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# Proceedings of National Irrigation Seminar On Challenges and Opportunities in Irrigation Development for Green Revolution

Department of Irrigation
Jawalakhel, Lalitpur

# Proceedings of National Irrigation Seminar

# Challenges and Opportunities in Irrigation Development for Green Revolution

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# Foreword

Irrigation plays vital role in increasing agriculture production and productivity with the intensification and diversification in agriculture. Irrigation is one of the key factors making the country self-sufficient in food grain production and contributes greatly towards agriculture GDP (Gross Domestic Production). Irrigation contributes for alleviating rural poverty in the country. It materialized that irrigation technologies are developing and all types of farmers including small and medium are involved more in the production process which enhanced their household food security in particular and national food security in general. Keeping in mind to this fact, the Department of Irrigation is constantly working in irrigation development and management since its establishment in 2009 B.S.

Irrigation systems developed in the past were particularly for protecting the paddy crop in drought with supplementary irrigation. The challenge ahead is to provide year round irrigation in the existing irrigation systems as well as in the new development. Efficiency improvement with management input and canal/structure improvement, conjunctive use of surface and ground water, storage projects from small single purpose to large multipurpose projects and diversion projects are the major way outs for achieving it. Irrigation is facing the impact of climate change, which has to be taken into account to mitigate or adopt accordingly. Shallow tubewell and non-conventional irrigation technology can contribute a lot to the disadvantaged and marginal farmers. To explore the roadmap of the said challenges and opportunities for the development and management of irrigation sector in the changed context, DOI is organizing a national level irrigation seminar each year from last few years. In continuation to it, National Irrigation seminar with theme "Challenges and Opportunities in Irrigation Development for Green Revolution" was organized on 2070/2/10-11 (24-25 May, 2013) 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 and IWMI-Nepal for being the co-organizer in hosting the seminar. I would like to thank Consolidated Management Services P. Ltd., Fulbright Consultancy P. Ltd., Sheladia-Multi Disciplinary P. Ltd and Silt Consult P. Ltd. for their support. My special thanks goes to Hon. Minister Mr. Uma Kanta Jha, Ministry of Irrigation for his support and guidance for overall irrigation development and management. I am very much thankful to Mr. Pratap Kumar Pathak, Secretary, Ministry of Irrigation for his constant encouragement and support in conducting the seminar. Paper presenters are well acknowledged for their valuable technical papers and presentation. I am equally thankful to the participants for the active participation and lively discussions. I would like to thank Er. Uttam Raj Timilsina, DDG, DOI and the members of seminar organizing team 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.

Shiva Kumar Sharma
Director General
Department of Irrigation

# Contents

# ACRONYMS

| | |
|---|---|
| CC | Climate Change |
| CED | Central for Empowerment Development |
| DAG | Disadvantaged Group |
| DG | Director General |
| DHM | Department of Hydrology and Metrology |
| DOCSET | Design of Canal for Sediment Transport |
| DOI | Department of Irrigation |
| DTW | Deep Tube Well |
| DWIDP | Department of Water induced Hazard Prevention |
| ED | Executive Director |
| ER. | Engineer |
| ET | Evapotranspiration |
| FAO | Food and Agriculture Organization |
| GCM | Global Climate Model |
| GWDB | Ground Water Development Board |
| GWP | Global Water Partnership |
| HH | Household |
| IFAD | International Fund for Agricultural Development |
| INPIM/Nepal | International Network for Participatory Irrigation Management/Nepal |
| IWMI/Nepal | International Water Management Institute/Nepal |
| IWRM | Integrated Water Resources Management |
| IWRMP | Irrigation and Water Resources Management Project |
| LILI | Local Infrastructure for Livelihood Improvement |
| MASSCOTE | Mapping System and Services for Canal Operation Techniques |
| MCM | Million Cubic Meter |
| MLD | Million Litre per Day |
| MOF | Ministry of Forestry |
| MoI | Ministry of Irrigation |
| NASC | Nepal Administrative Staff College |

| | |
|---|---|
| NIS | Narayani Irrigation System |
| SDE | Senior Divisional Engineer |
| SES | Social Ecological System |
| SMIP | Sunsari Morang Irrigation Project |
| SMTP | System Management and Training Program |
| SRES | Special Report on Emissions Scenarios |
| SSIS | Small Scale Irrigation systems |
| STW | Shallow Tubewell |
| SWAT | Soil and Water Assessment Tool |
| UN | United Nation |
| WECS | Water and Energy Commission Secretariat |
| WUA | Water User's Association |
| WUPAP | Western Upland Poverty Alleviation Project |

# 1. Introduction

## 1.1. Background

Department of Irrigation (DoI) has been organizing National irrigation seminar every year since 2007 A.D. The aim of the workshop is to review the achievements and explore future opportunities and challenges for the development of Irrigation sector. Senior Level officials from Ministry of Irrigation and its line agencies participate in the workshop. Seventh edition of the National seminar was held on 10-11 Jestha, 2070 at Dhulikhel Resort, Dhulikhel. It was jointly organized by Department of Irrigation (DoI), International Network for Participatory Irrigation Management /Nepal (INPIM/Nepal) and International Water Management Institute– Nepal (IWMI-Nepal). Twelve technical papers were presented in four different subthemes. The workshop was attended by more than 120 experts and intellectuals from Ministry of Irrigation and Water sector

