irrigation scheme.

4. Results and discussion

4.1 Household and Population

The Chaud irrigation scheme irrigates 60 hectares of 86 households. As 40 households have now been migrated to Mahendranagar (city area), only 46 households are now living nearby the command area. Altogether 328 numbers of 46 households are directly benefitted from this scheme. Similarly, the Danogad micro-hydro projects provides electricity facility to 112 households. As per the National population and housing census (2011), Sarmauli VDC has total households of 812. This shows that the Chaud Irrigation Scheme and Danogad micro-hydro project provides service to about 11% and 14% of households of Sarmauli VDC respectively. There was no electricity facility before this project and only 15 households were using solar system for lighting purpose and rest of them depend on oil or kerosene lamp.

4.2 Occupation and food sufficiency from land

The primary occupation of these people is farming and the secondary occupation is fishing in Chamileya river. A person can collect maximum 12-15 kg of fish per day.

There was acute food shortage (sufficient only for 3 months) before the implementation of the irrigation scheme. In contrast, there is food sufficiency round the year after the rehabilitation of the irrigation scheme. They are growing paddy, wheat, maize and vegetables now.

4.3 Irrigation Water User's Association

4.3.1 Composition of Irrigation Water Users' Association

The irrigation water user's association was established in 2012. There are 15 members in executive committee of Irrigation Water Users' Association. Out of 15 members, 7 (46.67%) are male and 8 (53.33%) are female. Posts of president, vice-president, secretary, vice-secretary and three members are headed by male. In contrast, posts of treasurer, vice-treasurer and six members are headed by female. Although there is majority of female members in the executive committee, most of the vital posts are occupied by the males.

4.3.2 Meetings of Irrigation Water Users' Association

The meetings of irrigation water users' association are held on as and when required basis. During the initial construction phase of the irrigation scheme, the meetings were held 8 times within 3 months period in fiscal year 2011/12. The minutes includes the formation of the executive committee, commitment to do the contribution works in the irrigation scheme, formation of construction works monitoring/supervision committee etc.

In fiscal year 2012/13, most of the construction works were carried out and total 8 meetings were held. The project was completed in fiscal year 2013/14 and only 4 meetings was held in this fiscal year. After that 4 meetings are generally held in each year.

The general assembly is held at least once in every year and the financial audit is done every year. The irrigation water users' association is renewed every year in the Irrigation Development Sub-division Office, Darchula.

The Water Users' Association (WUA) minute register shows that more than 50% of the households participate in most of the executive committee's meeting. In most of the irrigation schemes in Nepal, executive committee meeting is held without notifying other farmers and farmers do not get opportunity to participate and raise their voice in every meeting of the executive committee. Generally, farmers can raise their voice while participating in general assembly which is held 1-2 times per year. Such participation of farmers even in the executive committee meetings has helped every farmers to participate and give opinions in decisions to be taken by the executive committee. It has created economic transparency among the farmers. It is seen that there is no disputes between the farmers and the executive committee in the Chaud irrigation scheme. No fine has been done till now as all the farmers participate in maintenance work. So, it is always better to include more farmers even in the executive committee meeting although it is always not possible.

The farmers were asked whether they are satisfied with the WUA performance or not. 75% of the respondents ranked it as good while 25% of them ranked it as satisfactory. None of the respondents told that the WUA performance is poor. This shows that WUA is doing well.

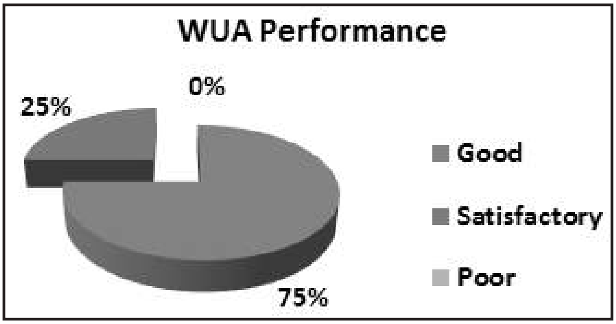

Figure 4: WUA performance from farmers side

4.4 Danogad Micro-hydro users' committee

The primary purpose of Danogad micro-hydro project is lighting. It has been providing lighting facility to four villages: Sejali, Chaud, Phiththad and Bharangkot of Sarmauli VDC-3 and 7. Total 112 households are benefitting from this project. The Danogad micro-hydro users' committee was established in 2014. There are total 15 members in the committee. 8 members (including president) are from Chaud village which is the command area of the irrigation scheme and 7 members are from the Sejali, Phiththad and Bharangkot villages. Majority of the members are from the irrigation scheme area. The president is same person in the irrigation water users' association and micro-hydro users' committee.

4.5 Multiple use of irrigation water

The rehabilitation work of Chaud irrigation scheme was completed in 2014. Just after completion of the rehabilitation works, farmers requested Poverty alleviation fund, Darchula to construct micro-hydro project mainly for lighting purpose. The fore bay of the micro-hydro lies in the main canal of the Chaud irrigation scheme at the chainage of 0+900 m. There is about 5 hectare of land in the upstream of fore bay. The tailrace water can not be used for irrigation.

Figure 5: The forebay of micro-hydro project in the main canal of irrigation scheme

The canal is being used for electricity from 6 PM to 12 midnight and 4 AM to 7 AM. This shows that water is used for electricity purpose for 9 hours and rest of the 15 hours is being used for irrigation purpose. When there is no need of water for irrigation, they use it for electricity in the day time also (if needed). Hence, optimal use of water is being done in the Chaud irrigation scheme.

During the field visit, farmers mentioned that although they do not need water for irrigation, they need to maintain and run canal for electricity purpose. And this has helped to maintain the canal system up to date. If there is some blockage or debris deposition in the canal, they quickly remove it to generate electricity for lighting purpose than for irrigation purpose. One of the old farmer told that crops can survive for 2/3 days without water but we cannot service a single day without light now. Light has become a part of our life these days without which we survived many years before its installation.

Each household is given 100 watt of electricity. They are paying NRs. 100/month/ household for electricity. As 112 households are using the electricity, total NRs. 1,34,400.00 per year is collected from the electricity. They are using this money for the operation and maintenance of power system as well as the canal system from the intake to the fore bay. Operation and maintenance of the canal system from intake to the fore bay is maintained by the electricity charges. This has transferred the responsibility of operation and maintenance of canal system (intake to fore bay) from the irrigation water users' association to micro-hydro users' committee. Combining the irrigation system with micro-hydro has now increased the sustainability of irrigation scheme as main canal is operated and maintained by the micro-hydro users' committee.

This has created awareness to pay for irrigation also and they are now convinced that they need to pay for irrigation (Irrigation Service Fee) as well. One of the woman argued that "we are using the same water for electricity and irrigation and as we pay for electricity for lighting purpose as it has given us new life, we need to pay for irrigation as well since our productivity has increased and we have grown more crops now".

They have kept 1 Dhalpa/Chaukidar (watchman) for the operation and maintenance of the canal and micro-hydro. He receives NRs. 2500 per month. His salary is given from the fund collected from the electricity charges (NRs. 100/household/month). In addition, maintenance of the canal is done by the farmers 2 times per year.

Apart from using the irrigation water for crops and electricity, farmers are using it for domestic use (washing, hygiene and sanitation) and water for cattle.

Fishery cum banana farming project is being run within the Rainastar irrigation scheme, Lamjung, Nepal covering 15 ha of land. This project provides NRs. 50,000 per year to the irrigation water users' association and this amount is used as salary for Dhalpa/ Chaukidar (watchman) who looks after the canal system. It has somehow helped for regular operation and maintenance of the irrigation scheme.

Figure 6: Fishery and banana farming project in Rainastar irrigation scheme, Lamjung, Nepal

Multiple use of irrigation water is being practiced in other irrigation schemes also. Micro-hydro schemes, water mills and fishery projects are increasing in Nepalese irrigation schemes. Such multiple use of irrigation water has helped to maintain the irrigation schemes and it is one of the options for sustainability of irrigation schemes.

5. Conclusions and recommendations

5.1 Conclusions

Participating more households in executive committee meeting has created economic transparency among the farmers. It has maintained harmony relation between the farmers and the water users' association.

The responsibility of operation and maintenance of canal system (intake to forebay) has been transferred from the irrigation water users' association to micro-hydro user's committee. People regularly operate and maintain the canal system for electricity as it is a day to day demand rather than the seasonal demand like irrigation water.
People are ready to pay service fee for electricity. It helps to aware farmers to pay for irrigation (Irrigation Service Fee) as well if micro hydro is combined within irrigation scheme. It is better to combine the micro-hydro within irrigation scheme in mountain and hill regions of Nepal for the sustainability of irrigation scheme.

5.2 Recommendations

It is recommended to include more farmers in executive committee meeting as far as possible in other irrigation schemes also as it helps to maintain good relation between farmers and water users' association.

There is high possibility of micro-hydro within irrigation scheme in mountain and hill regions of Nepal. It is suggested that Department of Irrigation check the possibility of multiple use within irrigation scheme during feasibility study. Possibility of multiple use of irrigation water must be kept as one of the project selection criterion. There is urgent need of collaboration between Department of Irrigation and other organizations like Poverty alleviation fund which work in such field.

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Utilization of augmented flow a case study of "Budi Gandaki Hydroelectric Storage Project"

Mr. Suraj Lamichhane

Abstract:

This paper makes an analysis of the principle of downstream benefit from augmented flow of reservoir operation of Budigandaki Hydroelectricity Storage Project within national boundary of Nepal. Besides, this paper deals with the potential downstream benefits like hydropower, irrigation, water supply, flood control, water transport etc. The augmented flow of the Project in dry seasons and reduced flow during wet seasons can be a utilized by implementation of suitable water utilities projects. The optimum combinations among proposed water utilities project need to be identified. The best optimal alternatives are suggested not only on the basis of monetary benefits and cost but are also based on the assessment of the socioeconomic impacts, trend of facility demand and possibility of future development of the projects. The Budhi Gandaki Storage Project presents a unique opportunity for implementing the new paradigm of cooperation for joint water resources development between Nepal and India.

1. Introduction

Nepal's rivers system is a part of Ganges River Basin. Total drainage area of Nepal's river is 194,471 square kilometres, 45.7% of which lies in Nepal. There are 33 rivers whose drainage area exceeds 1000 sq km. The total average annual runoff into Nepal's rivers is estimated to be 200,000 million cubic metres originating from areas within the country

Nepal has two rainy seasons: one from June to September when the south-west monsoon brings about 80% of the total annual rainfall, and the other in winter, accounting for the rest of the rainfall. About 64% of the rainfall some is retained in the form of snow and ice in the high Himalayas, while some percolates through the ground as snow and groundwater, and some is lost by evaporation and transpiration..

Nepal is endowed with immense water resource's potential, which, if utilised properly would be a benefit for countries further downstream as well. The benefits could be applied to several spheres, namely hydropower generation, the extension of year round irrigation facilities, and particularly for navigation, which is crucial for the landlocked countries of Nepal. Moreover, flood control, industrial, recreational and other benefits are also possible. However, the reality is that in order to gain maximum benefits, water resources should be developed in a holistic and integrated manner addressing diffrent barriers. It has been proved in several parts of the world that basinwide development of integrated water resources could provide immense benefits to all users.

Despite Nepal's large hydropower potential, less than 2% of the potentially economically feasible hydropower production has been achieved so far. The people are bearing daily power cuts for more than 16 hours during t dry season. This scenario is more critical at the peak time as the majority of the hydropower projects in Nepal are Run-of-River (RoR) type, and consequently the power available in the dry season is less by about one third to one fourth compared with the wet season, whereas the demand is higher during these times. This has led to the necessity of storage type projects that have many benefits like peaking, system balancing, flood control, navigation and can be used as multi-purpose projects for irrigation and water supply along with power generation. The storage type hydropower has various advantages in terms of storage of water and energy generation, instant generating capacity, and flexibility in providing base load and peak load services. Furthermore, the impact of climate change resulting less snow in the Himalayas is expected to aggravate the situation. For this, storage is an essential water requirement in the dry season. Nepal's storage type hydropower projects open the possibilities for bilateral and regional cooperation. This development is associated with the multiple benefits like flood control, navigation and increased irrigation in dry season, which lead in turn to economic growth along the region.

Nepal's agrarian economy is predominantly dependent on irrigation. The major water resources available for agriculture are rainfall, surface water from rivers, and ground water from aquifers. Irrigation – the artificial application of water to land – is one of the important inputs to accelerate the agriculture growth. It does not merely replenish soil moisture but also opens the door to other inputs such as agriculture roads, rural electrification, fertilizer and improved seed and generates a multiplier effect in the national economy.

Nepal has 2.64 million hectares (ha) of cultivable land. Of this area, 66% or 1.76 million ha is irrigable. Out of the total irrigable land, around 60% has some kind of irrigation facility and less than one-third has year-round irrigation. Agriculture production was 7.2 million tons in 2003, which just meets the minimum requirements of nation for food grains. Out of this, only 3.3 million tons were from irrigated agriculture (NWP, 2005). Hence, expansion of irrigated agriculture is essential to meet the food security requirement of the country.

Despite the abundance of water resources, only a fraction of it is utilized so far. Only about one third of the population has got access to safe water and only 42 % of the net cultivated lands have been irrigated so far. Several studies suggest that Nepal theoretically has 83000 MW of hydropower potential, and about 43000 MW is presently considered economically viable to harness of which only 848 MW is produced to this date (MoF, 2016).

Hydropower production is the only purpose of BGHEP and is aimed to alleviate the Nation's worsening energy crisis. Though the project is designed solely for power production, there remains huge opportunity of further exploitation of water resources. Utilization of the increased dry season flow from large dam can be utilized by the various water utilities projects. Similarly, the water regulation during wet season reduces the peak discharge downstream lowering the flooding risk and downstream erosion.

It is usual practice around the globe that to get the maximum benefit with optimum utilization of water resources the planning, construction and operation of large dam are carried out in integration with other water utilities systems within the basin. Consideration of this benefit due to regulated water ensures the optimum utilization of natural resources and makes the project more attractive.

In this background the present study was aimed to assess the downstream benefit due to BGHEP and help the project develop in more holistic approach.

2. Study Area

The Budhi Gandaki River is a tributary of the Trishuli River in the central part of Nepal. The river originates from two main source , one from the Lark Himal and the other, the Mowang Khola, from Tibet. After the confluence of these two tributaries , the river flows about 120 km to the south where it joins the Trishuli River. The catchment area in Tibet is approximately 1,750 km2 (SMEC 1979). The total catchment area of the basin at dam site is about 5,005 km2

Budhigandaki Hydropower Project is a storage type project proposed at the Budhigandaki River. The proposed high dam of 263 m of the project is located at 2 km upstream of confluence of Trishuli and Budhigandaki River. The dam will regulate 80% flow of Budhigandaki River. The gross storage capacity of the project is 4467 million m3 of which 2226 million m3 is usable storage. The installed capacity of 1200 MW and the average annual energy is 3383 GWh. BGHEP is designed to operate in such a way that it will produce 42% of total energy during four dry months.

Budhigandaki river contributes about 15% of the total flow of Saptagandaki river system. Average annual flow of Budhigandaki River is 222 cumecs. The average dry months flow is 51 cumecs. The BGHEP at its full capacity releases 672 cumecs.

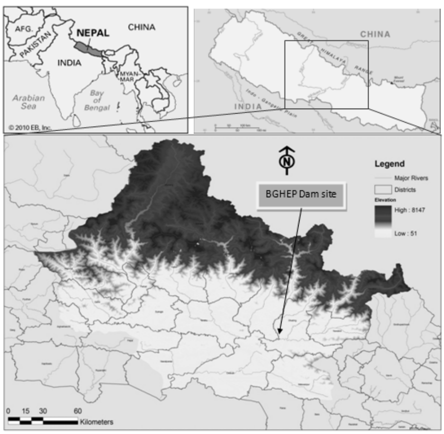

Fig. 1. Location map of the project area

Nepalese river has wide annual fluctuations in flow discharge with surplus water during monsoon and much lower than average water flow during dry months. Most of the present power plants in Nepal are designed to operate on the basis of dry season river flow. As Nepal is facing severe problem of power shortage during winter when the rivers are in the lowest discharge, the storage type of plant is required to solve the difficulties in power management. Accordingly a number of potential storage projects are studied and some of them are currently under construction. BGHEP is one of the storage projects in priority list.

1. Study Data and Execution

The reservoir regulation and release data are obtained from the BGHEP Study reports. For the hydrological calculation at different section along Narayani River and its tributaries the hydrological and metrological data obtained from the Department of Hydrology and Meteorology (DHM) of the Government of Nepal have been used.
Arc-GIS was used for generating data of the various terrain and geographic assessment of the study area. For the general evaluation of impacts of BGHEP on floodings in Terai of Nepal a SRTM 30 m DEM was used. Arc GIS extension HEC – GeoRAS was used for the extraction of topological data of the region. The extracted data were then used as inputs in HEC – RAS.

2. State of the Art Review

The utilization of water resources has become the key strategy for the development of the nation. A precise definition of downstream benefits upon which all are agreed cannot be found; however, if any water resources project activities in the upper reach of an IWC yield any type of benefit to the lower reach of a catchment area or downstream country, these are called 'downstream benefits'. In principle and in practice, such benefits must be shared equally and equitably. Professors Bourne, McCaffrey and Utton hold the view that: “There is support for the existence of a principle of downstream benefits in customary international law. Under the concept of equitable utilization, watercourse states are entitled to a reasonable and equitable share of the benefits of an international watercourse. It would seem to follow, therefore, that when a watercourse state does or refrains from doing an act that confers a benefit on another state sharing the watercourse, the latter state is under an obligation to share the benefit equitably with the former.

The treaty practice of states supports the existence of this principle of sharing benefit. While treaty practice can be invoked in support of the principle of downstream benefits where the act or the omission to act that confers the benefits was done or not done at the request of the downstream state, treaty practice does not exist to support the wider proposition that a downstream state is obliged to share benefits that it receives from the acts or omissions of an upstream state that it has not asked for or otherwise agreed to. The obligation to share downstream benefits, however, may exist under customary international law even when these benefits have not been solicited or agreed to. Logically, the obligation would seem to be implicit in the principle of equitable utilization; for, if benefits are to be shared equitably, it should not matter whether or not they were sought by the beneficiary. Furthermore, a failure to share windfall benefits would seem to be a case of unjust enrichment. This is not to say, however, that there may not be a difference between a case in which a downstream state has asked for a benefit and one in which it has not so asked; in the latter case, equity might dictate that the downstream state not pay as much as it would have to in the former case.

Another example is provided by the Owen Falls Dam in Uganda, where Egypt has developed and supplied hydropower to Uganda at her own cost; however, the water augmented in the reservoir was exclusively for her own use. In order to supervise the water and power arrangements, a resident Egyptian engineer was provided for in the agreement between the two states; in addition, electricity was produced for Uganda, and reparation for resettlement paid to her, at Egypt's expense, as a downstream benefit (accruing in this case to the upstream country). Besides this, in India, even in the sphere of inter-state relations, the states of UP and Bihar agreed to share both costs and benefits in proportion, in the jointly developed Muskhand Dam Project.

Until today, there are three bilateral agreements between Nepal and India on water resource management: the Koshi Project Agreement (1954), Gandak Irrigation and Power Project Agreement (1959) and Mahakali Treaty (1996). The Koshi and Gandak Projects were completed by India under the Agreements. However, immediately after the conclusion of these agreements, they were criticized for being unfair to Nepalese interest (Devkota 1980). These projects do not provide examples of downstream benefits. These agreements created an indelible scar of unfairness in the mind of Nepali people that could not be wiped out even by the Mahakali Treaty in 1996 which, unlike in the fifties when the decision was made during exclusive monarchy, was ratified by two-third majority in the Nepali Parliament (Upadhyay 2013). Article 3 (3) of the treaty states: "The cost of the project shall be borne by the Parties in proportion to the benefits accruing to them. Both the Parties shall jointly endeavor to mobilize the finance required for the implementation of the Project." This arrangement entails the acceptance of the principle that must be applied in future co-operation in the area of water resources development between two states. Unfortunately, The Mahakali Treaty was supposed to be much improved compared to its predecessor treaties, but this has not proven to be the case. Mahakali Treaty went to rough weather because of India's intransigent behavior regarding the interpretation and implementation of the Treaty's otherwise clear provisions. Thus, the Treaty again resulted in India reaping heavily one-sided benefits, and left the Pancheshwar Project (included in the Mahakali Treaty) in the lurch. Controversies over these three treaties have made water management a contentious issue between Nepal and India. And to date no meaningful harnessing of the vast water resources available to both the countries has materialized.

The real issue in the development of Nepalese water resources is the sharing of costs and benefits with her lower riparian states. Evidently, the sharing and allocation of benefits from Nepalese water resources is not only a bilateral issues in its nature: it has crossed over into the sphere of regional management. The fact is that Bangladesh would, like India, benefit from water resources development works in Nepal.

3. Utilization of Augmented Flow

The augmented flow of BGHEP in dry season and reduced flow during wet season can be utilized by implementation of suitable water utilities projects. Also, the augmented flow in dry season has the increased benefit from existing hydropower and irrigation projects. The hydrological flow along the downstream alignment was studied at river gauging station and then identified the impacts of augmented flow from the reservoir (figure 2 and 3) . Currently there are only two water utilities projects in operation in Nepal at downstream of BGHEP - Narayani Lift irrigation project (NLIP) and Gandak Barrage Project.