## 1.2. Rationale of Workshop

Nepal is rich in water resources. There are more than 6000 rivers in the country and drainage density is about 0.3 $km/km^2$. Rivers in Nepal can be classified into three broad groups on the basis of their origin. The first group of rivers is snow fed-types major rivers: the Koshi, Gandaki, Karnali, and Mahakali. The second group of rivers Bagmati, Kamala, Rapti, Mechi, Kankai, and Babai rivers are medium rivers, originates in the middle mountains and hilly regions. Their flow regimes are affected by both monsoon precipitation and groundwater. The third group of rivers originates in Siwalik zone Like Tinau, Banganga, Tilawe, Sirsia, Manusmara, Hardinath, Sunsari and other smaller rivers. All together about 225 BCM water flows away from the Country annually. In addition, there is good potential of groundwater Resources in the terai. Majority of Nepal's present population depends on agriculture for their subsistence but still only 32 % of the total irrigated land is facilitated with year round irrigation (Irrigation year Book, 2067). Thus winter crops depends solely on rainfall for irrigation and variability of precipitation in quantity and space often creates difficulties in cultivating these lands and could result in probable food scarcity for the population. Thus concept of the interbasin water transfer was simulated as an alternative to balance the non uniform temporal and spatial distribution of water resources and water demands year round. Likewise, where conventional surface Irrigation schemes are not feasible due to various reasons, role of micro irrigation system is felt vital.

While irrigation plays an important role in earning livelihood, trends in its development faces lots of issues and challenges like policy and strategic,  land acquisition, labour shortage, water management, environment and climate change , human resource management. So far efficiency of the systems monitored do not have higher than 35 %, thus rehabilitation and modernization of irrigation system at each level is felt necessary. It is observed that the production and productivity of irrigated land in the country is lower as compared to other countries.  Similarly, sustainability of the irrigation system depends on the ability of WUA to take over the responsibility of the system, thus capacity building through human resources development (training, education and extension) for WUA cannot be neglected. In addition, to address the climate change, assessment of effect and adaptive measures is now the concern for agriculture development. Taking above mentioned concern into consideration, Irrigation National Seminar, 2070 was formulated to review and assess the future roadmap of DoI activities.

## 1.3. Seminar Objectives

The overall objective of the seminar was to review the achievements and assess the opportunities and challenges in irrigation development for Green revolution. In this context, the specific objectives of the seminar were to:

- Assessment of the modernization of the irrigation system
- Comprehensive assessment of irrigated agriculture economics
- Governance issues for development and sustainability in irrigation sector
- Assessment of Groundwater resources for irrigated agriculture
- Share past experience and access the way forward.

## 1.4. Content of the Seminar

"Challenges and Opportunities in Irrigation Development for Green Revolution " was the theme of the workshop. It was divided into four subthemes to meet the objectives that were set. Subthemes were:

1. Irrigation Modernization for Water Productivity and Crop Production
2. Economics of Irrigated Agriculture
3. Governance in Irrigation
4. Groundwater Irrigation in Nepal

Following twelve technical papers were presented that focused in the above mentioned subthemes.

Agenda of the program is attached in Annex 1.

| S.no | Paper Title | Authors |
|---|---|---|
| Session I : Irrigation Modernization for Water Productivity and Crop Production | | |
| **1** | Application of MASSCOTE Tool for Enhancing Water Productivity in Nepal through Irrigation Modernization | Suman Sijapati |
| **2** | Design of Irrigation Canals for Sediment Transport A Case Study of Sunsari Morang Irrigation Project | Krishna P. Paudel |
| **3** | Application of the SWAT Model to a assess climate change impacts on water balances and crop yields in the West Seti River Basin | Pabitra Gurung, Luna Bhatati Saroj Karki |
| **4** | Improved food security and income for small farmers through pond irrigation | Susan Shakya |
| Session II : Economics of Irrigated Agriculture | | |
| **5** | Micro Irrigation for Rural Development in Nepal (A case study of Micro-Irrigation Piloting under IWRMP) | Krishna Bahadur Kunwar, Mr.Bashu Dev Lohanee, Dr.Kishor Bhattarai |
| **6** | Economics of Irrigated Crops: Major Indicator for modernization and Commercialization of Irrigated Agriculture | Tulasi Gautam |
| **7** | IWRM: Status in some of the river basins in Asia | Ashish Bhadra Khanal |
| Session III: Governance in Irrigation | | |
| **8** | Governance through Internal Auditing in Irrigation and Agriculture | Janak Raj Gautam |
| **9** | Small Scale Irrigation Systems in the context of Irrigation Policy of Nepal | Prachanda Pradhan |
| **10** | Rethinking Governance Framework in Irrigation Service | Laxman Neupane |
| Session IV : Groundwater Irrigation in Nepal | | |
| **11** | Analytical Status of Groundwater Irrigation in Nepal | Sagar Kumar Rai |
| **12** | Present Scenario of Groundwater Usages and Role of GWRDB in Development as well as Management of Groundwater Resources | Nir Shakya Surendra Raj Shrestha |

## 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 contributors
- Special invitees

- Official representation from Ministry of Irrigation (MoI)
- Official representation from Department of Irrigation
- Official representation from Department of Water Induced Disaster and Prevention (DWIDP)
- Official representation from  IWMI-Nepal
- Official representation from INPIM-Nepal
- Official representation from Auditor General
- Consulting firms
- Seminar Management Committee

List of Participant is attached in Annex 2.