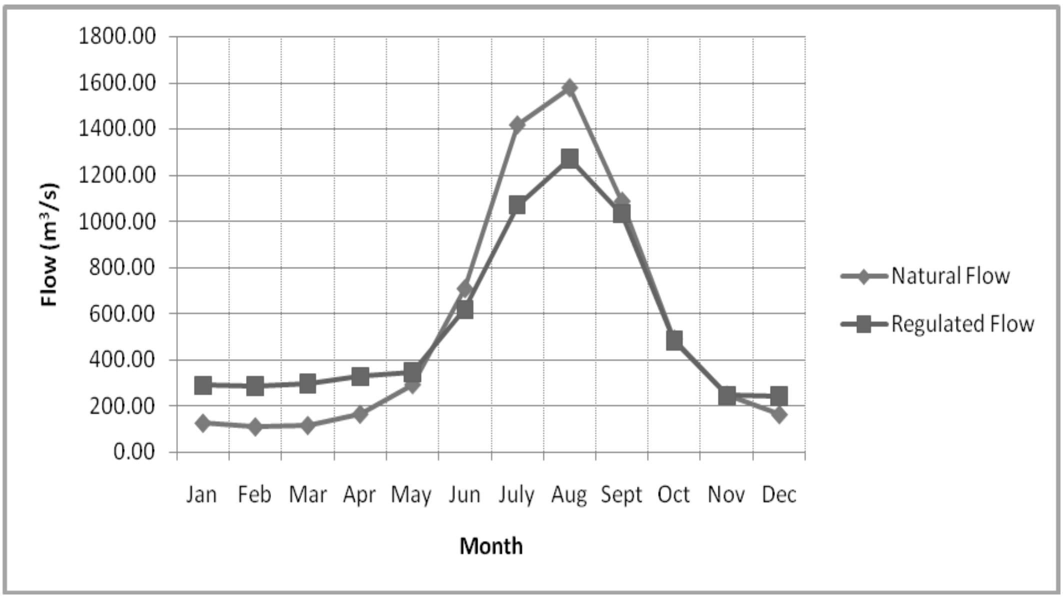

Fig. 2. River flow at Budhi Gandaki – Trishuli confluence before and after BGHEP (Source:: DHM)

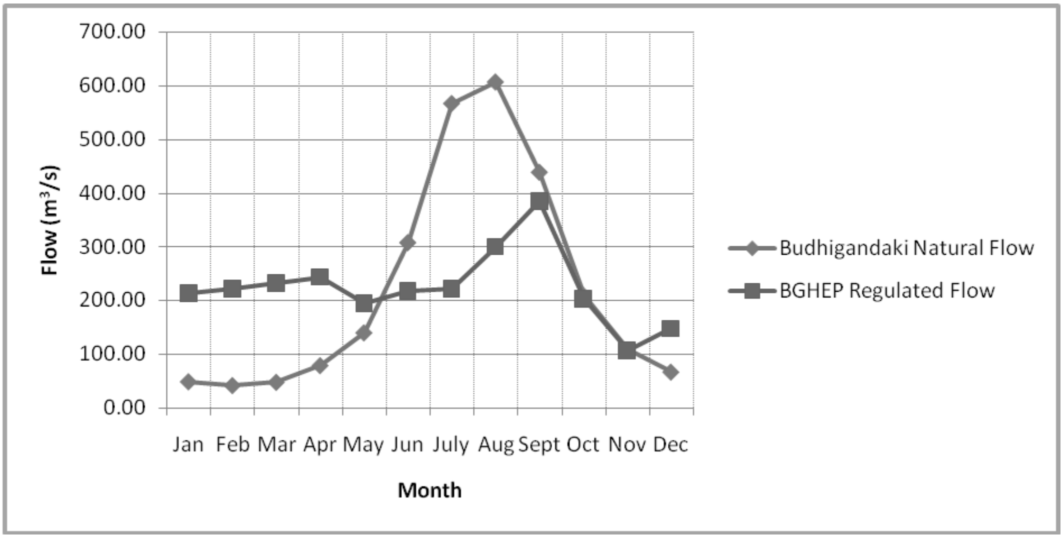

Fig. 3. River flow at Budhi Gandaki before and after BGHEP (Source: DHM)

This study introduces all existing projects and the potential water utilities projects that become viable after the implementation of BGHEP are also proposed. The additional benefit to each existing and proposed projects due to the regulated flow from BGHEP are assessed.

To achieve the maximum benefit some potential projects are identified. Table lists all existing and proposed projects directly benefited by the regulated flow. The impacts on each project are presented in details in subsequent sections.

SN	Project Name	Project Type	Status	Capacity	Remarks
1	Re-Regulating Dam Project	Hydropower	Proposed	112 MW	Current Study
2	Cascade of Re-Regulating Dam Project	Hydropower	Proposed	149 MW	Current Study
3	Trishuli – Chitwan Diversion Project	Hydropower/ Irrigation	Proposed	22 MW/ 39000 ha	DoI
4	Super Trishuli Hydropower Project	Hydropower	Proposed	100 MW	Private (Cancel)
5	Simaltal – Dasdhunga Project	Hydropower	Proposed	149 MW	Current Study
6	Dasdhunga – NLIP Canal Project	Irrigation/ water supply	Proposed	36 m3/s	Current Study
7	Narayani Lift Irrigation Canal	Irrigation	Existing	4700 ha	DoI
8	Devghat (Sapta Gandaki) Project	Hydropower/ Irrigation	Proposed	225 MW	JICA – NEA study (Cancel)

9	Nawalparasi Irrigation Project	Irrigation	Proposed	21000 ha	Current Study
10	Kali Gandaki – Tinau Diversion Project	Hydropower/ Irrigation/ water supply	Proposed	104MW / 63000 ha	DoI
11	Domestic Water Supply Project	Water supply	Proposed	Pop 1404488.0 0	Current Study
12	Gandak Barrage Project	Irrigation/ Hydropower	Existing	15 MW/ 41900000 0 ha	GON/GOI
13	Flood Control Project (Chitwan and Nawalparasi)	Flood	Proposed	2715 ha	Current Study
14	Indian Irrigation Project	Irrigation	Proposed	127,920 ha	Indian Part

Table1: List of downstream water utility project under study

Besides the direct benefit from water utilities projects, river regulation has additional benefit from the reduced risk of flooding, environmental and ecological conservation which ultimately have positive impact on socioeconomic development of community.

6. Benefit and Economic Analysis

All viable water utilization projects of the water from BGHEP are given above table 1. The optimum combinations among proposed water utilities project need to be identified. Net benefit in monetary terms for each set of alternatives are assessed and presented. An overview of cost and the benefit including added benefit due to the augmentation of flow form BGHEP for each project under our study are calculated. The best optimal alternatives suggested are not only on the basis of benefit and cost but are also assessed citing the socioeconomic impacts, trend of facility demand and possibility of future development of the projects.

SN	Project Features		SN	Project Features	
1	**Re-Regulating Dam**		2	**Cascade of Re-Regulating Dam**	
	Project Life (Year)	35		Project Life (Year)	35
	Power (MW)	112		Power (MW)	149
	Total Cost (NRs)	25,928,329,560.00		Total Cost (NRs)	28,715,190,000.00
	Annual Revenue (NRs)	4,523,760,000.00		Annual Revenue (NRs)	5,873,443,200.00
	Pay back period (yrs)	5.73		Pay back period (yrs)	4.89
	IRR %	11.96%		IRR %	13.91%
	B/C Ratio (10%)	1.19		B/C Ratio (10%)	1.39
	B/C Ratio (12%)	1.00		B/C Ratio (12%)	1.17
	NPV (10%), NRs	4,617,549,016.31		NPV (10%), NRs	10,704,118,493.35

SN	Project Features		SN	Project Features	
3	**Simaltal - Dashdhunga Project**		4	**Dasdhunga - NLIP canal**	
	Project Life (Year)	35		Project Life (Year)	30
	Power (MW)	149		Total Cost (NRs)	1,803,375,000.00
	Total Cost (NRs)	25,566,922,500.00		Annual Revenue (NRs)	405,849,380.35
	Annual Revenue (NRs)	5,585,616,000.00		Pay back period (yrs)	4.4
	Pay back period (yrs)	4.58		IRR %	17.49%
	IRR %	14.76%		B/C Ratio (10%)	1.58
	B/C Ratio (10%)	1.49		B/C Ratio (12%)	1.38
	B/C Ratio (12%)	1.25		NPV (10%), NRs	1,126,055,705.35
	NPV (10%), NRs	11,836,192,409.93			

SN	Project Features		SN	Project Features	
5	**Nawalparasi Irrigation Project (NIP)**		6	**Domestic Water Supply**	
	Project Life (Year)	30		Project Life (Year)	30
	Total Cost (NRs)	7,735,350,000.00		Total Cost (NRs)	14,044,880,000.00
	Annual Revenue (NRs)	1,651,547,365.00		Annual Revenue (NRs)	2,829,762,028.86
	Pay back period (yrs)	4.70		Pay back period (yrs)	4.96
	IRR %	16.52%		IRR %	15.49%
	B/C Ratio (10%)	1.50		B/C Ratio (10%)	1.41
	B/C Ratio (12%)	1.31		B/C Ratio (12%)	1.24
	NPV (10%) NRs	4,154,696,979.19		NPV (10%), NRs	6,265,995,090.92

Table 2: List of Summary of Economic Analysis of downstream water utility project under study

From the combination of overall current study and analysis project, overall economic study is done and the finding of the study is given below in Table-3.

SN	Project Features	
8	**Summary (Set of Optimum Projects excluding BGHEP)**	
	Total Cost (NRs)	103,794,047,060.00
	Annual Revenue (NRs)	20,869,977,974.21
	IRR %	14.77%
	B/C Ratio (10%)	1.43
	B/C Ratio (12%)	1.22
	NPV (10%), NRs	43,467,445,786.70
	Value of water (NRs/m^3)	6.17

Table 3: Summary of Economical Analysis of Project Excluding BGHEP

SN	Project Features	
9	**Summary (Set of Optimum Projects including BGHEP)**	
	Total Cost (NRs)	353,794,047,060.00
	Annual Revenue (NRs)	47,695,977,974.21
	IRR %	**13.79%**
	B/C Ratio (10%)	1.30
	B/C Ratio (12%)	1.12
	NPV (10%), NRs	91,973,973,215.67
	Value of water (NRs/m^3)	13.06

Table 4: Summary of Economical Analysis of Project Including BGHEP

From the above data and analysis, economical indicators of the project is more viable and social acceptable.

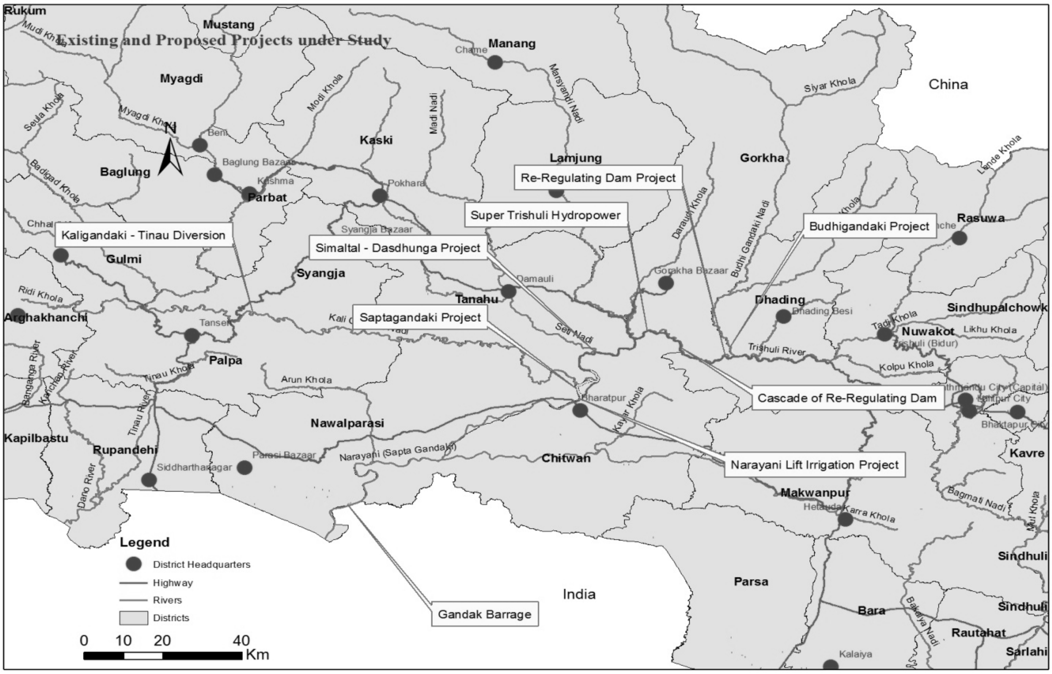

Fig. 4. Downstream water utility projects location

1. Optimum Project Combination

The combination of Re-Regulating Dam Project, Trishuli – Chitwan Diversion Project, Cascade of Re-Regulating Dam Project, Simaltal – Dasdhunga Project, Nawalparasi Irrigation Project, Narayani Lift Irrigation Project (NLIP), Domestic Water Supply at Chitwan and Flood Control Benefit (in Chitwan and Nawalparasi) is the preferred set of projects with highest net benefit. Overall economic analysis is given above (Table -3). The net IRR of the set of downstream project is 14.77%, with benefit cost ratio and net present value at 10% discount rate as 1.43 and NRs. 43,467,445,786.00 respectively.

2. Value of water

Value of water is the Net Present Value of set of the selected projects per unit volume of the regulated water. Budhi Gandaki Projects annually regulates 6592 million cubic meter of water (Table 5). The benefits from all projects, except Trishuli – Chitwan Diversion Project, included in Optimum Project Combination are used to evaluate the value of regulated water.

SN	Month	Monthly Release from BGHEP (m^3/s)	Days	Volume Released (m^3)
1	January	213	31	570499200
2	February	221	28	534643200
3	March	232	31	621388800
4	April	243	30	629856000
5	May	194	31	519609600
6	June	217	30	562464000
7	July	221	31	591926400
8	August	300	31	803520000
9	September	385	30	997920000
10	October	203	31	543715200
11	November	106	30	274752000
12	December	147	31	393724800
Total				**7044019200**

Table 5: Water volume regulated by BGHEP

Based on the economic assessment of the selected projects including BGHEP itself, the value of regulated water is estimated to be NRs. 13.06 per cubic meter. The value of water considering only the downstream projects (excluding BGHEP) yields to be 6.17 NRs per cubic meter (Table 6)

Projects	Total Project Cost (NRs)	Annual Revenue (NRs)	NPV at 10% (NRs)	Regulated Water (m^3)	Value of water (NRs/m^3)
Optimum Project Combination (*excluding BGHEP*)	103,794,047,060.00	20,869,977,974.21	43,467,445,786.70	7,044,019,200.00	**6.17**
Optimum Project Combination (*including BGHEP*)	353,794,047,060.00	47,695,977,974.21	91,973,973,215.67	7,044,019,200.00	**13.06**

Table 6: Economic Value of regulated water from

Cost of the BGHEP is assumed to be NRs 250 billion. The revenue from the project is solely by hydro energy (calculated considering annual 4250 GWh energy). Benefit from Indian side is not included in above estimation of water value.

1. Conclusion and Recommendation

Based on the downstream utilization study and analysis of augmented flow for Budhi Gandaki hydroelectricity Project, it is concluded and recommended that water utilization projects are financially viable, technically feasible and socially acceptable along the downstream of BGHP.

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Optimal reservoir operation based on economic value of different water uses in the Komati Catchmet*.

Krishna Prasad Upadhyay* [1], Pieter van der Zaag[2]

Abstract

Water use in the Komati catchment has been increased since the commission of large dams after late 1960s. As a result of the dams not only the economic activities increased significantly but also the availability of water with high level of assurance. Maintaining the cross border flow, effect of upstream activities on downstream part, increased water withdrawal and consideration of environmental flows has made the catchment feel more water stress. This research tries to undertake economic analysis of different water uses in the basin so that the current water allocation system can incorporate the economic values of these various water uses to find an optimal water allocation method.

Identified water using sectors in the Komati catchment are irrigation, commercial plantation, domestic, industrial, inter-basin transfer, hydropower, recreation and environment. Economic valuation of different water uses has been calculated. The current water allocation practices in the Komati Catchment is based on the Komati Treaty that endorsed the Komati River Basin development project for the sharing of water between South Africa and Swaziland taking into account the water requirements of Mozambique, a 3-day average flow of 2 m3/s at the Mozambique border.

Discrete dynamic programming method is used to find the optimal reservoir operation curve for the Maguga dam that divides the original optimization problem into sub problems which are solved sequentially at each time period.

Key words: water uses, economic valuation, reservoir operation, dynamic programming, optimal allocation

1. Introduction

The Incomati river basin, with a total catchment area of 46748 km2, in eastern region of southern Africa is shared by South Africa, Swaziland and Mozambique which discharge into the Indian Ocean. Major rivers of the Incomati basin are Komati, Crocodile, Sabie, Massintonto, Uanetze and Mazimechopes. These rivers originate in the South African highveld and the plateau area except Mazimechopes, which originates in the Mozambique (Figure-1).

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Water use in the Incomati basin increased significantly after the development of economic activities since 1970s. Irrigation, commercial plantation, domestic and urban use, inter-basin transfer are the major water users in the basin. Irrigation sector consumes a considerable proportion of the water in the basin: about 48% of the total water use. Increased available water with high level of assurance to these sectors is as a result of commissioning of major dams after late 1960s. These developments, in one hand, have increased the economies of three riparian countries, but on the other hand, have affected the environment (D. José Sengo et al., 2005).

Table1: Total consumptive water in Incomati Basin in 2002 (Mm3)

Country	Water generated	Domestic & municipal	Industry	Livestock & game	Exotic tree plantations	Irrigation	Inter-basin transfer	Total
South Africa	2 937	90	35	8	473	670	132	1 408
Swaziland	479	6	1	2	46	48	135	238
Mozambique	171	3	11	1	2	150	0	167
Total	3 587	99	47	11	521	868	267	1 813
Percent		5	3	1	29	48	15	100

According to Carmo Vaz and Van Der zaag (2003), domestic water use is about five percent of total water use. This amount of water is used by 2 million people in the basin. Sugar mills and Paper mills are the major industrial water user. Livestock and Game consume about 11 Mm3/a of the basin water.

To satisfy the demands of various water using sectors, small and large dams have been constructed in the Komati catchment. Some of the significant dams in the catchments are shown in the following table (Table-2).

Table 2: Major Dams in the Komati catchment

Dam	Natural MAR (Mm^3)	Full Supply Capacity (Mm^3)	Full Supply area (km^2)
Maguga	794.4	332.0	10.4
Driekoppies	241.7	251.0	18.7
Vygeboom	258.4	83.3	6.7
Nooitgedacht	67.4	78.2	7.6
Sand	4.9	49.0	7.0

Source: DWAF, 2009

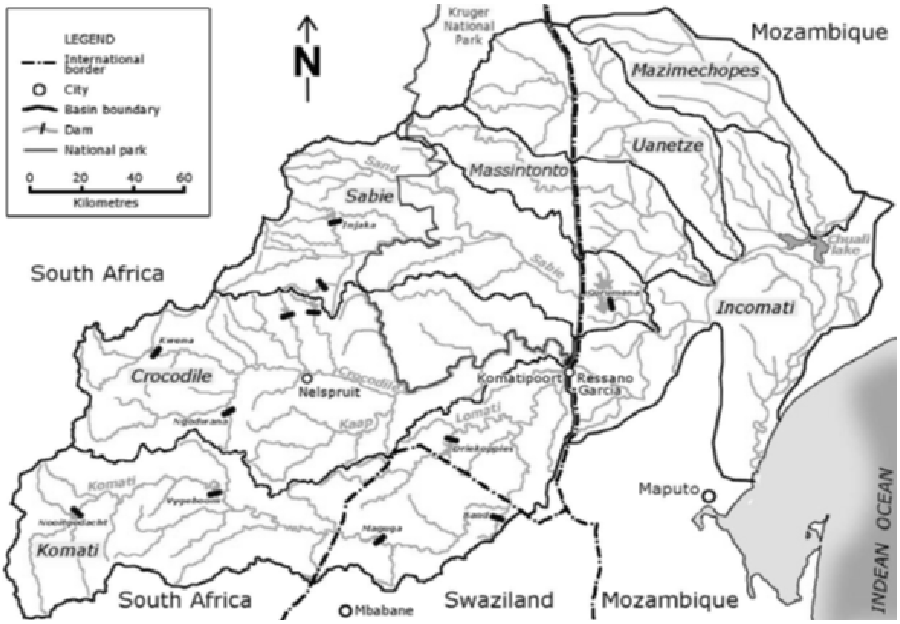

Figure 2: The Incomati basin and its catchment areas. Source:(Carmo Vaz & Van Der Zaag, 2003a)

Water allocation in the Komati basin is highly regulated after the commissioning of the major dams and weirs. Various water users and demographic changes and increasing economic development in the basin have created pressures on water allocation system within the basin. These pressures lead to the operation of the dams in a most productive way as suggested by the neo-classical economic theory that is to give water to most productive sector (Tilmant et al., 2012) .

Water resources economics tries to study the allocation of scarce water resources by taking into account the water availability, modes of production of goods and services and distribution of the benefits. Apart from the economic efficiency, social equity and environmental sustainability are other important issues that the decision-maker need to take account (FAO, 2004). In the absence of valuation in monitory term, the ecosystem services are given less concerns (Fanaian, 2013) and it is difficult to manage what we do not value (Salles, 2011). 'Monetization converts a complex multi-objective management problem into a simpler single-objective problem' (Harou et al., 2009).