# 2. Proceeding

## 2.1. Registration and Opening session

The seminar was formally inaugurated by Chief Guest Mr. Uma Kant Jha, Hon. Minister, Ministry of Irrigation (MOI) on 24th May, 2013 morning at Dhulikhel Lodge Resort, Dhulikhel by irrigating a plant. Mr. Pratap Kumar Pathak, Secretary, MOI, Mr. Bishwa Prakash Pandit, Secretary, WECS, Mr. Prakash Paudel, DG, DWIDP, Mr. Pramod Raj Sharma, ED, GWDB, Mr. Suman Sijapati, INPIM President were the special guest. Mr. Shiv Kumar Sharma, Director General, DOI chaired the opening session. Mr. Uttam Raj Timilsina, DDG, DOI was the seminar coordinator and Mr. Basudev Timilsina, SDE, DOI was the Master of Ceremony. One hundred and fifty persons participated in the program from Ministry of Irrigation, different government agencies, different international and national agencies and freelancer water resource experts.

Seminar Coordinator Mr. Uttam Raj Timilsina, DDG, DOI welcomed the participants and paper presenters. He briefly highlighted the needs of this seminar in the present context. Mr. Timilsina stressed on the importance of the workshop's theme for increasing production and productivity. Mr. Timilsina highlighted that the workshop participants would deliberate on their respective roles, scope, possibilities and challenges towards effective Irrigation Development for Green Revolution.

Mr. Basu Dev Lohanee, Chief, SMTP, DOI in brief presented the design and content of the seminar. He presented the different activities, the overview of the session structures and their objectives, content, outputs, methodologies, and program schedules, and briefly introduced the resource persons and guests.

Mr. Pramod Raj Sharma, ED, GWDB highlighted on the status and uses of groundwater in the Country. He also highlighted the role of Ground Water Development Board in ground water development and management and associated constraints behind it.

Mr. Pratap Kumar Pathak, Secretary, MOI focused on the Irrigation vision and mission for the future. He also stressed on the Irrigation governance Issues and professional ethics in providing service to the people.

Chief Guest Mr. Uma Kant Jha, Hon. Minister, Ministry of Irrigation, Energy and Science Technology and Environment highlighted on the status of irrigation development in

Nepal. He focused his speech on the irrigation development in country and challenges and constraints faced within. He extended his good wishes for the active participation in all sessions for fruitful outcomes.

Finally, Chairperson Mr. Shiv Kumar Sharma, Director General of Department of Irrigation welcomed all the participants in the seminar. He stressed in different dimensions of irrigation development in country. He said launching of mega projects like interbasin water transfer to prioritizing small scale micro irrigation has been the working modalities of the Department of Irrigation for providing Year Round Irrigation services. He added that these two days spend in vigorous discussions in the workshop will bring some fruitful outcomes for DOI working strategies.

## 2.2. Session I: Policy and Strategy- Irrigation

This session was chaired by Mr. Kamal Prasad Regmi, Joint secretary, Ministry of Irrigation and Rapporteur for this session was Mr. Min Raj Dhakal, SDE, DoI. Four Papers were presented in the session. Sub-theme of this session **was Irrigation Modernization for Water Productivity and Crop Production.** The first paper highlighted on Application of MASSCOTE Tool for Enhancing Water Productivity in Nepal through Irrigation Modernization, second paper described the Evaluation of Canal Design Methods for Sediment Transport in Sunsari Morang Irrigation Project. The third paper was focused on Assessment of Climate Change Impacts on Water Balances and Crop Yields in Koshi Basin and the fourth paper was emphasized on Irrigation Modernization for Water Productivity and Crop Production for Improved Food Security for Small Farmers through Pond Irrigation.

### 2.2.1. Application of MASSCOTE Tool for Enhancing Water Productivity in Nepal through Irrigation Modernization

Mr. Suman Sijapati, Chairman of INPIM /Nepal, presented first paper of the Session I on Application of MASSCOTE (**M**apping **S**ystem and **S**ervices for **C**anal **O**peration **Te**chniques) which is one of the tools developed by the United Nations Food and Agriculture Organization (FAO) used for developing irrigation modernization plans. It is a step-wise procedure for auditing performance of irrigation management by analyzing and evaluating the different elements of an irrigation system and develops a modernization plan consisting of physical, institutional and managerial innovations to improve water delivery services to all users and cost effectiveness of operation and management.

Mr. Sijapati started with highlights on the myth about MASSCOTE and described the elements of MASSCOTE such as service oriented management, cost effectiveness and merit of MASSCOTE. Mr. Sijapati presented pictorial view of MASSCOTE workshop carried out in Nepal in Sunsari Morang Irrigation System and Narayani Irrigation System in 2003. He also shared a brief overview of the international practices of MASSCOTE.

### 2.2.2. Evaluation of Canal Design Methods for Sediment Transport in Sunsari Morang Irrigation Project

Dr. Krishna Prasad Paudel, Irrigation Expert and Director of CMS Nepal, presented his paper on Evaluation of Canal Design Methods for Sediment Transport in Sunsari Morang Irrigation Project. Dr. Paudel started with methods adopted in canal design practice in Nepal and the limitation of each method. In practice, there is no consistency in the design approaches. The approaches have been found to vary from canal to canal even within the same irrigation scheme.

He tried to illustrate with canal system design of Sunsari Morang Irrigation Project where during earlier phases (stage I and II) of modernization, Lacey's regime method (Method I) was used while later on (stage III) the tractive force method with energy concept for preventing deposition was used (Method II). However, in the absence of clear and defined guidelines for the design, different approaches have been used. Thus design of the canal for sediment transport should be an integrated approach of hydraulic calculations and recommended to use rational canal design approach that takes into account of Holistic design/planning concept, prediction of roughness, adaption of sediment transport predictors, integration of water management plans and sediment management.

### 2.2.3. Assessment of Climate Change Impacts on Water Balances and Crop Yields in Koshi Basin

Mr. Pabitra Gurung, a Research Officer, International Water Management Institute (IWMI), Nepal, gave a presentation on Assessment of Climate Change Impacts on Water Balances and Crop Yields in Koshi Basin based on his model study.

Mr. Gurung started with saying that Himalayan region is considered sensitive to climate change (CC), and developing countries, such as Nepal, are more vulnerable to CC because they have limited capacity to adapt to it. In Between 1977-2000, the maximum temperature of Nepal increased by 0.06°C per year. Most of the agriculture land in the hills and middle mountains depends on the direct rainfall and only few lands have irrigation access from local streams. Then, he highlighted the central idea of this paper as to evaluate the impact of climate change on the soil water balance in the agricultural lands and subsequently to measure change in the yields of cereal crops.

He described the model (SWAT Model) used by him to evaluate the impact of climate change on water balance and crop yield and demonstrated the result given by the model.

Finally he highlighted his conclusion of the study as:

Under Current Climate: Declining trends of annual actual ET and crop yields

Under Future Climate: Precipitation will decrease on the summer crops fields except on the maize; and will increase on the winter crops, Actual ET will increase for all crops except in millet under future climate projection, Summer crop yields will decrease and winter crop yields will increase.

### 2.2.4. Irrigation Modernization for Water Productivity and Crop Production: Improved Food Security for Small Farmers Through Pond Irrigation

The last paper of this session was presented by Mr. Susan Shakya, a Research Officer of LILI, Helvetas, Nepal. Mr. Shakya described the use and importance of Pond irrigation for food security. He described the main features of pond irrigation system used in Nepal. He highlighted that the net income from pond irrigation system is more than that from canal irrigation system.

He added that it is very simple technique and more suitable for Disadvantage Group (DAG) of hilly areas of Nepal. Mr. Shakya concluded his presentation by highlighting the main factors which has made pond irrigation system sustainable.

### 2.2.5. Discussion session

After presentations, the chairperson opened the floor for discussion and comments. Irrigation Expert, Mr. Suman Sijapati raised the issue about consideration of change in sediment rate according to change in flow in the canal of SMIP. Similarly, S.D.E. Ashish Bhadra Khanal raised the query about the establishment of "Department of Water Management" to address the management issues of the System. Similarly, Mr. Kalanidhi Paudel, Senior

Legal Officer of Department of irrigation asked about the subsidy in irrigation systems. Mr. Bhesh Raj Thapa raised a query about the actual net income per hectre from the irrigated and un-irrigated agriculture so that we can justify the importance of irrigation. Project Director of Community Managed Irrigated Agriculture Sector Project, Mr. Navin Mangal Joshi raised the question on cost per hectre of small scale irrigation systems and its effectiveness compared to conventional irrigation systems and cost of construction of pond. Then after corresponding paper presenter responded to relevant queries and issues were discussed on floor as well.

## 2.3. Session II: Economics of Irrigated Agriculture

This session was chaired by Mr. Navin Mangal Joshi and rapporteur was Mr Hari Ram Shrestha, SDE, DOI. Three papers were presented in this session which was mainly focused on economics of irrigated agriculture. The first paper highlighted on the use of micro irrigation in rural development while the second paper focused on the major indicators for modernization and commercialization of irrigated agriculture. The third paper discussed about the status of IWRM in some of the river basins in Asia.

### 2.3.1. Micro Irrigation for Rural Development in Nepal (A Case study of Micro Irrigation Piloting under IWRMP)

Mr Krishna Bahadur Kunwar presented the paper on case study of micro irrigation piloting carried out in three districts Arghakhachi, Banke and Kailali. He stated that the main objective of the program was to improve livelihood of the poor households by providing micro-irrigation schemes with co-financed grant support for the enhancement of water use efficiency in water scarce areas. He discussed about the various activities of program in mobilization phase, construction/installation phase, post construction phase and financing and investment group support. He mentioned that Tube well/artesian in the foothill of Chure for high value crops, treadle pump for income generation in Terai, similarly earth dam, water lifting, recharging traditional Kuwa, water harvesting community tanks/ individual tanks were some of the main micro irrigation application in the program. He highlighted that improved food security, increased household income, intensified cropping pattern, increased social capital, increased access to input and market and skill development of farmers on installation and O&M of micro irrigation systems were some of the initial impacts of the piloting program.

### 2.3.2. Economics of Irrigated Crops: Major Indicator for Modernization and Commercialization

Mr. Tulasi Gautam has presented the paper on the above topic. He initially highlighted irrigation status of the country by ecological and development region and he also discussed about the reasons for low irrigated land area in the hills and mountain region. He highlighted that the Nonconventional irrigation technology is more suited for mid hills and high hills due to limits of low lands for surface irrigation and such irrigation technology should be expanded in upland hills while integrating market oriented agriculture products. He showed that the area of vegetable farming has increased considerably over time in every ecological zone. He also mentioned that benefit cost ratio for off season and main season vegetables are much higher than paddy and wheat. He further added that the only way to provide year round irrigation in mid hills and high hills is through micro irrigation. He concluded his presentation with recommendations for policy level to formulate land use policy, integration of irrigation and agriculture extension and to update statistical information on irrigation coverage, cropping intensity, productivity, food security and livelihood issues.