The main objective of this research work is to identify optimal water allocation system based on the economic value of different water uses.

2. Economic Valuation of Water

Resources get economic value whenever users are ready to pay a price for them. In the presence of effective market mechanism, the price of the resources will be set with respect to the objectives of producers and consumers. Even in the absence of effective market operations economic valuation of the resources need some estimating technique. In both cases values are measured in accordance with some specified objectives (Young, 1996).

The main idea of valuing the water resources is to set up the function that they provide. That is the goods and services provided by the water resources are valued by the society. The goods and services can be identified in different ways, for instance, extractive or in situ, which again are influenced by extraction and return flows. In any case, a meaningful valuation analysis is essential (FAO, 2004).

Total Economic Value (TEV) method is used most frequently for the valuation purpose. It is the sum of the use values and non-use values as shown in the following figure. Use values are categorised into direct and indirect use values. Direct use value refers to the comsumptive (e.g. harvesting fish), and nonconsumptive (e.g. recreational swimming) uses involving the direct interacting with water resources. Indirect use values are related to the services the water resources provide but not involve direct interaction (e.g. flood protection by wetland) (FAO, 2004).

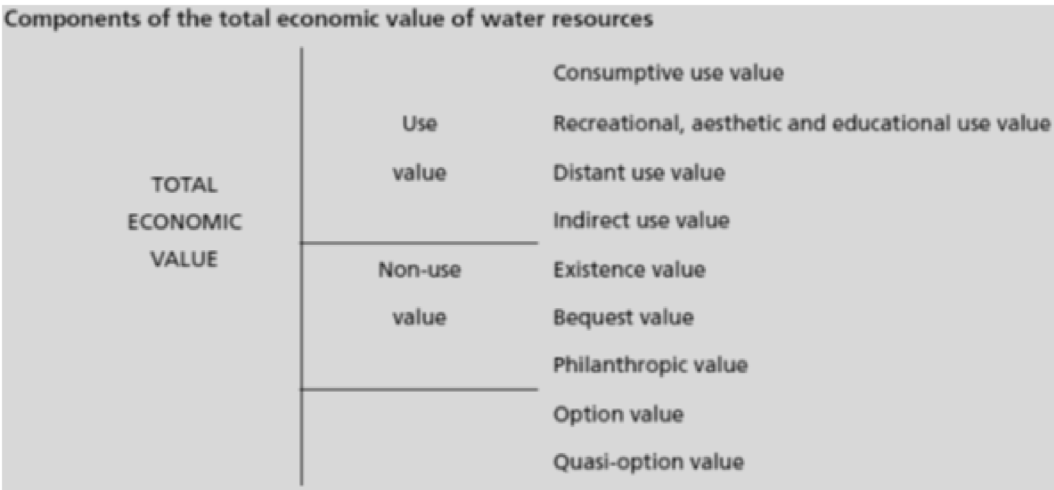

Figure 3: Total Economic Value *Source: (FAO, 2004)*

TEV is the sum of all the components described above. In practice, these elements need to be quantified. TEV method incorporates the social benefits of goods and services granted by the resources while analysing the alternative allocations. However, it is not the complete assessment of the value of the resources. It uses two approaches: individual value (e.g. recreational values, non use values) and production value (e.g. consumptive use values) (FAO, 2004).

2.1 Methods of water valuation

The crop production function can express mathematically the relation between outputs and inputs of the production. Marginal value of each unit of water is the marginal physical product times the price of the crop and marginal physical productivity of water can be estimated keeping all other inputs constant (Gibbons, 1986). Thus the marginal value depends on the selling price of the crop and physical productivity of each unit of water. One limitation of this method is the availability of actual amount of water being used when water meter system is not present.

Contingent valuation method (CVM), a kind of stated preference methods, is commonly used to find the value of domestic water use. CVM extracts the household's preferences in monetary terms with respect to change in quality and quantity of water resources (Birol et al., 2006). People state their maximum willingness to pay (WTP) for an increase in the quality and quantity of water resource allocated. According to Birol et al., (2006), design and implementation of the survey should be done with special care while conducting a CVM. Expert consultation, focus group discussions and pretesting are necessary before conducting the survey.

The economic value of water in hydropower production is very site-specific and the energy generation from the plant depends upon the discharge through turbines, hydraulic head and the efficiency of the turbines (Harou et al., 2009; Young, 1996). According to Young, (1996), there is need of two steps to derive the economic value of water used in hydropower. The first step is to estimate the value of electricity generated from a particular plant followed by the calculation, through the residual approach, of the portion of total value of electricity attributable to the amount of water used. Benefits of the hydropower can also be derived from the market price of the produced energy.

Recreational value of water can either be calculated through the TC (Travel Cost) method from the observation of actual expenditure of the consumers or through WTP method by the use of survey that ask consumer about the value they put for this service (Harou et al., 2009). The fundamental idea of TC method is that the time and the travel cost expenditure that consumers incur to visit and stay at a recreational site represents the "price" of that site. So that number of trips people make to a site at different travel cost can give the peoples' WTP to visit a site (Birol et al., 2006).

Table 3: Identified goods for valuation of different water uses in this study

Goods	Type of value	Valuation Method
Irrigated agriculture: Sugarcane	Direct use	PF
Industrial water	Direct use	PF
Domestic and Municipal water	Direct use	WTP
Hydropower	Direct use	MP
Recreation	Direct use	WTP

MP= Market Price, PF= Production Function, WTP= Willingness to pay

2.2 Value of Water in Irrigated Agriculture

Sugarcane cultivated in more than 80 percent of the total area that provides the livelihood of large number of rural people and it has a significant contribution in the employment and national GDP of both countries. So that value of water in sugarcane production can be assumed to represent the value of irrigation water in the study area.

The study was to estimate the marginal value of water in sugarcane using a production function approach. The Cobb-Douglas Production Function (CDPF) was chosen to analyse the different input factors in the production of sugarcane.

$$Y=\beta_0 X_1^{\beta 1} X_2^{\beta 2} X_3^{\beta 3} X_4^{\beta 4} X_5^{\beta 5} e^{\chi}$$

Y= sugarcane production (ton)
β_0= Constant
β_i= coefficients of inputs
X_1= farm size (ha)
X_2= labour (hrs)
X_3= chemical (lt)
X_4= fertilizer (kg)
X_5= Water (m^3)
χ = error term

For its easiness to interpret and to make it linear, natural logarithm of the output and input were used as

$\ln Y= \beta_0+\beta_1 \ln X_1+\beta_2 \ln X_2+\beta_3 \ln X_3+\beta_4 \ln X_4+\beta_5 \ln X_5+ +\chi$ ....(4.1)

Productivity (Y): This is the dependent variable of the function measured. It is the amount of sugarcane crop produced (tonnes). Others are the independent variables responsible for the productivity of sugarcane.

Now the marginal physical product of water (MPP_W) can be calculated by partially differentiating the sugarcane production with respect to water use as

$MPPW= \delta_Y/\delta_W = (Y/ X_5)* \beta_5$ ....(4.2)

Finally, the marginal value of water (MV_W) can be calculated by multiplying the marginal physical product of water by price of the output.

$MV_W= P_Y * MPP_W$ ....(4.3)
where P_Y is the price of sugarcane[1]

Value of water in Industrial use

Production function method was used to derive the value of industrial water as
Y = f (K,L,W,E)

[1]Farmers produce the sugarcane but when they sell it, the price of the sugarcane is paid based on sucrose percentage

where Y is the quantity of output and K,L,W,E are the quantities of inputs (Capital, Labour, Water and Energy respectively).

To be specific, the a production function can be specified as

$$\ln Y = \beta_0 + \beta_1 \ln K + \beta_2 \ln L + \beta_3 \ln W + \beta_4 \ln E + \beta_5 \frac{\ln K^2}{2} + \beta_6 \frac{\ln L^2}{2} + \beta_7 \frac{\ln W^2}{2} + \beta_8 \frac{\ln E^2}{2} +$$
$$\beta_9 \ln K \ln L + \beta_{10} \ln K \ln W + \beta_{11} \ln K \ln E + \beta_{12} \ln L \ln W + \beta_{13} \ln L \ln E + \beta_{14} \ln W \ln E$$

Then elasticity of production with respect to water is calculated as

$$\sigma_w = \frac{\partial \ln Y}{\partial \ln W} = \beta_3 + \beta_7 \ln W + \beta_{10} \ln K + \beta_{12} \ln L + \beta_{14} \ln E$$

Marginal productivity of water

$\rho = \sigma_w \cdot \frac{Y}{W}$, Where Y/W is the average value of output per unit of water

When Y is the total value of industrial output, then above equation gives the marginal value of water for industrial use.

2.3 Value of Water in Domestic use

WTP method was applied to calculate the value of domestic water. The relationship between the WTP and different socio-economic factors was tested using an econometric analysis. A regression analysis was done. WTP was expressed as

WTP = f (WATCON, HHINC, HHSZ, EDN, WATSOC, PAB, SNL, CLTL, LOC, AGE, GENDER)

In linear regression form WTP becomes

WTP = β_0+β_1WATCON+β_2HHINC+β_3HHSZ+β4EDN+ β_5WATSOC+ β_6PAB+β_7SML+ β_8CLT+ β_9LOC+ β_{10}AGE+ β_{11}DENDER+ε

Where:

β_0 = constant

β_0 - β_{11}= Coefficients of input factors

WTP = Willingness to pay of the households for improved quantity and quality of water

WATCON = water consumption m3/month/HouseHold

HHINC = Households' monthly income (E)

HHSZ = Household size (no. of individuals)

EDN = Education of HH head (no. of years spent in education)

WATSOC = water source of HH (1 for private, 2 for community tap, 3 for river)

PAB = dummy variable that HH practicing avoidance measures against water-borne diseases (1='Yes', 0= 'No')

SML = dummy variable indicating presence of small children in the HH (1='Yes, 0='No')

CLT = time spent by HH for water collection (hours/month)
LOC = dummy variable indicating HH location (1='urban', 0='rural')
AGE = age of HH head (years)
GENDER = dummy variable indicating sex of HH head (1='female', 2='male')
ε = error term

2.4 Value of water in Hydropower

Market Price method is used to get the economic value of water in hydropower. SEC (Swaziland Electricity Company) provided the data of monthly energy generation from the Maguga Hydropower Plant. KOBWA provided the monthly release of water to hydropower. From this information energy generation per unit volume of water (m3) was calculated.

SEC also provided average selling price and average cost of each unit (kWh) of electricity from which benefit of each unit of energy has been calculated by deducting the cost from the selling price.

Benefit per unit of energy generation = P - C
Here P and C are market price cost of production of each unit of energy.
The value thus obtained was attributed to the amount of water used to generate each unit of energy.

2.5 Value of Water in Recreation

Travel cost method was applied to estimate the value of recreational water. Total amount of money spent by the visitors for different recreational activities were calculated. Staffs of Maguga Lodge were asked about the various facilities they provide, number of visitors using these facilities and amount of money those visitors spent. The money spent by the visitors can be attributed to the peoples' WTP to visit the site.

Table 4: Value of water for different uses

Value of water (US$/ m3)			
Agriculture	**Industry**	**Domestic use**	**Hydropower**
0.102	17	0.35	.019

Calculation of value of per unit volume of water in recreation was not possible in this case. Instead, total revenue collected in one year season from the recreation is calculated which is around 1.5 million US$.

3.1 Reservoir Operations

Among the two reservoirs in the study area, only the Maguga dam is chosen for this purpose. There are two types of users in the proposed area- irrigation and domestic.

For the optimal reservoir operation of the Maguga Dam, the following steps have been proposed.

1. Preparing rule curve of benefit
2. Deriving dynamic rule curve
3. Comparing the dynamic rule curve with observed values

3.1 Preparing rule curve of benefit

A rule curve of benefit function or Net Economic Return (NER) is prepared taking into account the monthly benefit from the water use by users. The idea of this calculating benefit function is to make the base case scenario. To calculate the benefit function, monthly water use by the sectors are multiplied by their per unit value of water and then they are added. The proposed area has only two users- agriculture and domestic.

$NER = S_a*V_a+S_d*V_d$

S_a, S_d, and are the supply of water to agriculture and domestic sector respectively.

V_a and V_d, are the value of water to agriculture and domestic sector respectively.

3.2 Deriving dynamic rule curve

Dynamic programming is performed to derive the dynamic rule curve. The active storage capacity of the Maguga dam is 325 MCM . That is to say that the active storage in the reservoir can vary from 0 to 325 MCM. For the purpose of using discrete dynamic programming, this range of possible storage volume has been divided into intervals of 25 MCM. Hence, the initial storage volume, St, can have the values of 0, 25, 50, ..., 275, 300 and 325 for all time periods. Month is taken as time period, t,. For each month, let Q_t be the mean inflow and R_t be the release from the reservoir. Then the initial active storage, S_t, plus the inflow, Q_t, minus Release, R_t, and losses L_t equals the final storage. This final storage is the initial storage, $S_{(t+1)}$ for the next month.

$S_t + Q_t - R_t - L_t = S_{(t+1)}$, for each month.

$S_t \leq K$, capacity of the reservoir

Here, seepage losses and evaporation losses from the reservoir have not been taken into account assuming that they don't have any significant effect on this process.

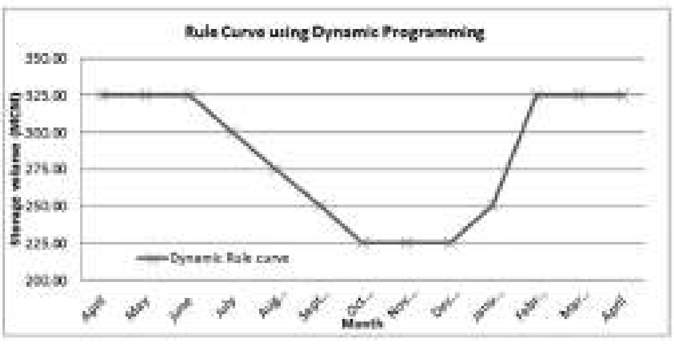

Figure 4: Rule curve using Dynamic Programming

Figure below shows the comparison between the dynamic rule curve and the observed pattern of storage volume from last three water years.

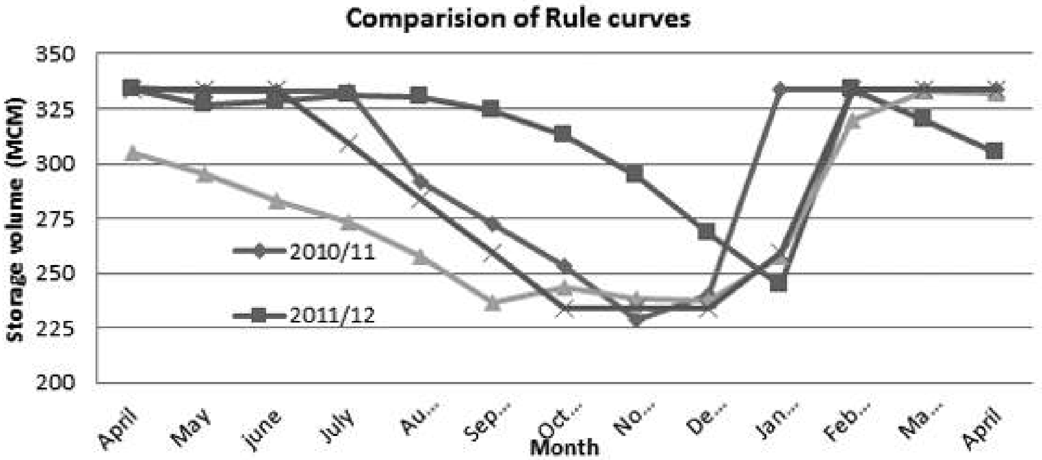

Figure:5 Comparison of Rule curves

We can observe a similar pattern of the curves. The dam is full at the beginning of the year (except in the year 2012/13). Water level goes down during the middle of the year and rises up towards the end of the year. It is observed that the combination of tributaries and inflows are affecting the storage pattern of the reservoir.

4. Conclusions

Marginal value of water in sugarcane crop using the production function method has been calculated as US$0.102/m3. This value is assumed to represent the agriculture sector within the study area. The marginal value of industrial water use is estimated as US$17/m3. Similarly, the value of water in domestic sector using WTP method is US$0.35/m3. Value of water in agriculture and domestic sector is comparable to the value of water found by other researches within the region. But the industrial value of water is higher than the value estimated by other studies. Average value of water in hydropower by using market price method is calculated as US$0.019/m3. Total revenue collected in one year season from the recreation is calculated as around 1.5 million US$. Total added value of lost banked water from the Maguga dam of last three years is estimated around 28 million US$.

A discrete dynamic programming model has been used to derive the rule curve of the Maguga dam with the objective of maximizing the NER. The dynamic rule curve derived here is based on the assumed inflows and initial storage which is compared with the observed pattern of storage level of last three years. Dynamic rule curve is found different from the observed ones. But overall pattern of the curve is comparable with them. The NER from each decision at each time period is dependent only on the state variable value of that time period and not on the decisions made at other time periods (Loucks et al., 2005). Value of environmental flow is recommended to be incorporated into the water allocation system.

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Practices and prospective of e-Procurement System in Department of Irrigation

Mr. Deepa Gautam

Abstract

The major portion of the government expenditure accounts for the public procurement process. In attempt to make public procurement process fair, transparent effective and efficient, the government of Nepal has up taken the ***e-Procurement*** system and Department of Irrigation has been practicing the same since Nov 2010. As there is very little research available that investigates the implementation of e-Procurement initiative from the organizational learning point of view, this paper is the outcome of the research, carried out to aid **organizational learning**, with the objective of revealing the status of up taken e-Procurement System and its future prospective in Department of Irrigation.

The research has been carried out with the qualitative as well as the quantitative approach making use of the primary as well as the secondary data. The analysis of the primary data has been made using Relative Importance Index **(SWOT Analysis), Pillar Strength Analysis**, Resource Effectiveness Analysis, whereas the analysis of secondary data has been made with **Gap Assessment** and the **Trend Analysis.**

This paper identifies the relatively important areas of strength, weakness, opportunity and threat. Another main result of this paper concentrates around the scenario of present and future resource effectiveness and the identification of the parameters acting as the pillars and their present degree of effectiveness in the implementation of e-procurement system. It has been recommended to fully address the factors hindering the pace of e-Procurement as identified by this research, for maximizing the strength and seizing all possible opportunities of e-Procurement system.

Keywords: e-procurement, organizational learning, SWOT analysis, Pillar Strength, resource effectiveness, gap assessment, trend analysis

1 INTRODUCTION

1.1 Background

Over the past decade, rapid progress in Information Communication Technology (ICT) has encouraged many governments to incorporate new technology into their national economic development strategies. e-Governance has been taken as an ICT based solution which improves government's internal administration as well as enhance its service delivery mechanism. Essentially, e-government delivery models can be briefly summed up in four models (Hai, 2007);

a. G2G (government to governments)
b. G2C (government to citizens)
c. G2E (government to employees)
d. G2B (government to businesses)

In Nepal, approximately 60%-70% of annual budget accounts for the Procurement purpose (PPMO, Annual Report, 2070). Hence, it becomes important to emphasize greatly on these activities in order to accomplish them in an efficient and transparent manner. Public procurement is the process by which governmental spend the public money following formal and specific guidelines like Acts / Regulations approved by the government. e-Procurement is simply aspects of the procurement function support by various forms of electronic communication, (Knudsen, 2002) and its use in both the public and private sectors takes many forms.

In the context of Nepal, all the public procurement is governed by The Public Procurement Act 2007 (2063), and The Public Procurement Regulation 2007 (2064)-Third Amendment 2068. The umbrella act for public procurement of Nepal 2007, (PPA, 2007) has stated on it's the Para 69 that; "Procurement Transaction May be Carried out through Electronic Communications Means". With reference to this clause of the act, The Department of Irrigation (DoI) started the practice of e-Procurement system since November 2010.

1.2 Objective of the study

General Objective: To find out the status of up taken e-Procurement System and its future prospective in DoI.

Specific Objectives:

- To study of the prevailing practice in the procurement via electronic means.
- To measure the effectiveness and the extent of use of e-Procurement System and the suitability in terms of available facilities.
- To recommend the areas of improvement for e-Procurement in DoI.

1.3 Significance of the study

- The study outcome can be used for the system improvement.
- It can be used as a reference tool to the implementing agency for effective implementation.
- It can be useful in the policy level for the appropriate decision making.

On the other hand, this system itself, in the long run, has positive impact on the environment as it aids for the zero- paper concept. In every way, it has a huge significance in the local, national as well as the global level.

1.4 Scope and limitations of the study

The scope and limitation of this research is worked out as below.

- The scope has been focused to the division offices. This limits the other units/ subunits of the organization from sampling.
- The data of (made available by) the division offices (considered with regional as well as geographical coverage point of view), after the implementation of e-Procurement system has been used for the trend analysis.

2. E-PROCUREMENT SYSTEM

e-Procurement effectively began in late 1990s when several startup software companies began to develop a suite of applications that allowed vendors to create electronic catalogs (Neef, 2001).

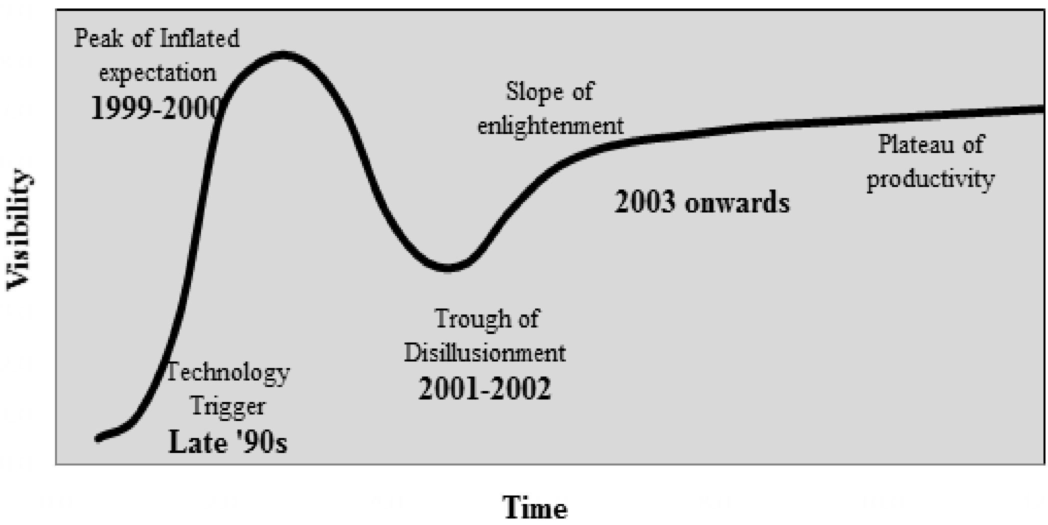

Figure 1 e-Procurement history (Dagg, 2005)

2.1 e-Procurement system in Asia

In a survey commissioned by ADB, to evaluate the state of readiness of e-GP system and e-GP implementation, the 11 e-GP systems are mapped onto a two-dimensional positioning map to obtain a snap-shot view on maturity of the systems (Somasundaram, 2011).

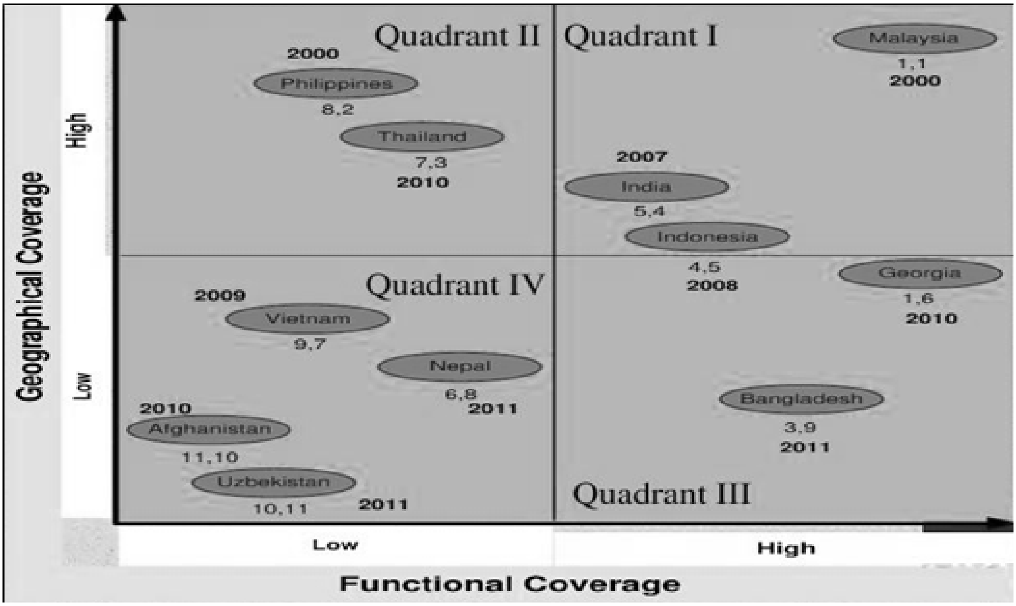

Figure 2 e-GP positioning map

Review of e-GP system in Malaysia

To review top ranked Malaysia's e-GP system (e-Perolehan), Key features of this system are:

- A pioneering initiative, functional for one and half decade since 2000
- Six functional components implemented
  - a. e-Publication / downloading
  - b. e-Bidding
  - c. e-Contracting
  - d. e-Payment
  - e. e-Reverse action
  - f. e-Catalogue purchasing
- Integrated with 2 other government systems
  - g. National Treasury & Budget
  - h. Contractor Registration and classification
- 53.85% of annual procurement spend is handled in the e-GP system in the year 2010; valued at 3.5 Billion USD
- 2534 registered procurement entities
- 183,029 registered suppliers

2.2 Need of e-Procurement system in Nepal

According to the Corruption Perception Index 2014, Nepal is ranked 126 out of 174 with total score of 29. Public procurement has been identified as the government activity, most vulnerable to corruption (Adhikari, 2015). In recent years there has been an indication that risks in public procurement.

Due to political protection and lack of effective cooperation of security, collusion among the bidders and intimidation at the time of bid submission are increasing both in the central and district level. It is said that sister organization of political parties are involved in the intimidation process including use of physical force by hired thugs by other individuals. Government officials are not in a position to take actions of blacklisting the bidders due to threats. Collusion and intimidation practices have adversely affected and weakened competitive environment of PP (PPMO, Nepal Public Procurment Strategic Framework Phase I (2010-2013), 2010).

2.3 Development of e-Procurement system in Nepal

The e-Procurement system that has evolved now is the outcome of studies, analysis, research and the recommendation over modifying, rectifying and simplifying the public procurement system in Nepal as a part of e-governance within the good governance motive.

1. Government published the notice intending to use electronic medium in procurement process for RSDP in Nepal Gazette dated December 10, 2007. For the first time, the DOR has started to use electronic media for submission and opening of bids. First electronically submitted bid was opened on 27th January 2008.
2. Amendment of PPR was made in 22 July 2011 to strengthen PPMO leadership for the establishment of e-GP. Hence PPMO mandated to establish, operate and manage single portal e-GP system.
3. Budget speech (2010/11) made e-GP mandatory for the procurement above NRs. 20 million.
4. Government of Nepal through budget speech for fiscal year 2013/14 (2070/71), declared to use single portal e-GP system mandatorily for any categories of procurement above 6 million. (CSC, 2013).

In absence of e-GP, 16 e-bidding portals were developed and used by 114 public entities (Shrestha, 2011). PPMO in support of WB and ADB procured consultant services to review existing software and develop e-GP software Phase-I which has already been completed.

Table 1 e-GP phases

Phase-I has been designed to include	Phase II intends to serve the complete e-
• bidder and buyer registration	• e-Bid-evaluation
• central database system of	• e-contract award
• central bid notice publication	• e-contract administration
• e-submission	• e-Payment and archiving
	• e-catalogue

2.4 e-Procurement system in Department of Irrigation

Department of Irrigation started the practice of e-Procurement system for e-submission on Nov 2010 onwards. The system was developed by Yomari Incorporated Private Limited. DoI switched to the PPMO managed e-Procurement portal due to the amendment made in PPR for the establishment of a single National portal e-GP system.

Interface to external system/ organizations

A well designed e-Procurement system should have necessary interfaces with external systems. The diagram below summarizes the interfaces (to be) implemented between the existing e-Procurement system and the other key IT applications/systems of govt.

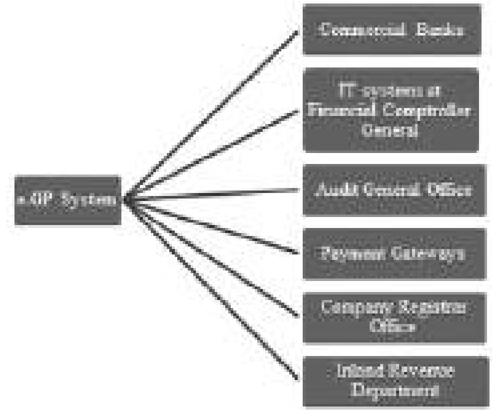

Figure 3 External interfaces required for e-GP System

3. METHODOLOGY

The research has been carried out with qualitative as well as quantitative approach.

3.1 Study population/ sample size

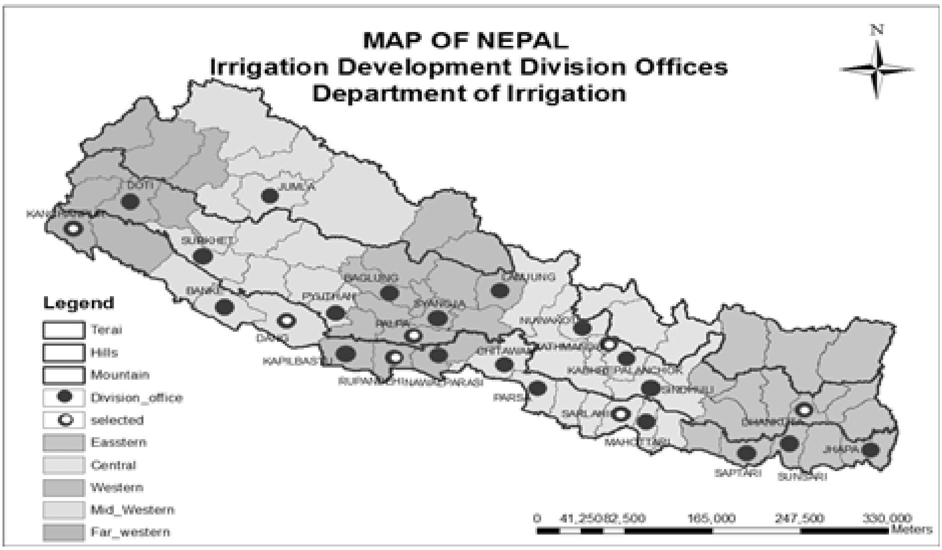

Figure 4 Irrigation Development Division Offices under DoI indicating population/ sample

Total population for this study is the technical personnel of the Division Offices and the sampling strategy has been guided by stratified proportionate sampling method. The stratification has been done in terms of regional basis followed by the geographical basis. The sampling was done according to the formula, given by (Cochran, 1997)

Division Offices and the sampling strategy has been guided by stratified proportionate sampling method. The stratification has been done in terms of regional basis followed by the geographical basis. The sampling was done according to the formula, given by (Cochran, 1997)

$$no = \frac{t^2 * pq}{d^2} \quad ; \quad n1 = \frac{no}{1 + no/P}$$

Where,

t =1.64 (for 90% confidence level)
p.q =0.5*0.5 taken (estimate of variance)
d = 10% taken (acceptable margin of error for proportion being estimated)
n_o = required return sample size according to Cochran's formula
n1 = corrected sample size for finite population

3.2 Methods of data collection

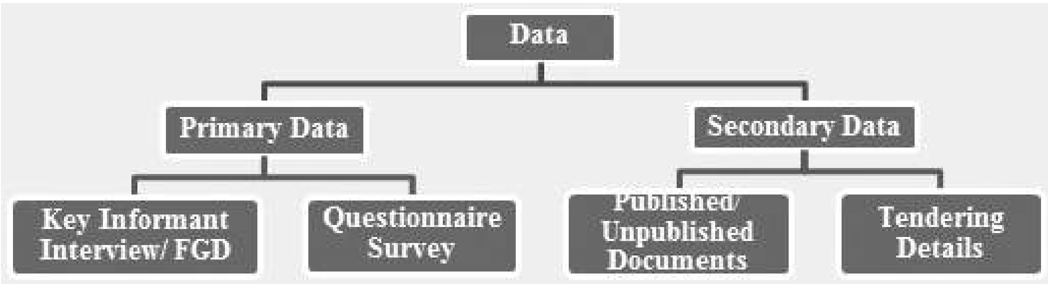

Figure 5 Data structure

3.3 Data analysis

Relative Importance Index (RII)

Relative importance index $= \frac{\sum w}{AN}$

Where w is the weighting given to each factor by the respondents, ranging from 1 to 5, A is the highest weight (i.e. 5 in the study) and N is the total number of samples. This tool has been used for the SWOT analysis, potential driver and barrier analysis and the major areas of improvement.

Pillar strength assessment

This assessment is based on four parameters established by the researcher. They are: effectiveness of the electronic procurement policy, organizational support, bidders' participation and performance satisfaction. The obtained data was weighted in a linear scale and represented on the basis of a scoring system of 3 to 0 for each parameter.

Resource effectiveness analysis

This is a figurative analysis and hence has been done through the figures which represent the effectiveness in terms of time, cost and paper usage in present against the future in the same figure.

Gap assessment and the trend analysis

This part of the study was conducted through the secondary data to review the current practice in the procurement in terms of means of tendering, participation means and project funding overview. The analysis was made over the gap created in the electronic tendering and electronic participation and followed by the assessment of trend in e-tendering, e-Participation and winning through e-bidding.

4. KEY FINDINGS

1. Tendering overview

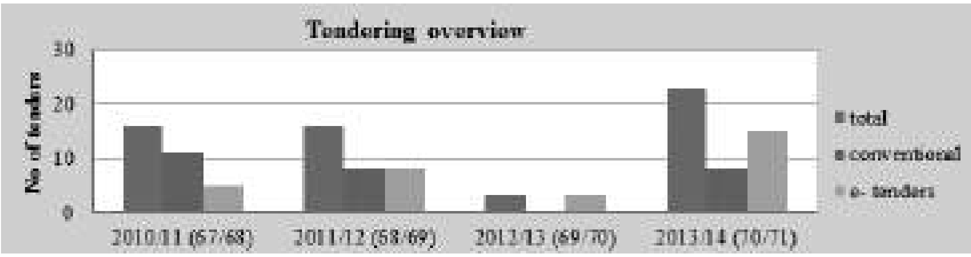

Figure 6 Tendering overview of DoI

It can be observed from the figure that the number of the e-tenders is ascending with the time leading to the descending number of the conventional method of tendering.

2. Project funding overview

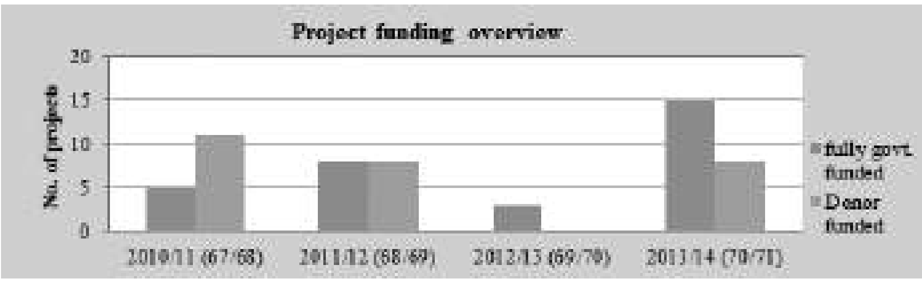

Figure 7 Project funding overview

It can be observed from the figure that the government funded is maximum in the year F/Y 2013/14 (2070/71).

3. Bidding medium overview

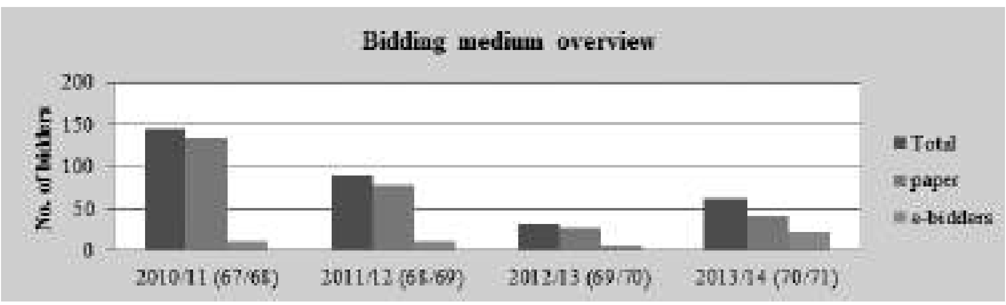

Figure 8 Bidding medium overview

Figure 8 represents the details of the procurement in terms of bidding medium against the tender issued. It can be observed that the number of the e-bidders has been rising with the slow pace.

4. Problems faced by DoI staffs due to the implementation of e-Procurement system

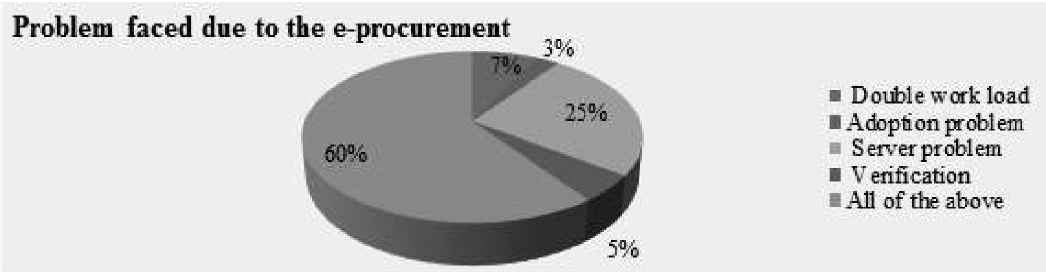

Figure 9 Types of problem faced during e-Procurement practice

The figure 4.11 gives the clear idea about the extent of types of problem that has been faced by the users. The figure helps in the realization of the main hindrance in the effectiveness of e-Procurement system.

5. Frequent Complaints made by Bidders while e-bidding

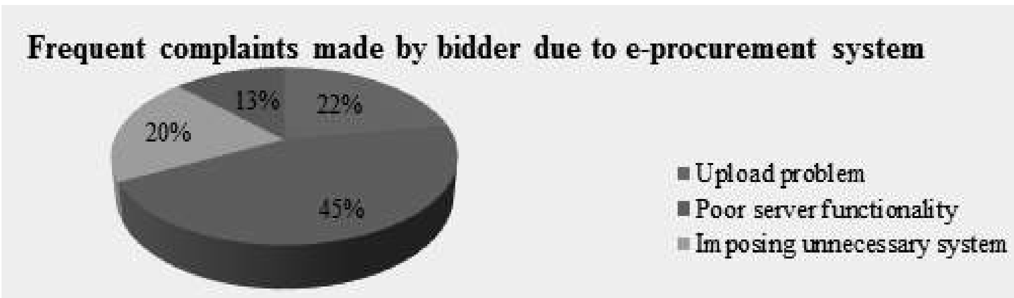

Figure 10 Frequent complaints made by the bidders.

Figure 10 reveals several complaints that bidders make and purchasers come across, the maximum of which is for the server related problems (45%). The server related problem has made similar impact to the bidders as well as the purchasing entity.

6. Measurement of effectiveness of e-Procurement system

The figure 11 and 12 and 13 gives the scenario of cost/time/paper use respectively in present (represented by blue balls) against the future (represented by yellow balls). In the figures, X-axis represents the percentage change in the cost/ time/ paper use (as indicated by the caption) and the y- axis represents the percentage of respondents which is again supported by the size of the balls for easy inspection.

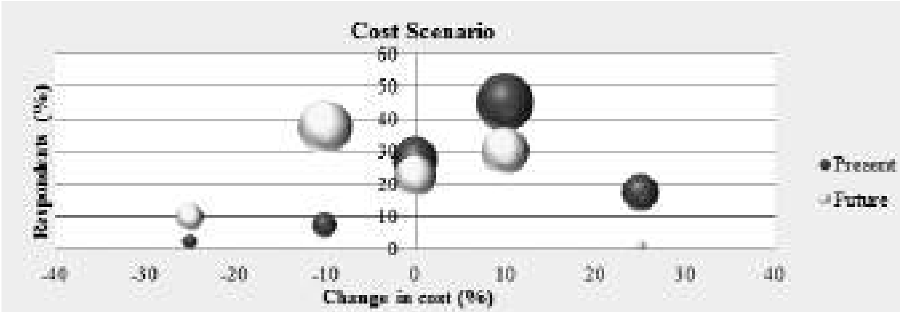

Figure 11 Cost Scenario in e-Procurement implementation

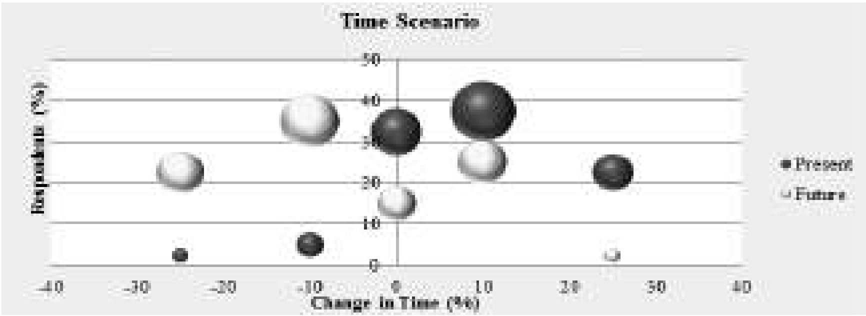

Figure 12 Time scenario in e-Procurement implementation

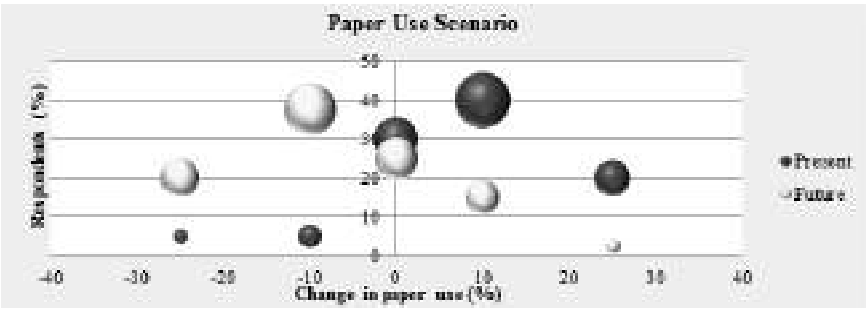

Figure 13 Paper use scenario in e-Procurement implementation

In all three cases, it can be seen that use of resources in the present context has been skewed toward the right/ positive part of the chart which can be visualized from the position series of the blue/ dark colored balls. On the other hand, the response upon the use of resources in the future context has been skewed toward the left/ negative part of the chart, but some major part lying in the right as well, which can be visualized from the position series of the yellow/ light colored balls.