### 2.3.3. IWRM: Status in some of the river basins in Asia

Mr. Ashish Bhadra Khanal, SDE, of DOI was the presenter of this paper. He started with the definition of IWRM by Global Water Partnership as a process which promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems. He stated the UN Water report 2000 which revealed the existence of diverse interpretation among countries of IWRM planning and management process and their frameworks. He then highlighted some of the features, strategic plan and frameworks, principal duties and institutional arrangement of Nam Ngum river basin, Laos and Bengawan Solo river Basin, Indonesia. He pointed out that the concept of IWRM in Nepal was first documented in Water Resource Strategy 2002 and National Water Plan 2005. He highlighted the key activities to be carried out for mainstreaming of IWRM. He also discussed about the activities of IWRM being carried out in various river basins of Nepal. He concluded his presentation saying that the South Asian nations can benefit from the learning of the successful lesson of River basin organizations and this will be useful not only for interstate but transboundary issues too.

At the end of the session, the floor was opened for the discussion. Questions were asked to the presenters related to their presentation and each presenter responded to the respective queries. The chair then summed up by saying that in addition to the economic benefit, there is also social benefit as well as multiplier effect of irrigation. He finally thanked all the presenters and participants and closed the session.

## 2.4. Session III: Governance in Irrigation

Third session was chaired by DDG Mr. Madhev Belbase and helped by S.D.E. Mr. Kishor Kumar Bhattarai as a rapporteur. Four papers were presented under the sub theme of "Governance in Irrigation."

### 2.4.1. Governance through internal auditing in Irrigation and Agriculture

Mr Janak Raj Gautam, Director of Nepal Administrative Staff College (NASC) presented paper titled "Governance through internal auditing in Irrigation and Agriculture". Mr Gautam's paper was both refresher and revealing for all the participants. He correlated auditing with the good governance and highlighted importance of auditing for the transparency and fight against corruption. He dealt about various the aspects of auditing in great detail and made it understandable to participants most of whom were technicians. He explained about the different duties and responsibilities of auditors and elaborated about concept of performance audit. He talked about regulatory financial audit. He emphasized that auditing not only controls financial transaction but also helps to ensure quality in works, effective and efficient use of resources, promotion of public trust and internal cooperation in organization. It is a source of responsibility in executor. He also drew attention of the participants towards the most common mistake made by authorized person in handling resources and gave clues regarding avoiding such mistake. Finally he closed his presentation with latest report of Auditor General.

His conclusion was that good governance can be realized if government makes public service delivery effective through transparency, participation, accountability, and legitimacy particularly in development affairs.

### 2.4.2. Rethinking Governance framework in irrigation service

Second paper titled 'Rethinking Governance Framework in Irrigation Service" was presented by Mr. Laxman Neupane, Phd scholar, Central for Empowerment and Development (CED) Nepal. This presentation dealt with issues of sustainability and governance in detail. His presentation was very informative with theories to deal with social and economical aspects of proper governance. He talked about different aspects of sustainability, types of governance and different approaches propounded for the welfare of common man. He tried to establish a linkage between sustainability and type of governance. After talking in detail about Capability Approach by Amartya Sen and Social Ecological System (SES) by Ostrom, he tried to correlate them with governance in irrigation sector in particular. He talked in detail about various elements of irrigation service governance. He concluded his deliberation with findings of UN body on water and in particular irrigation related issues.

### 2.4.3. Small Scale Irrigation systems in the context of Irrigation Policy of Nepal

Third paper of the session was jointly presented by Dr. Prachandra Pradhan, Horiane Clement and Fraser Sudgen. The title of the paper was small irrigation systems in Nepal: Its role and contribution in the livelihood of the local community in the context of irrigation policy of Nepal. Paper focused on small scale irrigation systems and their impact in local community. Paper tried to estimate number of small scale irrigation system in Nepal and stressed on the importance of inventory of such projects. Paper also dealt in detail about O&M aspect of such systems, peoples participation in it local governance and assistance from local and international agencies both governmental and non governmental agencies.

Dr. Pradhan started the presentation with the discussion on importance of Small Scale Irrigation system (SSIS) for addressing scattered agricultural uplands. Paper highlighted about the institutional arrangements for Irrigation Development and Maintenance.

This paper was basically based on the study conducted by International Water Management Institute (IWMI), on Irrigation Improvement intervention in Western Upland Poverty Alleviation Project (WUPAP) funded by International Fund for Agricultural Development (IFAD). The study was carried out in Bajhang and Mugu Districts. Study included social, biophysical environment, process of intervention, role, power and responsibility of the users committees and management of the system. The intervention had positive results in water service delivery but large variation was within irrigation system about ownership, rights and O &M.

Paper also forwarded few issues toward assistance to SSIS where irrigation system development should not be always seen from engineering-centered approach rather it should be inclusive, give attention to gender concern, emergence of self governing local water institutions, provision of self-supporting institutions and poverty alleviation. He added community engagement during intervention through project preparation to implementation and O&M has to be the prime concern in the implementation of small scale irrigation development programs. Since many agencies have been providing assistance to

SSISs, there has not been uniform and consistent policy on intervention. Paper also gave information about arrangements made in previous laws for the maintenance of the farmer managed irrigation systems.