7. Pillar strength analysis

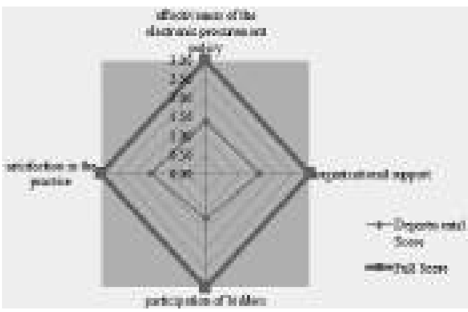

Fig. 14 Pillar strength analysis

From the result obtained, it can be said that all four pillars are of similar strength since the shape depicted by the figure is not very much asymmetrical, but to define the strength, all the areas needs significant improvement, since all of them have obtained the score less than 2. Moreover, the degree of effectiveness of electronic procurement policy has been assessed to be the pillar of weakest strength, followed by the degree of participation of the bidders. Degree of satisfaction in e–procurement practice and organizational support activities are assessed to be relatively strong pillars.

8. SWOT Analysis

To identify the internal and external factors which have positive as well as negative impact upon the e-Procurement system, SWOT analysis has been carried out.

Table 2 SWOT matrix

Factors	Positive	Negative
Internal	1. Transparency 2. Fair competition 3. Human resource reduction 4. Time and cost resuction	1.Insufficient training 2. Low participation by bidders 3. Double work load 4. Inefficient policy
External	1. Competitiveness 2. Technology enchancement 3. Organizational strengthening 4. Capacity Building of employee	1. Internet/ load shedding problems 2. Security issues 3. Server funtion 4. System risk (collusion)

9. Officially trained number of staffs and the sufficiency

Figure 15 Officially trained staffs and sufficiency for handling e-Procurement system

The figure 15 represents the result of two important aspects of human resources for handling e-Procurement system; number of officially trained staffs as reported by given % of purchasers (x-axis) and the sufficiency in handling e-Procurement process (y-axis) reported in terms of yes, no or conditional yes. Conditional yes refers to the situation where there is assumed to have sufficient number in the present, but needs to be more in case of extensive use of e-Procurement.

10. Difference in bidding environment due to e-Procurement system

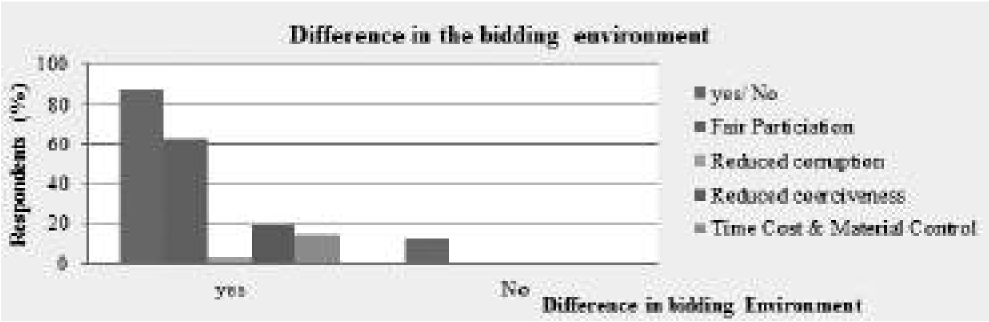

Figure 16 Difference in the bidding environment due to e-Procurement system

From figure 16, although the main purpose of e-Procurement is to eliminate any kind of mal practicing associated with the procurement process, it has not been able to address the issues of corruption in reference to the result obtained. Though, fair participation has been much noticed.

11. Gap assessment

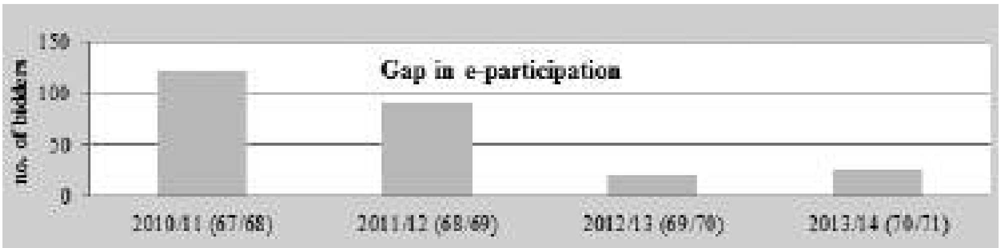

Figure 17 Gap in e-tendering

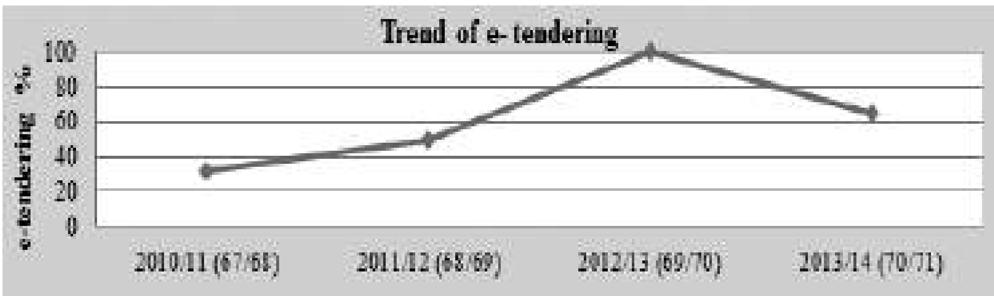

Figure 18 Gap in e-Participation

Figure 17 and figure 18 represents the gap in the current e-Procurement practice in terms of e-tendering and e-Participation respectively. It has been observed from the figure that the gap is gradually decreasing with the time. In the F/Y 2012/13 (69/70), the gap has diminished to minimum, but it should be remembered that the obtained level may have been resulted (in this as well as succeeding figures) due to the special budgetary circumstances for that year.

12. Trend analysis

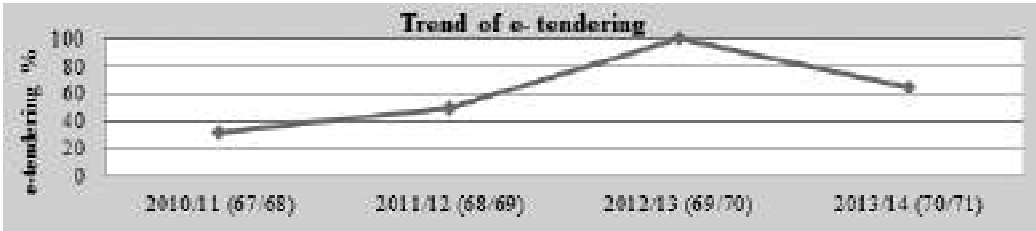

Figure 19 Trend of e-tendering

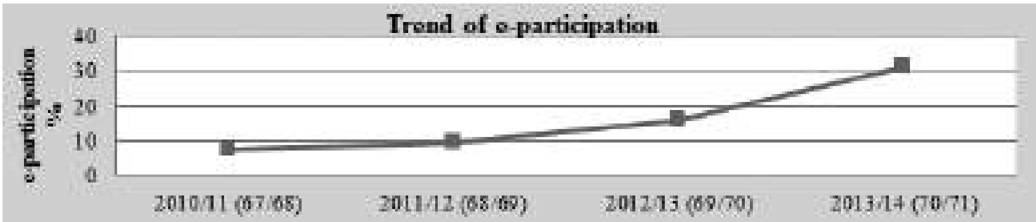

Figure 20 Trend of e-Participation

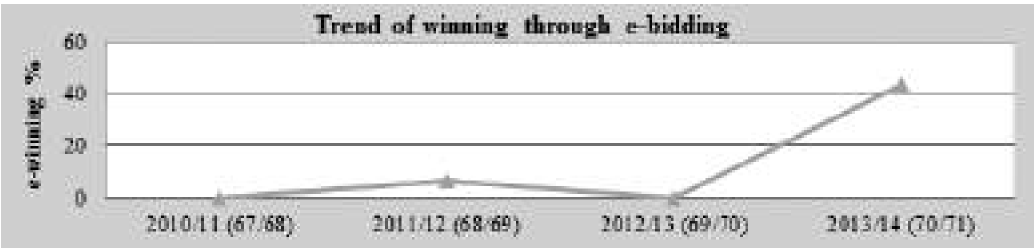

Figure 21 Trend of winning through e-bidding

Figure 19 and figure 20 represents the trend in the e-Procurement practice regarding the e-tendering and e-Participation and Figure 21 represents the trend in the e-Procurement practice regarding the winning of the bid through e-Participation and is also considered as the success factor. It can be seen that all three parameters are in the rising trend.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

1. The non implementation of e-Procurement in donor funded projects has limited the use of e-Procurement system in the government funded projects only, limiting the extensiveness of e-Procurement system.
2. The uploading of the bidding documents during the last hours of submission has created the speed and server related problem, which indicates this scene is expected to amplify in terms of magnitude and intensity in the single portal, if attention not given.
3. Since, the e-GP system demands at least 3 hierarchical levels of staffs; it challenges

the use of e-Procurement system in number of trained staff, training extensiveness as well as the current hierarchy level, practically available in every units under DoI.

4. There is another significant integrated aspect of e-Procurement; the internet facility and continuous power supply, both of which cannot solely be addressed at the individual level of procurement act or regulation. The unavailability of these facilities at the expected level cannot lead the e-Procurement to achieve its full momentum, whether or not, the users or the policy makers dream to achieve its full implementation within years.
5. For the time being, the implementation of e-Procurement system has not met its pre-conceived motive of addressing corruption in the procurement phase. Though, it has been much noticed as a wiser medium in creating the equal opportunity of participation.
6. The scenario of resource utilization in terms of time, cost and material usage (paper use) has been observed to be increased at the present. But as the time progress, with the full implementation of e-Procurement system achieving its motives, these parameters has to be reduced significantly unlike the perception of majority of purchasers. This means that the purchasers are not in the position to perceive the full functionality of e-Procurement system and suppose the system merely to intensify its effectiveness and not the re-engineering of the procurement process. This signifies the insufficient orientation of the DoI engineers about the strength and opportunities of the electronic procurement system.
7. The gap assessment and the trend analysis lead to the conclusion that the extensiveness of the e-Procurement practice in on the rising trend.

5.2 Recommendations

1. In addition to review of international practice in e-Procurement system, it is recommended to review the experiences from PEs and bidders, to draft the suitable regulation/ guidelines for e-Procurement system.
2. The extensive trainings and the basic level training as applicable should be organized by the implementing agency as well as the respective organization as well.
3. The governance should soon transform to the full e-governance so as to integrate all the G to G information required by the e-Procurement process by the system itself.
4. Government should make a strong attempt towards the national level issues hindering the full implementation of e-Procurement system; internet facility and continuous power supply, since, the need to implement the e-Procurement system is dragged forward by the level and extent, in which these issues are addressed.

Model recommendation:

The key findings and conclusion drawn over these have revealed that the implementation of e-Procurement system is geared up with two factors; internal modules and the external facilities. The effective implementation of e-Procurement system in this combination of gear is interlinked with strengthening of internal modules as well as improvement of external facilities.

Figure 22 e-Procurement system geared up with internal and external factors

Hence, the full fledged e-Procurement system is recommended to be built on its strengths, minimizing the weaknesses, seizing the opportunities and counteracting the threats as identified by the research, incorporating strengthened internal modules and improved external facilities for the effective implementation of e-Procurement system, to achieve the improved fairness, transparency and efficiency in procurement practice.

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Strategic Approach to Small Scale Irrigation Development: Action Research Experience

-by R.R.S. Neupane, Irrigation Management and Transfer Specialist

Abstracts

In 1990, during Irrigation Management Project (IMP) Period (1985-1992), an action research with an aim to learn program effectiveness in achieving targets on small scale irrigation development ,was lunched at Malebagar Farmer Managed Irrigation Schemes (25 ha) in Tanahu Districts of Nepal. The strategic approach adopted for problem diagnosis, system planning and program implementation over traditional feasibility study approach and rehabilitation focused project development, appeared result oriented, effective participative and more sustainable development. This study imparts knowhow, how built in capacity of WUA help in the performance of physical system rehabilitation, water management and agricultural productivity. The approach and knowledge sharing of the study would be very much useful to the promoters of small scale farmer managed irrigation schemes in Nepal and elsewhere.

The primary objective of the research was to apply result oriented approach on small scale irrigation scheme rehabilitation and modernization. Physically, the scheme diverts water from Buduwa Khola by boulders, mud and bushes temporary bunds built across the river, and the divides the diverted water into Pahilo Kulo that irrigates 8 ha and Dosro Kulo irrigating 16 ha of land.

After study (Feb-June,1990) the existing performance situation against the target performance of conveyance and diversion performance, water control performance, WUA performance and agricultural performance of major crops including yields and cropping intensity were monitored. The results showed improvements over previous performance and were highly encouraging.

1. Background of the Scheme

Malebagar Farmer Managed Irrigation Scheme lies in Tanahu District of Western Region of Nepal and is about 1 km south to Khairanitar on Pokhara- Kathmandu highway. During spring rice season (March to June of 1992) Irrigation Management Center (IMC) under Irrigation Management Project (IMP), lunched an action research to learn more effective Farmer Managed Irrigation Schemes improvement approaches. Key drives for this action research were the following prevailing and general issues involved in farmer managed irrigation schemes in Nepal.

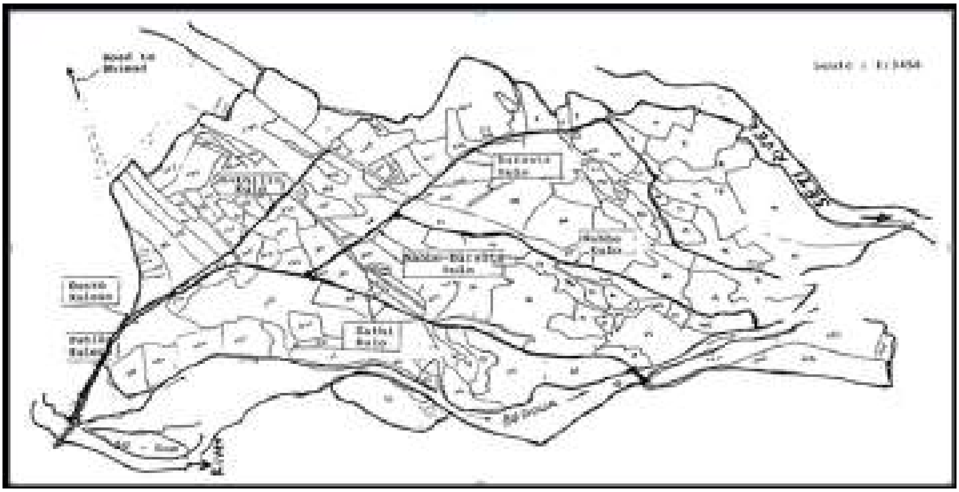
Key Drives

- Apparently, farmers were using water with less conflicts in their schemes, however, there lagged actual equity of water distribution between branch canals or within their sections.
- Lack of appropriate water diversion and control structures made them helpless to decide adequacy of water diversion & division.

- Farmers were far behind of basic technical water management techniques and this led them adopt flooding irrigation method resulting in low agricultural production.
- Farmer Groups or Water Users Groups were more concerned to water diversion and lesser concern to equitable water distribution and least concern to field irrigation technique to crops because of poor irrigation knowledge.

Scheme Features

A Perennial river named Badhuwa Khola, which originated from the spot from where Maidi and Pirugha met, was the main source of water for irrigation. Every year in general and in every season in particular users used to build or repair semi-permanent water diversion structure made of loose boulders, mud and bushes across the Badhuwa khola. The main canal started from an open ditch or a simple opening on the left side of the riverbank and ran up to 186 meters after which it divided into two branch canals: Pahlo or Mathillo Kulo irrigating upland (8 ha) and Dosro Kulo or Tallo Kulo irrigating low land (17ha). The Dosro Kulo further divided into Sathi kulo, nabbe Kulo and Birauta Kulo. Both Pahilo and Doshro Kulo originally started parallel from the river common intake. Later it was made common up to 186 meter length.



Canal networks and command area of Malebagar Farmer Management Scheme

The Tallo Kulo further bifurcates to Sathi and Nabbe -Birauta Kulo which drain into Baduwa Khola which ultimately drains into Seti river. There were no permanent brick or concrete structures built in this scheme except a long six inch dia plastic pipe aqueduct that Irrigated 2.5 ha of land on the right side of Buduwa Khola (refer sketch map above).

2. Action Research Plan and Process

In order to implement the intervention activities the approach was fabricated into action research. The main purpose of this approach was to make intervention approach more rational, systematic and learning oriented. The applied procedural steps of action research are briefed below.

- Introduction and first hand information collection
- Defining vision and objectives
- Detail appraisal
- Constraints analysis or defining development needs
- WUA consultation for possible solution
- Solutions plan (intervention) for development
- Program Implementation
- Performance Monitoring and evaluation
- Further correction and improvement

In order to implement above procedures the following specialists and field staff were deputed in the field : ESI engineer. Water management engineer, Field Sociologist, Association Organizer

3. Implementation of Action Research

3.1 Program Initiation: Rapid Information Collection

A Team of engineer and sociologist visited the irrigation scheme and introduced the purpose of visit to water user group and leader farmers. The first hand information collected from users comprised of water availability (estimation based on farmers' experience) diversion water requirement, households, land area, rough hand written sketch map of canal networks and crop cycle per season.

A joint irrigation scheme development committee formed already by the IMP was informed for a discussion meeting in the field with WUA and farmers. In the joint meeting, vision and objectives were developed jointly by project office and farmers. After developing vision and objectives a separate team for assessing irrigation system constraints and potentialities was mobilized.

3.2 Detail Appraisal

Development potentialities and constraints in physical, institutional, water management and agricultural sub system performance were assessed as following.

A. Physical system : constraint and issues

Table-1 : Constraints and Issues on Physical Canal System

Items of constraints	Issues
1. Open entrance at the intake	Water control as desired was not possible Entry of excess water caused d/s canal wash out Uncontrolled entry of water caused water logging in wheat field (2 ha).
2. Right bank of lower reach of main canal leaking considerably	The leakage caused water logging during wheat season and over irrigation for spring paddy

3. No flow division structure at canal bifurcation point	Equitable water division practice at two branches (Tallo and Mathillo Kulo) did not exist. Farmers of Mathillo Kullo were unhappy for water unavailability during wheat season.
4. Old aqueduct at Sathi Kulo leaking continuous	Continuous leakage through old wooden aqueduct caused water shortage in down stream areas.
5. Un cleaned, unshaped and widened canals in many places.	Due to widened capacity of main canal, more water was drawn from river, more water was delivered to small canals during rainy season resulting in frequent canal breaching in Nabbe Kulo.

B. Water Management

For the detail assessment of the water management activities, farmers' practices of field irrigation process were documented by the field technician stationed at Malebagar. Observed irrigation practices reported by the field technician are described below.

a. Watering technique during rice seedlings raising

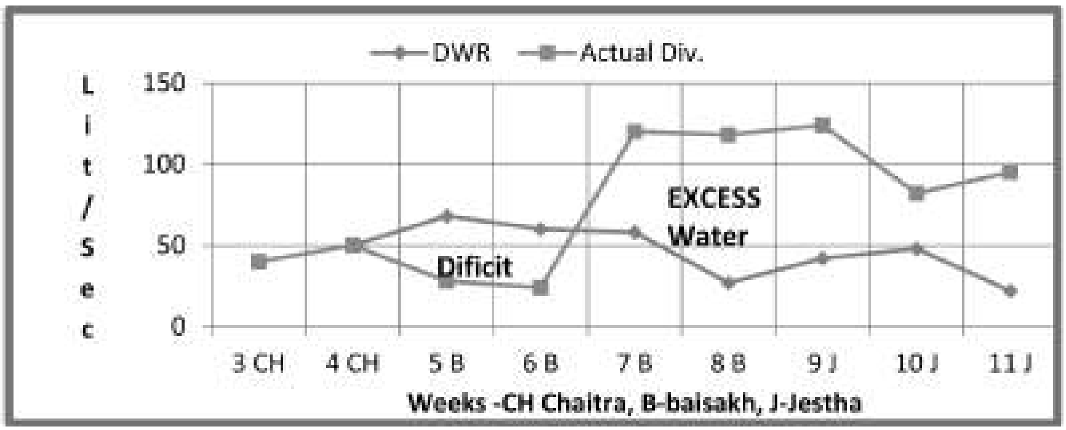
A practice of spreading paddy seeds over a standing water of one inch depth on the seed bed (ploughed, pulverized and smoothened) prevailed in Malebagar. This submergence condition is maintained for 4-5 days for seed soaking and uniform spreading of seeds that lead to better germination of seeds. Then after, water was applied intermittently.

Applied Seed rate – 5 kg/ Ropani (farmer's practice)
Total area of seed bed - 0.25ha for 10 ha (farmers' practice)
Seed bed water flow need – 208 lit/sec (at seed bed)

b. Paddy irrigation practices and concerned issues

Average amount of irrigation water applied by farmers for land preparation and transplanting was 120 mm.

Diversion Water Requirement VS Actual Diversion



- Water supply was low during the first two weeks of Baisakh. So, in this period, farmers adopted rotational water distribution based on time ignoring area and available stream size.
- During the heavy rainfall period (from Baisakh 14 or April 27 onward), the swelling of river increased water diversion rate also as seen in the above figure.
- From 3rd week of Baisakh, canals were passing higher discharge from various Kulos, showing as if canals are working as drains. A huge portion of diverted water could be seen flowing from the canal ends to the river in this time.

C. Institutional Performance and issues

Water user's organization was informal and only focused to water diversion tasks. Its organisation was informal and did not match to canal net works. It was unregistered and has no rules, regulation, responsibility and accountability, work departmentalization among the members. It had no technical know how about water management and existing irrigation system overall performance. Once a year or frequently during flood time, farmers gathered for repair and maintenance of river water diversion works only.

C. Agricultural Sub-system

The existing level of average crop yields, cropping intensity and annual total crop yield are shown in the following Table-2.

Table- 2: Average Crop Yields, Cropping Intensity and Annual Total Crop Yield

Items	Head (%)	Middle (%)	Tail (%)	Average
Cropping intensity	218	215	186	206
Crop yield (kg/ha) Early padding spring padding Wheat	2481 3340 1678	2389 3023 1290	2128 2379 1120	2355 2229 1364
Average calculated grain yield was 4t/ha/year in the command area				
Cropping pattern	Summer padding-wheat-early paddy Summer padding- fallow-early paddy/maize			

4. Methodology of Assessment

Observation of the farmers' field practices (canal operation, water distribution, canal maintenance and agricultural practices) were closely observed and documented by field technicians and other data were collected as follows.

4.1 Assessment of field irrigation requirement and scheme water demand

Meteorological data collection: pan evaporation, rainfall etc were collected from KharaniTar. Percolation rate, land preparation water requirement, efficiencies were taken from experiences and crop co-efficient data were taken from USDA and FAO bulleting.

4.2 Seasonal water availability and demand was assessed by

- Estimating weakly diversion
- Determination of weekly water requirement of early rice, monsoon rice and wheat.

It was assumed that values of seepage, deep percolation and evapo-transpiration did not change during paddy irrigation period, thus, water consumption by paddy field was recorded as 33 mm per day.

4.3 Farmers practice of water supply and water application was assessed by

- Installation of cut throat flume at each canal or Kulo and then recording water flow regularly by field supervisor
- Measuring the water recession rate (change in standing water depth) by using simple wooden peg installed in the farmer's field.

5. Summary of Existing and Planned Performance Targets for Achievement

The performance items, indicators of performance, existing and target performance levels were fixed by WUA and field expert team consultation, observed field data analysis and potential local and national feasibility. The potential target levels against the existing levels of performance are shown below

Table -3 : Existing and Target Performance Levels

Performance items and indicators	Existing Performance Levels	Target performance Levels	Remarks
1. A. Agriculture performance • Overall grain yield-t/ha • Cropping Intensity- Percentage of total irrigated crop area divided by net irrigated crop area per year for particular crop	4t/ha/year 193%	7t/ha/year 270 %	National target for that period
2. B. Diversion and conveyance performance • Diversion ratio- Qa/Q • Canal capacity- Q'/Qn • Adequate water control structures-Yes or No	>1 >1 No	1 Existed provide	Qa=actual diverted Qn=discharge needed Q'=observed capacity Qn=needed capacity
3. C. WUA requirements • Organization matched to level of water control-Yes or No	No	Organization matched to level of water control	Decision making on canal operation and maintenance. Roles and responsibility for tasks
• Registration, rules and norms-Yes or NO	No	Registration, rules and norms completed	Water management rules Fund generation (ISF)
A. Knowledge and skill, Yes or No • Water management • Agriculture	No	WUA and farmers trained	Canal operation and maintenance Crop water use technique Seasonal crop farming Linkage with DADO

D. Water Management Equity of water supply • Tallo kulo - O/R • Nabbe kulo- O/R	 1.48 (More) 0.48 (Less)	 1+-10% 1+-10%	 O= observed flow R=required flow
• Irrigation Reliability- T'/T	<1	1	T'=Actual Frequency T=planned frequency (7)

6. Intervention and Activities for target achievement

The following activities were implemented in order to achieve the planned targets

Table -4 : Items of intervention and performed activities

Items of intervention	Detail activities performed
Construction of essential structure	Construction of head regulator at intake to regulate river flow. Main canal with gated outlet at each bifurcation Steel pipe aqua-duct at the tail of Nabbe kulo for crossing Budhi Khola as decided by WUA
1. Established formal WUA	Registration with constitution Developed rules for water allocation and distribution Adequately trained for O and M and field irrigation techniques
2. Established water control procedures	All structures were painted and marked with the level of water. Prepared rules of water distribution Maintenance skill and water distribution skill developed in WUA
3. Improved agricultural practice initiated	WUA visited local Sajha, JT and DADO office for agricultural information Improved crop variety and adequate dose of fertilizer applied

7. Achievements

After one year of intervention, the existing performance level indictors were evaluated for their changes which are reported as in the following table.

5 Table -5 : Items of Changes and Achievement

Changes	Percent Achieved	Procedures
A. Output Level 1. WUO institutional development a) a) Constitution prepared b) b) Organization developed c) c) Organization registered d) d) Trained on Adm. &Finance	 100% ,, ,, ,,	 All required WUA establishment works were completed with the assistance of office Sociologist and Association Organizer. Office provided nominal fund for stationary and office supports
2. ESI Works Head regulator-1, Gated outlet -5, Steel pipe aqueduct-1, other minor repairs	100% All constructed ,, ,,	 All required ESI works were constructed and test operated by WUA.Office provided financial assistances to WUA.

3. Water Control Works a) Structures indexed/calibrated b) Diversion water control c) Water delivery to • Tallo kulo • Nabbe kulo d) O & M Manual prepared	 All division box Full control Full control Full control	All bifurcation points were indexed for due share of flow divisions. Water entry at intake was fully controlled and Nabbe & Tallo Kulo got their due share Mathillo Kulo and Tallo Kulo was united
4. Agriculture Development Works a) Linkage developed b) Demonstration started	100% O.K. ,,	Near by Agricultural Service Center provided necessary technology and other accesses.
B. Effect (Goal) 1. Increased Production: 1. S. Paddy - 2.25t/ha 2. Wheat -1.36t/ha 3. E. paddy - 2.35t/ha 4. Maize -1 t/ha Total yield -4t/ha/year	First year data 13% -2.40 -1.45 -2.40-6t/ha -1.2 4.5t/ha/yr	Target change was by 20%. This 13% change could be due to impact of improved delivery performance & proper canal maintenance and control 6t/ha- this yield was obtained with K-39 variety of paddy and by application of full dose of N-P-K fertilizer.
2. **Increase in cropping intensity** 1. S. Paddy -100% 2. Wheat -17% 3. E. paddy -48% 4. Maize -28% Total - 193%	 -100% -30% -60% -20% 210%	No changes Increase by 13 % Increase by 12 % -Maize decreased below target. Increase by 17 %

8. Learning and Recommendations

a. If rehabilitation or improvement of physical (canal systems) canal infrastructure is based on actual constraints or needs to update irrigation operation performance, water delivery performance can be improved.

b. Cost of rehabilitation or improvement item works should be decided on the basis of water availability and potential possible changes in the agricultural farming system.

c. Simple rapid appraisal of the system, involving water users of command area, on potential strengths, weakness of existing physical canal networks, water users organization (institution), water management activities and agricultural activities would lead to an appropriate strategic solution to design overall improvement plan of the system.

d. Farmers' continuous cooperation and participation can be achieved provided user committee is made accountable and empowered on irrigation scheme development activities.

e. Water management and scheme operation plan should be discussed and finalized with users or user committee prior to scheme construction but immediately after rapid appraisal to create new hopes and trust over the past frustration.

f. The strategic procedure of FMIS improvement approach would start by :

- Knowing the existing status of irrigation service delivery, willingness of the farmers and possibility for potential changes in agriculture, and
- Following WUA empowered scheme improvement strategy that leads to sustain FMIS performance.

Water Lifting Technologies for Tar Irrigation

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Abstract:

Machuwa and Akhuwa two big and flat agricultural land lands so called Tars are situated at the right and left banks of the Arun River. Both Tars belongs to the southern parts of the Bhojpur and Dhankut districts. Both Tars are situated on the north dipping Phyllite type of rocks having east – west strikeand contained about 100/100 ha agriculture land. Both Tars are made up of very fertile type of soil however the most of the local people of these area have found economically poor, socially backwards and suffering from malnutrition. They don't have enough food since of low agricultural producing and it is due to the lack of reliable irrigation facilities round the year. It doesn't mean that the local people don't have agricultural land. Obviously, they have enough agricultural land which range is about 10 to 30 ropanies per family. For irrigation, all of the local people would have to depend upon the rainfall. They used to put maize which is rainfall based crop and produces in rainy season only. After the maize crop almost whole land of the Tara would be left dry and barren though the big Arun River is flowing just 50 m below the Tars. Not only irrigation, the local people have the drinking water problem also. Every day, they should bring drinking water from the Arun River.For this women and children are getting very good job but without salary. In addition, no any reliable sources of either of groundwater or of surface water are seen in our observation.

To address the situation as mentioned above, reliable irrigation facilities should be provided in the Tars so that, the local people will able to put 3 to 4 crops in a year and able to produce enough agricultural production (grains, fruits and vegetables) from the land; they will able to be maintained a better life even able to be a ***rich and prosperouscitizen*** in their homeland. For this, there is no any alternate except ***lifting and supplying*** of water from Arun River. It is only one solution to manage the problem of irrigation facility in the Tars. It is possible also since the Tars are only 40 to 50 m high above of the river. The altitude of the Arun River is about 130 to 135 m and the altitude of the Tars is about 175 to 180 m from msl. For this, there would be two possible technologies, which are ***the construction of a modified type of DTW and a modified type of lifting water.*** These are just modified techniques of traditional techniques which are using in the practice. It is also simple, doable and can be affordable as well in the practice. The cost also low and will be the range of 70 to 80 hundred thousand. It can irrigate about 40 to 80 ha land during the dry season. However, before the implementation, detail survey and design need to be done again. These kinds of models can be implemented all over the country where the big agricultural Tars are existed in the banks of snow fed type of rivers.

Introduction:

There are a lot of irrigation schemes in Nepal. Some of them are focused in Terai region and some of them are focused in hilly region. In Terai, diversion of river water by constructing dam and canal are very common. Similarly, using of groundwater by constructing deep and shallow tube wells is also common. In hilly region, numerous canals have been constructing for irrigation purpose. Besides, the reservoir ponds are also being constructed in dry area of hilly region. However, no any irrigation schemes and techniques for Tar region (Bank of the river and streams) has started in Nepal though there are thousands of hectors of agriculture land are available in the Tar area. Thousands of farmers of the Tar area are very poor and backwards due to the lack of reliable irrigation facility in Nepal. Therefore, both government and private sectors should give pay attention for development of new technologies and schemes of irrigation for Tar region of the Nepal.

Studied Area:

The study area is located in the southern part of the Dhankuta and the Bhojpur districts. The Akhuwa Tar is situated in the left bank (Dhankuta) and the Machuwa Tar is situated in the left bank (Bhojpur) of the ArunRiver. The Akhuwa Tar has about 80 ha agricultural land and it is about 50 m high from Tamor River. In the same way the Machuwa Tar has about 100 ha agricultural land and it is also about 60 m high from the Arun River.

Fig-2. Akhuwa Tar

Fig-1.Machhuwa Tar

Problem:

Due to the lack of irrigation facility all agricultural lands of both Machuwa and Akhuwa Tar are being dry for whole year except rainy season. Only one crop i.e. maize have been producing in the wet season. Most of the farmers of these Tar areas have been severely suffering from poverty and malnutrition. They don’t have crop production even for 6 months also. If they got irrigation facility during winter and dry season they will able be to produce additional two crops also. According to local farmers, they have about 1 to 2 ha land per household now. It is enough land for per family if there are three crops per year and enough productivity. But to increase more productivity and production of three crops round year irrigation facility is needed first. Besides, the farmers of this Tar area are suffering from problem of drinking water as well. The river water from Arun River is being used by local people since long time. Actually the water of the Arun River is not drinkable.

Ideas for Problem Solving:

The main problem of the Tar areas is the lack of irrigation facility expat rainwater. There are no any alternative sources of water except the Arun River. Therefore, lifting of water from Arun River will be one of the best solutions of the existing problem. In lifting, there will be two possible techniques. In which first will be the direct lifting technique and the second will be tube well technique. However, there should be done little modification in both techniques.

Fig-3. People of studied

Fig-4. Carrying drinking water

1. Direct Lifting Technique:

Procedure:

First of all reliable fresh outcrop of mother rock is find out. On the rock outcrop two cemented pillars with recommended height is constructed. In those two pillars a horizontal axel is fixed as shown in fig.-7. On the center of the axel 8" (200mm) submersible pump with GI 8" column pipe is fixed. The pump can move in 0 -90oangle.The 8" column pipe is connected with 8" discharge (delivery) pipe which outlet is ended in overhead tank.The 8" column pipe is connected with 8" discharge (delivery) pipe which outlet is ended in overhead tanks. The submersible pump is connected to the control panel in a pump house and control panel is again connected to the 100 Kv transformers. The height of overhead tank is about 6 m high and two underground delivery branches (6" each) are constructed from the overhead tanks. The pillars for submersible pump are constructed just above the high flood level.

Fig-5. Fresh rock outcrop, Akhuwa Tar

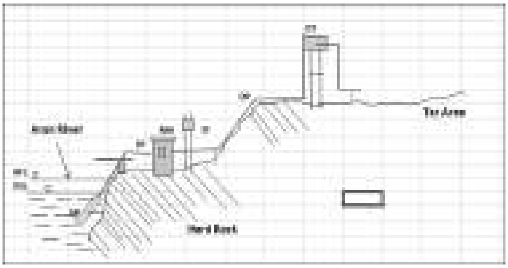

Fig-6. Scheme of water lifting techniqe

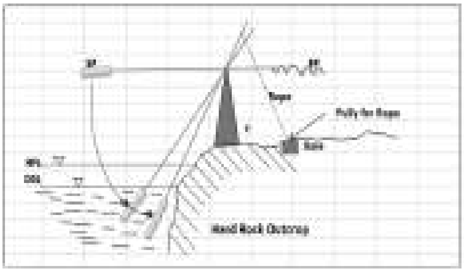

Fig-7. Different position of pump

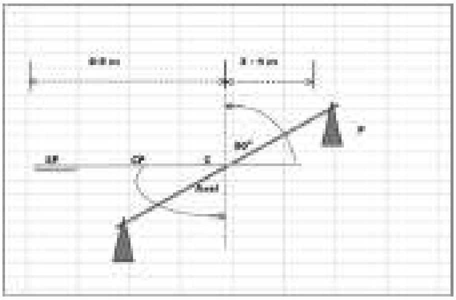

Fig-8. Pump in horizantal state

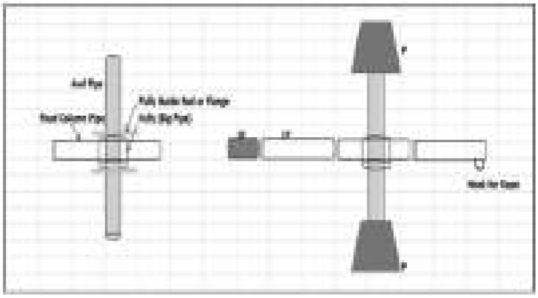

Fig-9. Nonnection of pump and pipe

The submersible pump is connected to the control panel in a pump house and control panel is again connected to the 100 Kv transformers. The height of overhead tank is about 6 m high and two underground delivery branches (6" each) are constructed from the overhead tanks.

Technical Design:

A). ***Total Head of Pump*** $(h_T) = (h_E + h_F + h_L)$

Where,

- ***Elevation head*** (h_E) ***= 50 m (174 -130 m = 44 + 6)***
- ***Frictional loss in HDP/GI Pipe*** (h_F) ***= 2.5 m***
- ***Local loss of pipe*** (h_L) ***= 4 m (5 valves and bends)***

Total Head (h_T) ***= 56.5 m = 57 m (Ave.)***

B). Frictional Loss $(h_F) = 1.131 \times 10^9 \, (Q/C)^{1.852} \times D^{-4.87} \times L$

Where,

- ***Discharge (Q) = 80 l/s (0.08*** m^3/s***)***
- ***Roughness Coefficient of HDP/GI Pipe (C) = 150***
- ***Diameter of pipe (D) = 200 mm (0.2m)***
- ***Length of the delivery pipe (L) = 100 m (44 + 6 + 50 m)***

Frictional Loss (h_F) ***= 2.5 m***

C). Local loss $(h_L) = K v^2/2g$; $V = Q/A$

- ***Roughness of Cast Iron (K) = 2.5***
- ***Area of 8 valve (A)*** $= \pi r^2 = 0.0314\ m^2$

Local loss (h_L) ***= 0.8 m***

D) Power of Pump (Kwt) $= \dfrac{Q.\varrho.g.h}{P_{eff}}$

Where,

- ***Discharge of pump (Q) = 80 l/s ($0.08\ m^3/s$)***
- ***Density of pumped water (Q) = 1***
- ***Acceleration due to gravity (g) = $9.81 m/s^2$***
- ***Total head on pump (Ht) = 57 m***
- ***Efficiency of pump (P_{eff}) 80%***

Power of Pump (Kwt) = 56 Kwt or 75 Hp

(Since 1 Hp = 0.746 Kwt)

E) Annual Power Consumption:

Annual Kwh = *(Kwt x T)*

Where,

- ***Power of pump (Kwt) = 56 Kwt***
- ***If ,Operation hours per year (T)= 1200 hrs.***

Annual Kwh = 67200 unit /year

F) Capacity of Transformer:

Max KVA Demand of TF = (InputKWt per Pump / Power Factor)

Where,

- ***Input KWtper pump (Kwt) = 56 Kwt***
- ***If, Power Factor of transmission line (P_f)= 80%***

Max KVA demand of TF = 70 Kva or 100 Kva

Cost:

The average cost of the direct lifting technique in studied area is given as below.

- ***Electrical = 15,00,000.00***
- ***Mechanical = 30,00,000.00***
- ***Civil = 30,00,000.00***

Total = NRs. 75,00,000/- (Ave)

2. Modified Type of Tubewell Technique:

Procedure:

Fig-10. Point bar deposition, Machhuwa Tar

First of all the thick point bar deposition is found out in the bank of the river as shown in fig-10. Bore hole size of 32" to 34" dia. is constructed up to 10 - 12 m depth. In constructed borehole 24" dia, 5 - 6 m long screen pipe and 5 - 6 m long casing pipe is inserted. In the tube well 6" dia. submersible pump including GI column pipe is inserted. Pump is connected with the 6" delivery pipe up to the overhead tank. The overhead tank is only for maintain the distribution of water in the agriculture field. The pump is electrified with the control panel and control panel is connected with the transformer. In the same way the two 5" delivery pipes are connected with the overhead tanks. The tube well is constructed above the high flood level and it is well protected by making gabion wall of boulders.

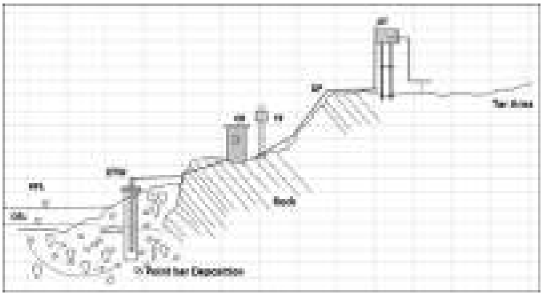

Fig-11. Technique of modified tube well

Fig-12. Point bar deposition

Technical Design:

A). Discharge of TW:

Discharge of DTW (Q) = $(2\pi r \times S_L) \times \rho \times (V_e)$

Where,

- ***Radius of screen pipe (r) = 300 mm (0.3 m)***
- ***Length of screen pipe ($S_{L)}$ = 5 m***
- ***Percentage of open area in screen pipe (ϱ) = 15 %***
- ***Density of water (ρ) = 1Kg/lt***
- ***Entrance Velocity in screen ($V_{e\,)}$ = 2 cm/sec (0.02m)***

Discharge of TW (Q) = 28.3 l/s

B). Other Technical Parameters:

- ***Total Head of Pump (Ht) = (Swl + Dwl + Eh + Fh + Lh) = 60 m***
- ***Power (Capacity) of Pump (Kwt) = 22 Kwt***
  (29.5 = 30 Hp)
- ***Annual Power Consumption (Kwh) = 26400 Kwh (unit/ Year)***
- ***Capacity of Transformer (Kva) = 27.5 = 50 Kva***

Cost:

The average cost of the modified tube well technique in studied area is given as below.

- ***DTW construction = 20,00,000.00***
- ***Electrical = 15,00,000.00***
- ***Mechanical = 10,00,000.00***
- ***Civil = 30,00,000.00***

Total = NRs. 75,00,000/- (Ave)

Production in Cash (Extra 1 Crop):

After the facility of irrigation in the dry season in the studied area the farmers will be able to produce extra one crop i.e. wheat or potato. The average cost of the agriculture production will be about 45, 00,000/- per year in each 50 ha land. It is an additional income and can be change the socioeconomic life of the poor and backward farmers.