## 2.5. Session IV: Ground water Irrigation in Nepal

Mr. Siddhi Pratap Khand, DDG, DOI was the chairperson for the session and Mr. Andy Prakash Bhatt was the rapporteur. Two technical papers related to Ground Water Irrigation in Nepal were presented. First paper dealt with analytical status of Groundwater Irrigation in Nepal and Second paper highlighted the present scenario of Groundwater Usages and Role of GWRDB in development as well as Management of Groundwater Resources.

### 2.5.1. Analytical Status of Groundwater Irrigation in Nepal

The paper was presented by Mr. Sagar Kumar Rai, Project Chief, Groundwater Irrigation Project. He shared the Groundwater Irrigation status in Nepal analytically according to the state of Groundwater Irrigation facilities. According to the report of DoI, the developed infrastructure of the groundwater irrigation is about 342,376 ha out of total developed infrastructure in 1,311,960 ha. In the groundwater infrastructure, about 969 DTWs and 111,517 STW are constructed. However, 395 DTWs are seen older than 15 years which covers about 20,248 ha (42%) irrigated land. Similarly, the 31,825 STWs are seen older than 15 Years and its coverage land is about 108,649 ha (32%). All together about 128,933 ha (33%) land which showing irrigated through the groundwater irrigation may not be existed in the field. Thus he recommended that there is the urgent need to do assessment of present status of facilities and accordingly carryout immediate rehabilitation program for both Shallow and Deep Tube well.

### 2.5.2. Present Scenario of Groundwater Usages and Role of GWRDB in its management

Mr. Nir Shakya and Mr. Surendra Raj Shrestha, Senior Hydrogeologist presented paper on scenario of Ground water Usages and role of Groundwater Resources Development Broad in its management in Nepal. Mr. Shakya started with the present status of Ground water resources in Mid Hills and Terai. He said that the total groundwater extraction for irrigation is 1146 MCM per year. At present, only 20% of the available dynamic groundwater recharge (8800 MCM per year) in Terai is being utilized. In 2011 and 1996 this figure was only about 16% and 10% respectively.

He then gave few prospects of groundwater over utilization in Kathmandu valley to fulfill the increasing water demand and said that every year 10,000 new houses are being built in Kathmandu Valley and if this continues then in 35 years there is no absolute no recharge zone. He also said that nearby Chandragiri Valley is the potential valley for groundwater storage. He then highlighted the role and responsibility of the Groundwater Resources Development Board for the management of the resources.

## Plenary Session: Sharing Past experiences and Way Forward

A plenary session was organized to share the past experiences in the irrigation development in Nepal and assess the way forward. Mr. Bhuwanesh Kumar Pradhan was the chairperson of the session and Ms. Sarita Dwadi and Saroj Pandit were the rapportuer for the session. Mr. Shiv Kumar Sharma, Dr. Umesh Nath Parajuli and Mr. Prachanda Pradhan were the panel of Experts. Mr. Shital Babu Regmee and Mr. Som Nath Paudel were the Key Note speakers for the session.

Mr. Shital Babu Regmee, Ex- Secretary of GoN highlighted in the Development Chronology of Irrigation in Nepal. He highlighted on the process of irrigation development through traditional farmers managed irrigation system to intervention of GoN in Irrigation infrastructure development in periodic plans. He added that in future, water need and utilization scenario will differ as different water user sector viz agriculture, hydropower, drinking water, industry will be competing. The issues of climate change, water ecology, groundwater sustainability is raising and to top that, effect of climate change is additional threat in water resources. In such, issues of riparian water rights will be increased, thus a very intelligent vision and plans are needed. He suggested that to assure water delivery, it is essential to introduce high efficiency irrigation methods, reduce water loss, increase financial transparency and introduce new irrigation technologies.

Mr. Som Nath Paudel, irrigation expert, in his speech said that it is impossible to increase the agricultural land so it is important to increase the water productivity. He said that an ample resource is needed for irrigation system planning. O & M has always been weak and got very little attention but to ensure the increased water productivity, management of the system should also be prioritized. In addition to it, appropriate technology according to the site is needed. He added that the strong coordination has to be established between WUA and Government Agency. Many hindrances due to legal issues, environmental issues and financial issues often led to the delay of the projects thus these needs to be addressed appropriately. He also said that we have lots of Plan, Policy, Acts and Regulations but these are very weekly implemented thus for way forward, DOI need to concentrate on coordination between stake holders, focused on year round irrigation, local skill development for planning, implementation and management, Reduce political interference during project identification, effective and meaningful farmer participation, collection ISF for sustainability of system, Develop sustainable, reliable and equitable distribution system, Develop groundwater development acts and regulation, Increase irrigation efficiency, adopt technology compatible to the local level, environmentally friendly technology, enhance public awareness and climate change friendly technology.

Mr. Shiv Kumar Sharma, DG, DOI stated that up to third periodic plan (1956 to 1970) , the focus was only on development of infrastructure and from 3rd to 6th plan, focus was on water management in irrigation development but now DOI is focusing on construction of new infrastructure as well as management of existing projects. He added that to achieve the goal of year round irrigation, DOI is now concentrating on ground water projects. Similarly inter-basin diversion projects have initiated. DoI has also started focusing on the regional balance of irrigation development.