1. Wheat in 25 ha

Wheat production 3000 Kg/ha = 75000 Kg - @ Rs.20/Kg = 1500,000 /-

2. Potato in 25 ha

Potato production 8000 Kg/ha = 200,000 Kg - @ Rs.15/Kg =30,00,000/-

Conclusion:

There are nice exposure of frfesh rock outcrops and point bar deposition in the banks of the Arun River. Both Tars are in appropriate heights (< 60 m). In these two Tar areas those are the appropriate technologies. These techniques are simple, economical and practical and environmental friendly as well. By implementing the techniques additional 1- 2 agriculture productions will be increased in the studied areas and its increased cost is mentioned as above. The lifted water will be clean since of dry season and underground filtration. There is no any market problem since of Dharan and Chatara Bazar near the studied area.
Recommendation:

In the studied area an investigation (Trail) program of water lifting technologies of direct pumping or modified tube well scheme should be implemented soon. The program should be implemented either by government or by private sectors. If the result will be socioeconomically successful the technics will be implanted in all over the country where Tar area are existed in the banks of the big or medium rivers.

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Potential of using Solar Energy for Irrigation in Hilly Region of Nepal

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ABSTRACT:

This paper tries to identify areas that are suitable for using solar water pumps for irrigation in hilly region of Nepal. With more than 300 days of sunshine in a year, Nepal can be considered as a country gifted with abundant solar energy resources. The use of solar energy for pumping water to so call 'difficult terrains' or 'Tars' could be one of the sustainable solutions that help to increase the food security and reduce poverty. The study identified about 120 thousand hectares of cultivable land, within a buffer distance of 2000 m along the bank of major rivers in hilly region of Nepal, are suitable for single stage pumping (pumping head between 30 m to 200 m). The study further estimated that benefits equivalent to about 0.95 USD could be obtained from agricultural products by using unit volume of water for irrigation. The cost involved in lifting a unit volume of water using solar pumps installed along with drip or sprinkler irrigation system varied from 0.6 USD/ m^3 at an elevation of 30 m to 0.79 USD/m^3 at an elevation of 200 m. Providing irrigation facilities on these 120 thousand hectares of suitable areas, about 860 thousand population in hilly region are directly benefited and country can save approximately 104 billion Nepalese rupees flowing out annually from the reduction in import of agricultural products from foreign countries.

Keywords: Sump well, Sprinkler, Drip, Solar pumps, Photovoltaic, Irradiance, Insolation

1.1 Introduction

Food, water and energy are believed to be important basic needs without which human life cannot sustain. Due to the limited resources in earth to satisfy these basic needs, crucial efforts for sustainable development should be taken to pave the pathway that preserve these limited resources for life of future generations in planet. Eradication of extreme poverty and hunger is one of the Sustainable Development Goals (SDGs) as set by United Nations. Nepal, among many least developed countries, still has majority of population under poverty and suffering from insufficiency of food.

The fluctuation in the monsoon of Nepal, directly effects the GDP growth of the country. Parasai, Balkrishna (2010), in his paper 'National issue paper on the agriculture sector' has also pointed out how crop yield of Nepal has been reduced by the climate change and poor monsoon. The impact of climate change on agriculture and its influence on the GDP can be directly related the status of irrigation services in Nepal.

According to the ecological regions of Nepal, irrigation systems can also be classified as Mountainous, Hilly and Terai irrigation systems. Terai region includes about 50% of the total cultivable land of the country and more than 98% of this land is irrigable. **Hilly region occupies 40% of the total cultivable land of which only 34 % is irrigable with conventional irrigation systems.** Mountainous region has only 10% of the total cultivable land of which only 22 % of land is irrigable.

Almost all of the upland areas in Hilly region of Nepal called “Tars” are under cultivation. These “Tar” land can be irrigated either through gravity flow surface irrigation schemes or through lift irrigation schemes. Naturally, for gravity flow irrigation schemes length of the canal depends on the elevation differences between “Tar” and the river water level. If the length of the canal is large, the construction, operation and maintenance cost can be large compared to lift irrigation schemes.

Hence, in this study, an effort to find the potential sites for installation of solar pumps, design efficient irrigation system and perform the economic analysis of the selected project has been made. This study is supposed to be helpful in connecting food and water through renewable energy and make the irrigation schemes in Hilly region of Nepal sustainable.

1.2 Photovoltaic powered pump

Use of Solar PV panels for generating electricity has been increasing rapidly around the globe (as shown in Figure 2-1). The commercial use of Photovoltaic pumping system in 2007 increased more than 10 times compared to that in 2000 (GTZ, 2007). The key reasons for this significant rise in use are the decrease in price of Photovoltaic (PV) panels (from about $75 in 1977, as shown in Figure 2-1, to less than $0.3[1] in 2015), increase in the efficiency of PV panels (as shown in Figure 2-4) and the need of sustainable development of energy systems by minimizing environmental effects. The advancement in technology, reduction in cost of PV panels and solar energy being the most abundant renewable energy on the earth, has positively influenced in the development and deployment of PV powered water pumps. Such PV power based water pumps can be used for lifting water to irrigate agricultural land and increase the yield of the crops. Albeit, low operation and maintenance cost, the initial investment cost of PV powered system is high compared to conventional power systems. Solar energy being clean and renewable energy, the PV powered pump system has smaller environmental footprint compared to conventional system and therefore, help in sustainable development of irrigation systems. However, design of PV powered pump systems should be done carefully to optimize all the components of the system and thereby reduce the investment and maintenance cost. A proper design of all the components can result in long-term cost saving and make the PV powered pumps more attractive than the conventional pumps in economic terms as well.

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[1] based on average sales price of $0.3/W on 29.04.2015 2015 from http://pv.energytrend.com/pricequotes.html accessed on 30.04.2015

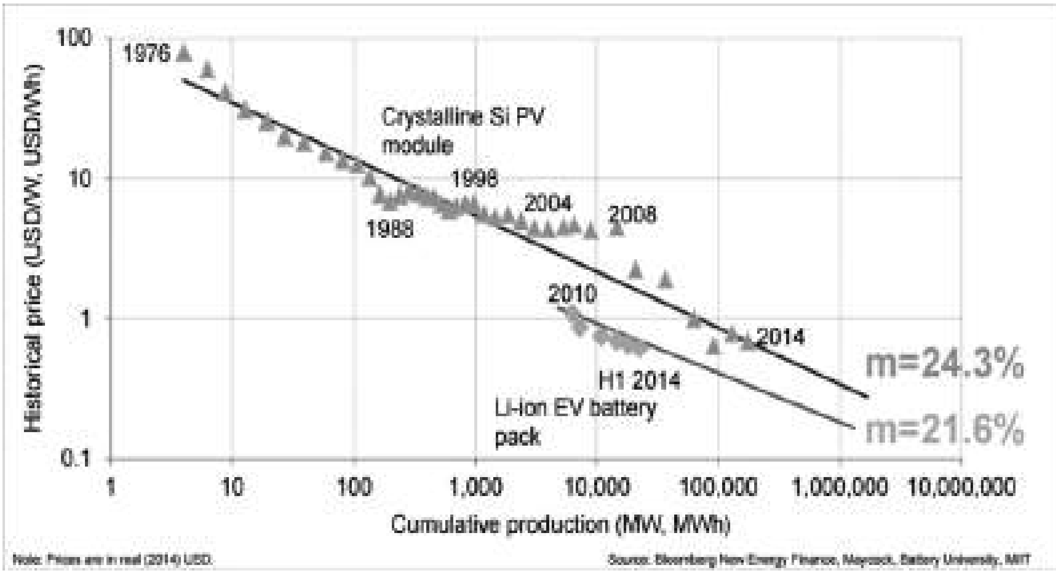

Figure 1: Historical price and cumulative production of silicon PV cells in USD per watt

Source: Bloomberg New Energy Finance, Maycock, Battery University, MIIT [2]

1.3 Land use Suitability analysis and Multi Criteria Decision Making using GIS

Land use suitability analysis is a technique to find appropriate parcels of land that satisfy already established criteria, the most (Hopkins, 1977 ,as cited in Malczewski, 2004, pp 4-5). Food and Agricultural Organization (FAO) defines agricultural land suitability analysis as a measure to identify to what extent the qualities of land match the criteria of a particular form of Landuse. Analysis of agricultural land suitability using solar pumps is a multidisciplinary approach, which requires information from soil science to metrological science, environmental science to water science and social science to management. Kalogirou (2002), Prakash (2003) Peveen, et al. (2007) have used multi criteria for analysis of agricultural land suitability. Albeit, there can be many criteria associated with each stream of science, not all of them are equally important. Selection of criteria is an important part of suitability analysis (M.A., et al., 2006). Selection of different sets of criteria will results to different output of the analysis. Better degree of output of the analysis is obtained when the criteria are group together in the hierarchy of importance. Simplest method that has been widely used for the suitability analysis with multi criteria approach is ranking and weighting or weighted summation. In this method the weightage on the criteria are assigned with degree of importance. The critics of this method is that it lacks theoretical foundation in assigning the weight to the selected criteria and cannot reflect the view of decision makers clearly (Malczewski, 2004).

The suitability potential analysis of land for agriculture does not have certain standard to select the criteria therefore; criteria used in similar studies are generally used (Akıncı, et al.,

[2]http://about.bnef.com/content/uploads/sites/4/2015/04/Final-keynote_ML.pdf p.14 accessed on 10.05.2015

2013). Such analysis uses large variety and quantity of physiographic data, climatic data, soil characteristic (Wang, 1994).

Until the rapid development of computer systems and Geographical Information System (GIS), MCDM analysis were carried out non-spatially, assuming homogenous spatial characteristics on the area under consideration. Neglecting the importance of spatial variation is not realistic specially when analyzing land suitability (J. Malczewski 1999, as cited by Prakash 2003).

1.4 Potential of solar energy in Nepal

It is essential to know the potential of solar irradiance for designing and sizing of solar photovoltaic and solar pumps. The development and deployment of solar energy in Nepal is at initial stage. Therefore, very few studies and researches on the potential of solar energy has only been carried out.

Nepal lies within latitude and longitude varying from 26.35-30.35 degrees and 80-88 degrees. Shrestha (2006) points out that average sunshine hour per day in Nepal is 6.8, which sums up approximately to 2482 hours in a year with average solar insolation ranging from 3.9 to 5.1 kWh/m^2/day. Solar insolation is the rate at which energy from the sun reaches to the surface of earth. It is a contracted from of 'INcoming SOLar radiATION'. The maximum value of irradiance (power per unit area) on the surface of earth is about 1000 W/m2. In October 2004, high resolution solar radiation assessment of Nepal was carried out by United Nations Environmental Program (UNEP)[3]. The assessment was done using three years (2000, 2002 and 2003) data of Meteosat (Schillings, et al., 2004). Alternative Energy Promotion Center (APEC, 2008) conducted the study of solar potential for Concentrated Solar Power (CSP) and Photovoltaic systems using UNEP data. Concentrated Solar Power system collects the energy from sun and provides energy in the form of heat. The study shows that the CSP potential of Nepal ranges from of 3.5 to 5.7 kWh/m2/day. Similarly, Photovoltaic potential in isolated system[4] ranges from 3.6 to 5.2 kWh/m^2/day. The database of Solar and Wind energy Resource Assessment (SWERA)[5] shows that the Global Horizontal Irradiance (GHI) of Nepal varies from 3.5 to 5.4 kWh/m^2/day.

1.5 Study area

The study was focus on Hilly region of Nepal. Terai region occupies nearly 23% of the total area of country. Out of which, about 1.3 million hectares of land is cultivable and on 0.94 million hectares, irrigation services has already been provided[6] . Similarly, Himalaya with altitude ranging from 3000 m and above lies on the northern part of Nepal and touches the border of China. This region also occupies approximately 35% of the area of the country and encompasses many mountains and peaks. The middle region in terms of altitude, ranging from 300 m to 3000 m, is the Hilly region. It occupies maximum area (42%) of

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[3]http://www.dlr.de/tt/Portaldata/41/Resources/dokumente/institut/system/publications/SWERA_10km_solar_finalreport_by_DLR.pdf accessed on 10.05.2014

[4]Not connected to Grid- in Remote areas of Nepal

[5]Prepared by DLR – activities within SWERA, Deutsches Zentrum für Luft- und Raumfahrt, with spatial resolution of 0.1 degree (nominally 10 km).

[6]Department of Irrigation, presentation on progress report of fiscal year 2012/2013.

the total land of Nepal and most of the cultivable land of Hilly region is still lack irrigation facilities. This study focuses only on the Hilly region as the study area which has about 700 thousand hectares of land which are cultivable but not irrigable through conventional irrigation system as shown in figure below.

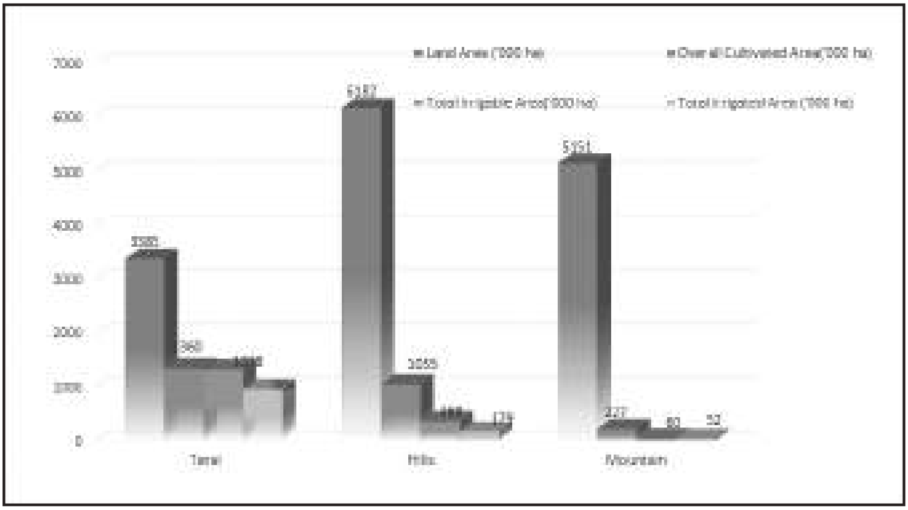


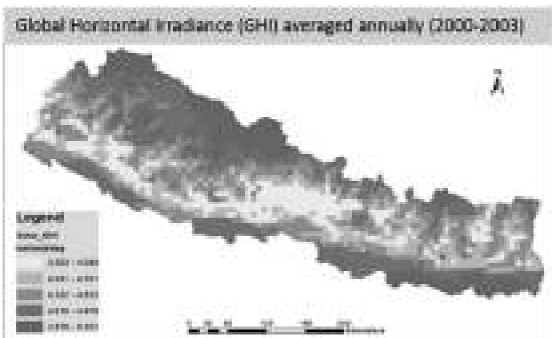
Figure 2: Cultivable land in different regions of Nepal

1.6 Research Methodology

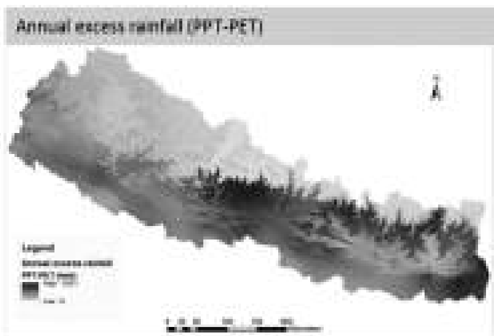
To find suitable potential sites for installation of solar water pumps for irrigation in Hilly region of Nepal, following methodology was adopted. The detail process of analysis is as shown in Figure 4.

- Acquisition and processing of data
- Standardization of the data using selected criteria
- Assigning weight to different raster
- Performing weighted overlay analysis in ArcGIS
- Obtaining the result of the analysis

1.7 Dataset used for analysis



source – Author, map prepared in ArcGIS based on data downloaded from SWERA



Source – Author, prepared based on PET and PPT data, using ArcGIS

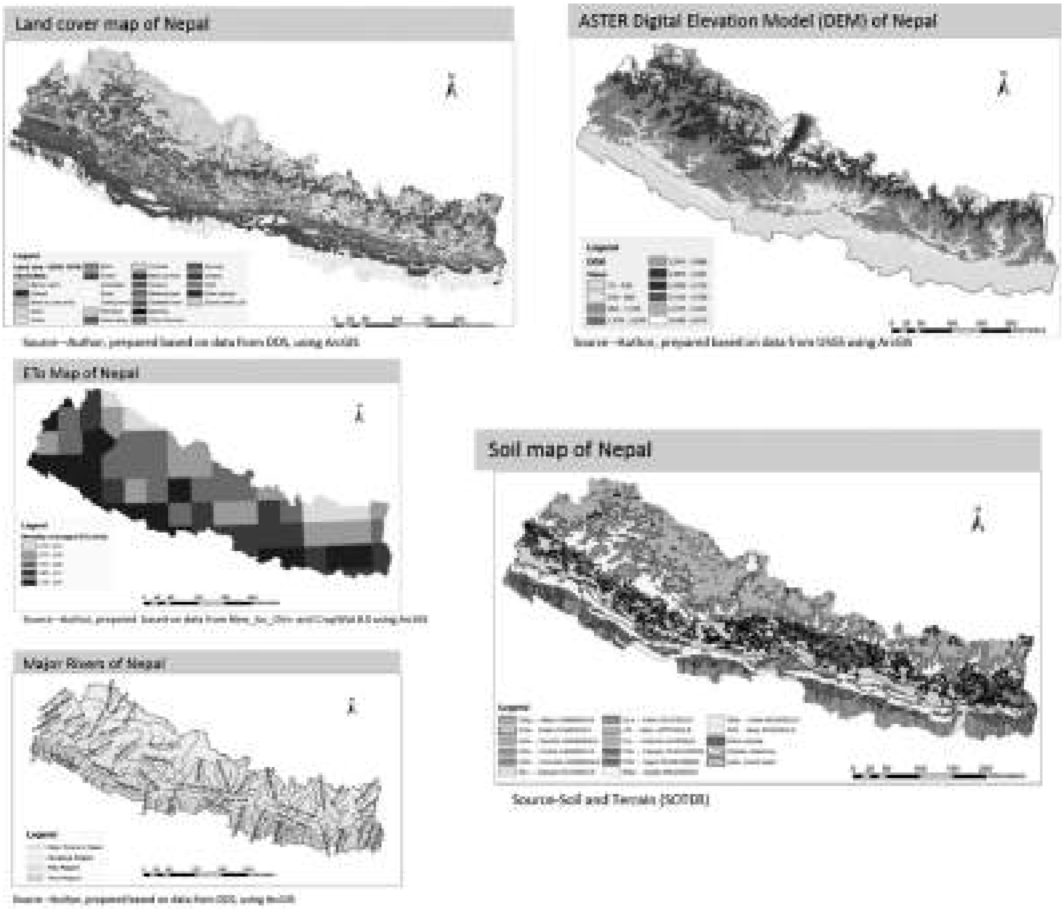


Figure 3: Dataset used for analysis

1.8 Analysis Model

An ArcGIS model as shown in Figure 4 was prepared to input the selected datasets and to analyze these data using the criteria, assumptions and methods as explained above. This model only contains the sequences of steps that has been explained in the methodology and has been used to analyze the areas by varying height (10m to 800m) and the buffer distance from the river (500m, 1000m, 2000m). The obtained result was plotted to get an idea how the potential area vary with height.

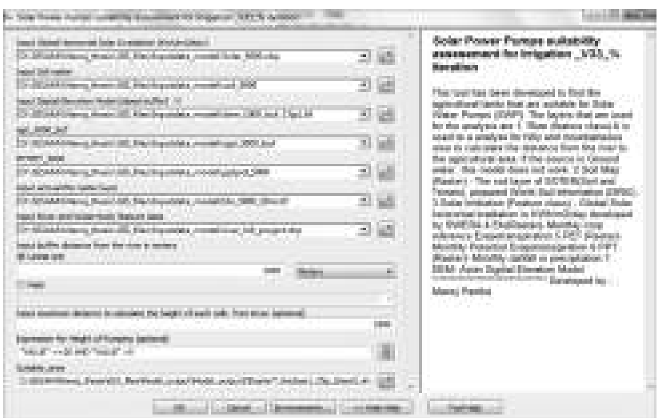


Figure 4: ArcGIS Model for suitability assessment of solar pumps for irrigation

1.9 Result and discussion on the analysis of suitable area

Figure 5 shows the total potential area at buffer distances – 500, 1000 and 2000 meters from the river at different elevations. The X- axis represents the elevation and the Y- axis represents the areas in thousand Hectare ('000 Ha). From the figure, it can be seen that up to 400 m, potential area increases as the elevation increases and above 400m, areas remains almost constant.

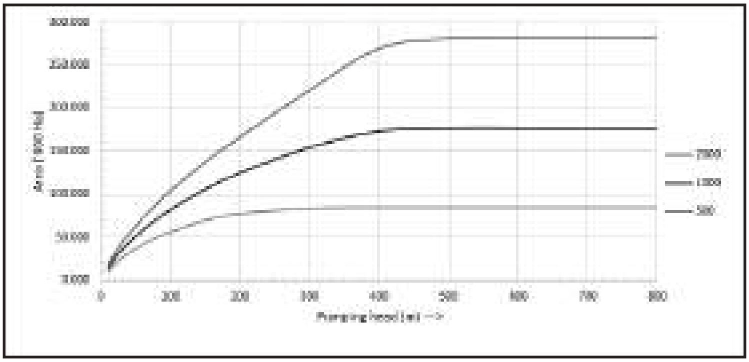


Figure 5: Potential area at different distance from river

It has been assumed that for areas with head higher than 30 m when irrigated through conventional gravity irrigation, requires long length canals, which will is costly and incur higher maintenance cost, solar pumps can be installed to irrigate the areas above 30 m elevation. Hence, the areas below 30 m is irrigated by conventional irrigation system and only areas above 30 m has been considered for installation of solar pumps. The area between 30 m to 200 m pumping head has been considered as suitable areas for single stage pumping and economic analysis has been performed accordingly. The map of cultivable areas suitable (between elevations of 30 m to 200 m) for irrigating using solar pumps within a distance of 2000 m from major rivers in Hilly region of Nepal is shown in Figure 6 below.