Dr. Umesh Parajuli said that increment of water efficiently can be achieved either by adequate supply or by demand management. Adequate supply can be achieved by development of diversion projects, development of small (low height) reservoir, development of farm pond and for demand management, introduction of low water consuming crops are needed. He added flexibility, reliability and equity in water service delivery are the key factors of system management. In addition to that market demand crops and high value crops are needed to be introduced for the agricultural commercialization to increase the economy of irrigation water. He said that focus is needed in four aspects of management i.e. system maintenance, system operation, water accounting and users participation. He also highlighted that private sector involvement can be beneficial in operation and maintenance of the irrigation system. Likewise, DOI should draw its attention on river basin management issues.

Dr. Prachanda Pradhan said that there is an urgent need of research and training center in DoI. He added that it is now need to discuss the institutional development and social component in large irrigation projects. He further said that irrigation is all way should mean for the poverty reduction of the community.

Mr. Ratneshwor Lal Kayestha said that the commericaligation of agriculture can be promoted with focus on land management and form irrigation management. Introduction of cash crops and crop diversification should be in accordance with to market demand. He added research and development unit is needed to be strengthened. He also agreed that private sector investment is needed in O & M for the sustainability of the system and for effective service delivery. Similarly, pilot programs and impact study should get importance in river basin management.

Chairperson opened floor for discussion after the view of key note speakers and panel of experts. Mr. Pradeep Raj Pandey said that DOI need to focus on maintenance of existing irrigation infrastructure and he added that often problem arises due to selection of maximum projects mainly in case of medium irrigation projects. He also raised the issue of less number of technical manpower in field level. Likewise, Mr. Sagar Kumar Rai said that only 70 % of budget is allocated in 20 Terai districts but now it is high time to focus on hilly region. Similarly advantages of micro irrigation to address the remote agricultural patches in hilly region and terai should not be overlooked. Er. Madhav Belbase added that focus on less water consuming crops is needed. Continuing the floor discussion, Er. Susan Shakya added that there should be very clear scoping of DOI and DOLIDAR in small irrigation projects. Er. Rajendra Adhikari dragged the attention to incorporate water induced disaster during planning phase of irrigation project.

Concluding the session, Chairperson, Mr. Bhubanesh Kumar Pradhan said that it is needed to motivate engineers in quality work. In addition to that, DOI should start implementing diversion project to ensure water service delivery and said that Surface, Ground water and Non-conventional irrigation projects should be collectively implemented to achieve our goal.

## Closing Session

The seminar concluded on the evening of the 25th May, 2013. Mr. Shiv Kumar Sharma was the chairperson of the session and Mr. Uma Kant Jha, Hon. Minister, Ministry of Irrigation was the chief guest of the session. Mr. Pratap Kumar Pathak, Secretary, MOI was special guest of the session.

Mr. Basu Dev Lohanee, Chief, SMTP, DOI summarized the seminar and conveyed the vote of thanks to all paper presenters and participants for the active and fruitful participation. He highlighted the key points raised in the group discussion.

Mr. Uma Kant Jha, Hon. Minister, Ministry of Irrigation congratulated the DoI for successful organization of the National Irrigation Seminar. He showed appreciation towards the efforts of organizing team and paper presenters to exercise on the different national issues of irrigation development, modernization and irrigation management. He added that similar program should be constantly organized and also emphasized on making necessary changes in the policy and strategies as according to the valuable conclusions made in the seminar and their timely implementation of the activities in the future. He also highlighted and committed on irrigation development and inter basin transfer project.

Mr. Pratap Kumar Pathak, Secretary, Ministry of Irrigation said that it is now imperative to focus on research and development sector to meet the responsibility as laid by Government. He added National Irrigation seminar is a platform to share knowledge and experience among the experts in Irrigation sector so as to narrow down the gap in irrigation development & management for fulfilling food security of nation.

The chairperson, Mr. Shiv Kumar Sharma appreciated Chief Guest Hon. Minister Mr. Uma Kanta Jha for interest, guidance and participation in the sessions. He also thanked Mr. Pratap Kumar Pathak, Secretary, MOI, panel of expert of plenary session, key note speakers and chairperson, co-organizer INPIM Nepal, IWMI Nepal, sponsors viz Consolidated Management Services P. Ltd., Fullbright Consultancy P. Ltd., Sheladia Multi Disciplinary P. Ltd. , Silt consult P. Ltd., water resources experts, press and organizing committee for the successful program organization. He finally thanked paper presenters for highlighting on the related issues of irrigation development and irrigation modernization. He thanked session chairs and rapporteurs for their cooperation. He also thanked participants for active participation and said that the workshop was successful in generating conclusion to address the objectives.

# 3. Conclusion and Recommendations

The highlights of the sessions and the recommendations generated from the seminar are highlighted below:

## 3.1 Highlights of the technical sessions

Brief highlights of the different papers presented in the technical session are enumerated as key points in following sections:

**Technical session I: Irrigation Modernization for Water Productivity and Crop Production**

- MASSCOTE (**M**apping **S**ystem and **S**ervices for **C**anal **O**peration **Te**chniques) which is one of the tools developed by the United Nations Food and Agriculture Organization (FAO) used for developing irrigation modernization plans. It is a step-wise procedure for auditing performance of Irrigation management by analyzing and evaluating the different elements of an irrigation system and develops a modernization plan consisting of physical, institutional and managerial innovations to improve water delivery services to all users and cost effectiveness of operation and management.