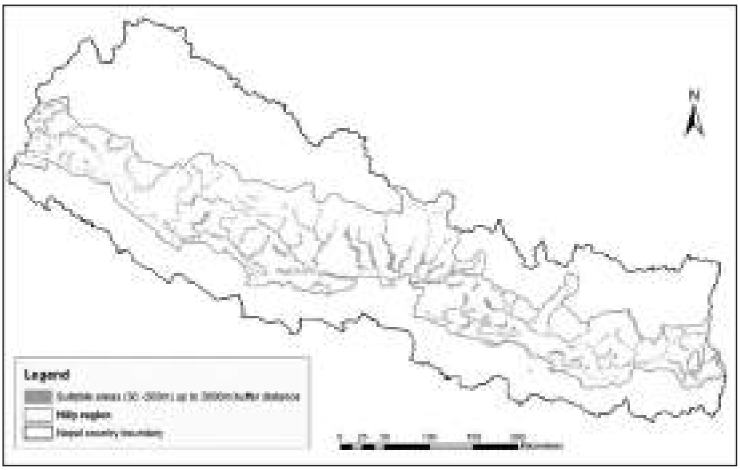


Figure 6: Suitable site map (between 30 -200 m elevation) within buffer distance of 2000 m in Hilly region of Nepal

Table 1 shows the total areas between 30 to 200 meters elevation at buffer distance of 500, 100 and 2000 meters. The cumulative area up to 500, 1000 and 2000 meters of distances from river are approximately 50, 89 and 122 thousand Hectares respectively.

Table 1: Area between 30m to 400m elevation at different buffer distance

Buffer distance	Area between 30m to 200m elevation ('000 Ha)	Cumulative area ('000 Ha)
500	50.985	50.985
500 to 1000	37.762	88.747
1000 to 2000	33.454	122.201

The total cultivable area suitable for pumping water in a single stage and percentage of such suitable area compared to total cultivable area of each districts in Hilly region of Nepal has been shown in the Figure 7 below. From the analysis, it was found that in Kaski district more than 24% of total cultivable area are suitable for installing solar pumps. Similarly, Okhaldhunga district has only about 3.5% of the total cultivable area suitable for installing solar pumps to irrigate farms within a buffer distance of 2000 m and pumping head between 30 m to 200 m.

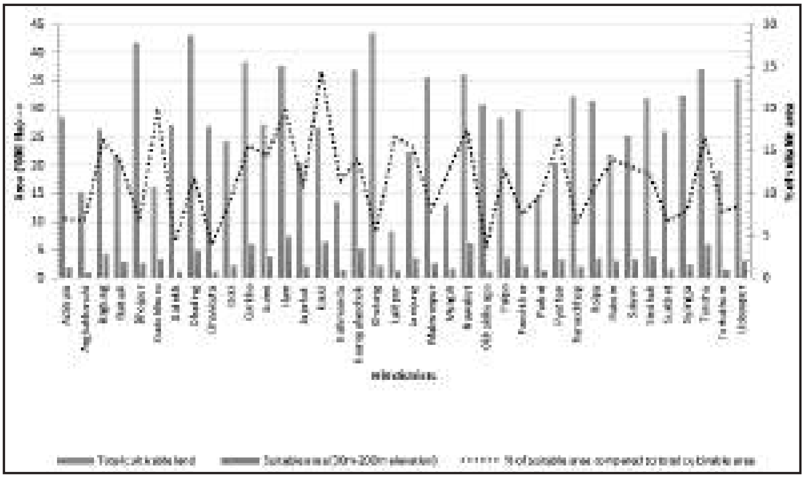


Figure 7: Suitable area (elevation between 30 m-200 m) for installation of single stage solar pumps for irrigation in Hilly region of Nepal

1.10 Water availability

Is there enough water available to irrigate the analyzed suitable areas?

The daily water requirement per hectare of land for irrigation using modern irrigation technique for the proposed cropping pattern is 25 m^3/day. If we assume all the available water is equally distributed to the basin area (for greater assurance of water in cultivation area), only Babai basin (14 m^3/day/ha) has less water available then what is required (25 m^3/day/ha[7]). Figure 8 shows the total area that is suitable, in different water basins, for providing irrigation services using solar water pumps in Hilly region of Nepal. To address this issue of water deficit, in Babai basin only 50% (1.48 thousand Ha) of the suitable area has be considered as water available areas.

[7]Please refer Chapter 3 , Table 3 3 Available discharge in major water basin at different gauge stations of Nepal

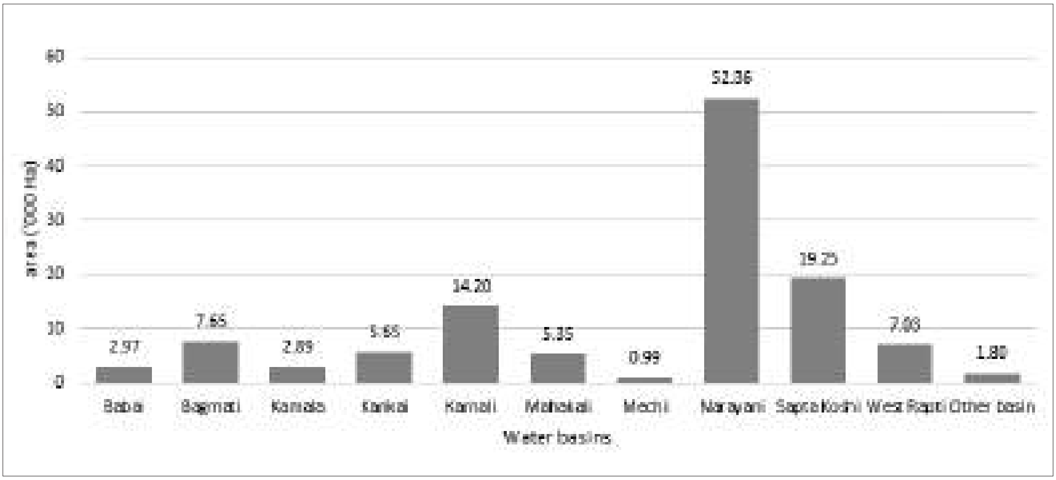


Figure 8: Suitable area between 30 -200 m pumping head ('000 Ha) of Hilly region of Nepal, in different water basins

Source: Author

Water resources act of Nepal has prioritized the use of water for irrigation as second priority after use for domestic and drinking purpose. Hence, from the preliminary analysis of water availability in the water basins of Nepal and the higher priority in the water resources act, it can be said that on 120,000 Ha of suitable area (between 30-200 m) along the banks of major rivers in Hilly region, water can be made available for irrigation purpose.

1.11 Food security

By how much can these suitable area help for improving food security within country?

In fiscal year 2012/13, Nepal imported raw and processed agricultural products worth NRs. 99.34 billion[8] which is 30.6% more than that in fiscal year 2011/12. Food security for Nepal has been one of major challenges to fight against poverty. From a hectare of irrigated land, farmer can earn annually 0.87[9] million (1.26 million with project – 0.39 million without project) compared to unirrigated land. According to the population census of Nepal in 2011, the average household size of Nepal is 4.88 and average agricultural land holding per household is about 0.68 Ha (CBS, 2011, p. 2) . Therefore, by providing irrigation facilities on 120 thousand hectare of unirrigated land along the banks of river in Hilly region of Nepal, about 860 thousand population are directly benefited and agricultural products worth 104 billion can be produced. These areas when provide with irrigation facilities can help Nepal largely to become independent on agricultural products and export when surplus to other countries.

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[8]Published in daily newspaper http://www.ekantipur.com/the-kathmandu-post/2014/05/20/money/nepal-imported-agro-products-worth-rs-99.34-billion-last-fy/263035.html on may 20. Accessed on 09.08.2015

[9]From cost benefit analysis form with project and without project, explained in section 5.2.4

1.12 Conclusion

The main findings of the study can be concluded with following points:

- The total potential area (maximum lift of 800 m) for installation of solar pumps along the banks of major rivers in Hilly region of Nepal up to a buffer distance of 2000 m from the source (rivers) is estimated to be approximately 280 thousand hectare.
- The benefit (0.95 $/m^3) obtained from agricultural products by using a unit volume of water has been always found to be higher than the cost (0.6 $/m3 at elevation of 30 m to 0.79 $/m3 at 200 m elevation) that is involved to pump water using solar pumps.
- Out of 280 thousand hectare of potential area, 120 thousand hectare (area between 30 m to 200 m elevation) of land is found to be technically, economically and from the view of water availability, suitable for installing single stage pumping system using solar water pumps for irrigation.
- Providing irrigation facilities to 120 thousand land suitable for installing solar pumps along the banks of river in Hilly region of Nepal directly benefits about 860 thousand of the population in Hilly region of Nepal and saves an annual import of agricultural products equivalent to 104 billion Nepalese rupee. This helps for food security within the country and increase the living condition of farmers.

Therefore, this study can help the stakeholders related to solar pumps and irrigation to plan and to find the suitable areas for installing solar pumps and provide irrigation to rein fed cultivable farms, which allows for cultivating more than two crops per year. Using the result of this study, one can also estimate the cost of installing solar pumps for irrigation in Hilly region of Nepal. Hence, from this study, it can be concluded that the use of solar pumps for irrigation along the banks of major rivers in Hilly region of Nepal can help for the sustainable development of irrigation systems and increase in food security within the country. Such irrigation projects can help to reduce poverty through employment opportunities and increase the living standard of farmers in Nepal.

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ANNEX - III

PARTICIPANT LIST

National Irrigation Seminar 2016 (2073)

Dhulikhel Lodge Resort, Dhulikhel, Kavre

Date : 2073/02/28-29 (2 days) (10-11 June, 2016)

Participant List

S.No.	Name	Designation	Organization
Ministry of Irrigation			
1	Umesh Kumar Yadav	Minister	MOI
2	Gajendra Kumar Thakur	Secretary	MOI
3	Madhav Belbase	JS	MOI
4	Sagar Kumar Rai	JS	MOI
5	Sanat KC	JS	MOI
6	Maheswor Narsingh K.C.	JS	WRD & TC
7	Promod Kumar Shrestha	SDE	MOI
8	Krishna Prasad Upadhyay	SDHG	MOI
9	Kushang Sherpa	SDE	MOI
10	Ramesh Paudel	US	MOI
11	Bhim Prasad Regmi	US/ Account	MOI
12	Dhamendra Prasad Dhamala	US/ Admin.	MOI
13	Ram Prasad Oli	Officer	MOI
14	Manish Maharjan	SDE	MOI
15	Krishna Giri	Officer	MOI
16	Raj Bahadur Bista	Officer	MOI
17	Ramananda Prasad Yadav	DG	DOI
18	Sushil Chandra Tiwari	DDG	DOI
19	Ashok Singh	DDG	DOI
20	Basu Dev Lohanee	DDG	DOI
21	Sarita Dawati	DDG	DOI
22	Churna Bahadur Oli	DDG	DOI
23	Basu Dev Dahal	CAO	DOI
24	Dev Prasad Gyawali	CAO	DOI
25	Kala Nidhi Poudel	SLO	DOI
26	Rukmanghat Katuwal	SDE	DOI
27	Indra Dev Bhatta	SDE	DOI
28	Suresh Kumar Sharma	SDE	DOI
29	Danda Pani Jaisi	SDE	DOI
30	Dhubra Kumar Pokharel	SDE	DOI
31	Andi Prakash Bhatta	SDHG	DOI
32	Rajendra Bir Joshi	SDE	DOI
33	Rabi Shakya	SDE	DOI

34	Rajan Bhattarai	SDE	DOI
35	Kailash Shrestha	SDE	DOI
36	Dhubra Prasad Acharya	SDE	DOI
37	Dinesh Bhatta	SDE	DOI
38	Raj Narayan Sah	SDE	DOI
39	Sangita Singh	SS	DOI
40	Gauri Lal Upadhaya	SS	DOI
41	Rajan Shakya	SS	DOI
42	Manoj Lal Pradhan	SS	DOI
43	Chetman Budthapa	SS	DOI
44	Tika Ram Baral	SDE	DOI
45	Prabin Shrestha	SDE	DOI
46	Rajerdra Prasad Sharma	SDE	DOI
47	Binod Kumar Timilsina	SDE	DOI
48	Kofula Shrestha	SDE	DOI
49	Prem Lasiwa	SDE	DOI
50	Sailesh Pokharel	SDE	DOI
51	Sunil Man Byanjankar	SDE (Mech.)	DOI
52	Jamuna Bana Shrestha	SDHG	DOI
53	Sanu Maiya Shrestha	SAE	DOI
54	Santos Kokh Shrestha	SAE	DOI
55	Tek Bahadru Karki	PC	DOI
56	Kausal Kiswor Jha	PC	DOI
57	Sashi Bahadur Bista	PC	DOI
58	Dev Raj Niraula	PC	DOI
60	Krishwor Kumat Bhattarai	PC	DOI
61	Shiva Kumar Ghimire	Account Officer	DOI
62	Shree Ram Acharya	Account Officer	DOI
63	Yubraj Acharya	Officer	DOI
64	Krishna Kumar Bista	Officer	DOI
65	Mitra Prasad Khatiwada	Officer	DOI
67	Shishir Koirala	JS	DWIDP
68	Noor Muhamod Khand	DDG	DWIDP
71	Rajendra Prasad Adhikari	Director	CRID
72	Ezee G.C.	SDE	CRID
73	Raj Kumar Tandukar	SDE	CRID
74	Jebin Tamrakar	Chief	Ktm Irr. Div
75	Purna Kumar Shrestha	Chief	Kavre Irr. Div
76	Dipendra Laudri	Chief	Kavre GW Div

77	Dipak Ghimire	Director	GWD
78	Jagat Prasad Joshi	ED	GWRDB
79	Niyaj Waris	Director	IMD
80	Roshan Pradhan	Chief	IDD
81	Dhan Bahadur Tamang	Secretary	WECS
82	Keshov Dhoj Adhikari	JS	WECS
83	Jeebach Mandal	JS	WECS
84	Madav Dev Acharya	SDE	WECS
85	Maheswor Shrestha	SDE	WECS
86	Dinkar Khanal	SDE	WECS
87	Ugranath Jha	SDE	WECS
88	Kiran Gutam	SDE	WECS
89	Suka Dev Chaudhary	SDE	WECS
90	R.R.S. Neupane		Paper Presenter
91	Suraj Lamichhane		Paper Presenter
92	Umesh Parajuli		
93	Keshav Sharma		
94	Bishnu Mani Adhikari		
95	Deepa Gautam		
96	Ashok Chaudhary		
97	Prachanda Pradhan		
98	Manoj Pantha		
99	Kashi Raj Dahal		
100	Santosh Kaini		
101	Birendra Yadav		
102	Dilli Raj Prasi		
103	Dinesh Pathak		
104	Randhir Sah		
106	Rajendra Mishra	PC	IWRMP-DOA
107	Niru Dahal	PC	CMIASP-DOA
108	Sushil Chadra Acharya	PM	Mahakali (III Phase)
109	Ramesh Basnet	PM	Ranijamara Kuleriya Irrigation
110	Madhukar Prasad Rajbhandari	PM	Babai
111	Saroj Pandit	PD	Sikta
112	Rajendra Yadav	PM	Bagmati
113	Laxman Singh	PM	Sunsari Morang

114	Shiva Kumar Basnet	PD	Bheri-Babai Diversion
115	Binod Kumar Jha	Director	ERID(Regional Director)
116	Dan Ratna Shakya	Director	WRID
117	Prakash Chandra Paudel	Director	MWRID
118	Krishna Nepal	Director	FWRID
119	Bal Krishna Ghimire	JS	NPC
120	Suresh Nepal	US	NPC
121	Gita Ghimire	Officer	NPC
122	Ram Saran Pudasaini	JS	MOF
123	Govinda Prasad Subedi	US	MOF
124	Prem Upadhayay	US	MOF
125	Lal Bahadur Khatri	US	MOF
126	Ambika Subedi	Officier	MOF
127	Kashi Raj Dahal	Chairman	Administration Court
128	Anup Kumar Upadhayay	ex-secretary	Special Invitees
129	Shetal Babu Regmee	ex-secretary	
130	Bhubanesh Kumar Pradhan	ex-secretary	
131	Shiva Kumar Sharma	ex-DG	
132	Ratneshwor Lal Kayastha	ex-DG	
133	Surya Nath Upadhayay	ex-secretary	
134	Sharda Prasad Sharma	ex-DG	
135	Mahesh Man Shrestha	ex-DDG	
136	Khom Raj Dahal	ex-DG	
137	Madhu Sudan Paudel	ex-DG	
138	Som Nath Paudel	ex-DDG	
139	Mahendra Nath Aryal	ex-Secretary	
140	Pradeep Raj Pandey	ex-DG	
142	Prakash Paudel	ex-DG	
144	Uma Kanta Jha	ex-DG	
145	Uttam Raj Timilsina	ex-DDG	
146	Khem Raj Sharma	ex-SMTP chief	
147	Yuka Kitamatsu	Researcher	JICA
148	Nabaraj Adhikari		JICA
149	Purna Chhetri		World Bank
150	Kenichi Yokoyama		ADB
151	D.B. Singh		ADB
152	S.Wahid	Co-ordinator	KBP/ICIMOD

153	Arun Bhakta Shrestha	Reg.Prog.Manager	ICIMOD
154	Nihari Neupane	Soc.Eco.Analyst	ICIMOD
155	Luke Kolavito		IDE
156	Raj Kumar G.C.		IDE
157	Pravakar Pradhan	Cl_Change Expert	AITM
158	Purna Charan Lal Rajbhandari	Cl_Change Expert	AITM
159	Navin Mangal Joshi	Chairman	FMIST
160	Bhesh Pradn Bhurtel	Chief	Treasury Controller Off.
161	Suman Kumar K.C.	Officier	Treasury Controller Off.
162	Udaya Prasad Pathak	Officier	Treasury Controller Off.
163	Paban Kumar Mahato	Officier	Treasury Controller Off.
164	Yam Raj Padney	ED	NARC
165	Ram Prasad Meheta	President	NFIWUAN
166	Ram Chandra Bastakoti	Researcher	IWMI/Nepal
167	Romules Okwany	Irrigation Engg.	IWMI/Nepal
168	Ambika Khadka	Research Officer	IWMI/Nepal
169	Ram Prasad Khanal	Treasurer	INPIM/Nepal
170	Bhagwan Jha	Engineer	SMTP
174	Upendra Regmi	Engineer	SMTP
175	Rajendra Thapa	S. Tech	SMTP
176	Krishna Kumar Bista	A/C	SMTP
177	Guru Prasad Regmi		SMTP
178	Umesh Neupane		SMTP
180	Radha Joshi		SMTP
181	Laxman Thapa		SMTP
183	Khyaju Gurung		SMTP
185	Rajan Khatri		SMTP
186	Bed Bahadur Thapaliya		SMTP
187	Chandra Singh Syantan		SMTP
188	Laba Krishna Shrestha		SMTP
189	Gopal Shrestha		DOI
190	Ram Hari Khadka		DOI
191	Ram Krishna Bhandari		DOI

ANNEX - IV

PHOTOGRAPHS OF THE WORKSHOP

Figure 1 Seminar Banner

Figure 2 Chief Guest with Participants

Figure 3 Welcoming Chief Guest Hon. Minister Mr. Umesh Kumar Yadav by DG Mr. Ramananda Prasad Yadav

Figure 4 Hon. Minister Mr. Umesh Kumar Yadav Inagurating the Seminar by watering the plant.

Figure 5 Chief/Special Guest in the Dash

Figure 6 Mr. Ramananda Prasad Yadav, DG delivering his speech

Figure 7 Mr. Kashi Raj Dahal, President, Adminstration Court, presenting his speech.

Figure 8 Master of Ceremony Mr. Devraj Niraula, SDE, DOI

Figure 9 Participants in the Seminar Hall

Figure 10 Presentation by Mr. Prachanda Pradan, Water Managment Specialist

Figure 11 Mr. Bhubanesh Kumar Pradhan, ex-Secretary, MOI expressing his views

Figure 12 Mr. Sharda Prasad Sharma, ex-DG, asking question to presenter

Figure 13 Mrs. Sanu Maiya Shrestha, SAE raising her confusion to presenter

Figure 14 Mr. Romulus Okwany, Expert, IWMI presenting his paper

Figure 15 Mr. Churna Oli, DDG, DOI asking questions to presenter

Figure 16 Mr. Khem Raj Sharma, ex-SMTP chief expressing his ideas

Figure 17 Mr. Rishi Ram Sharma Neaupane, Water Management Expert, presenting his paper

Figure 18 Mr. Sagar Rai, Joint- Secretary, MOI, explaining his lifting techniques

Figure 19 Panels of expert for Plenary Session

Figure 20 Mr. Madav Belbase, Joint- Secretary, MOI concluding plenary session

Figure 21 Mr. Shiva Kumar Sharma, ex-DG expressing his experience on Seminar

Figure 22 Token of Love received by Hon. Minister Mr. Umesh Kumar Yadav

Figure 23 Concluding speech by DG, DOI Mr. Ramananda Prasad Yadav