- The design manuals of the Department of Irrigation recommends Lacey's regime equations and White-Bettess-Paris tables with the Tractive Force equations for the design of earthen canals carrying sediment. But in practice, there is no consistency in the design approaches. The approaches have been found to vary from canal to canal even within the same irrigation schemes as a result according to the assessment done on Sunsari Morang Irrigation Project, unwanted erosion or deposition in the canal network was experienced, thus requiring heavy investment for annual operation and maintenance.

- The Soil and Water Assessment Tool (SWAT) done on West Seti Basin was used to simulate water balances in different cropping patterns under current and future climates. The results shows that as impact of climate change Precipitation will decrease on the summer crops fields except on the maize; and will increase on the winter crops and accordingly summer crop yields will decrease and winter crop yields will increase.

- Pond irrigation system has highly potential for fresh vegetable farming. This irrigation system is successful because the technology is simple to understand and implement by local technicians and farmers. It is a low-cost technology having a high probability of economic benefits. The technology is suitable for hill areas which account for more than 50% of the land area in Nepal, and is appropriate for small farmers striving for additional income from their small land and is environment friendly.

## Technical Session II: Economics of Irrigated Agriculture

- The Micro Irrigation Piloting Programmes has been successful in two ways, one in developing the infrastructure and second in institutional development process. It supported the community groups with capacity building in social mobilization, group savings, leadership and microfinance for institutional development.

- Irrigation can contribute to enhance agricultural production if it is properly integrated as a part of agricultural development package.

- Successful application of IWRM tool in many river basin; Tennesse, Murray and Mekong and learning the successful lessons of RBO, South Asian countries can benefit more and suffer less. This will be useful not only for interstate but transboundary issues too which will avoid incremental, project by project activities in upper and lower riparian.

## Technical Session III: Governance in Irrigation

- Good governance can be in motion when government can make public service delivery effective through transparency, participation, accountability, and legitimacy particularly in development affairs. Internal auditing is a process of practicing Good Governance.

- Small scale irrigation systems (SSIS) not just a means to increase food production for food security but offer many development opportunities for the rural population. SSISs in the past have been considered by government agencies and donors as infrastructures but in fact it represents the embodiment of local knowledge, local technology and skills, and reflect the system of social relations, resource mobilization and institutions for natural resource management by the community.

### Session IV: Groundwater Irrigation in Nepal

- In irrigated land, the groundwater irrigation is contributing on 342,376 ha (26% of total irrigated area) but 395 DTWs are seen older than 15 years which covers about 20,248 ha (42%) irrigated land. Similarly, 31,825 STWs are seen older than 15 Years and its coverage land is about 108,649 ha (32%). All together about 128,933 ha (33%) land which showing irrigated through the groundwater irrigation may not be existed in the field

- The total groundwater extraction for irrigation is 1146 MCM per year. At present, only 20% of the available dynamic groundwater recharge (8800 MCM per year) in Terai is being utilized. In 2011 this figure was about 16% and it was only 10% in 1996 respectively.

- There is no control mechanism of Groundwater Resources utilization. Construction of tubewells (personal household level and commercial uses like hospital, housings, industrial area etc) haphazardly is causing groundwater resources depletion in Kathmandu Valley and so constructed wells has reported arsenic Concentration from many parts of Terai.

## 3.2. Recommendations

- MASSCOTE can be used as a tool for capacity building and motivating the O&M staff. There should be sequence the work so that interventions that help restoring confidence and trust of the users are carried out first and proper communication with the stakeholders is vital for successful implementation.

- Design of the canal for sediment transport should be an integrated approach of hydraulic calculations and recommended to use rational canal design approach that takes into account of Holistic design/planning concept, Prediction of roughness, Adaption of sediment transport predictors, Integration of water management plans and Sediment management.

- Pond Irrigation system serves the most vulnerable groups of the society. To upscale, technology should be incorporated in governments' plan and policy. Trainings related to technology should be provided to authorities of government bodies at local and national level but also disseminated with farmers, other governmental and non-governmental organizations and donor agencies world-wide.

- To foster the economics of irrigated agriculture, Land use policy should incorporated to restrict Irrigated land used in housing construction. Strong mandatory of integration of irrigation and agricultural extension technology program is needed. Need to establish one Apex Body to look for irrigation system by restructuring the existing organizational structures. Need to update statistical information on irrigation coverage, cropping intensity, productivity, and food security and livelihood issues.

- Internal audit system should address economy, efficiency, effectiveness, Equity and fairness, accountability and responsiveness.

- Need consideration of inclusiveness, gender concern, self-governing local water institutions, provision of self-supporting institutions and poverty alleviation provisions during implementation of small scale irrigation system projects.

- Rather than package of "deliverables" to be provided by the government or donors for SSIS projects, due consideration to be given to local skill, knowledge, local technology and local materials during feasibility and design and construction time for the success and sustainability.

- There is an urgent need to conduct reassessment study of groundwater irrigation to find the real (as per observation ) status of DTW and STW and Causes of failure of DTW and STW and accordingly Rehabilitation program should be lunched for both Shallow and Deep Tube well.

- The withdrawal of the GW in Kathmandu valley is more than recharge rate thus artificial groundwater recharge applying suitable technology to balance the overdraft condition should be adopted and for unlimited abstraction and pollution control, the regulating institution should be established.

- Groundwater is a valuable resource of the Country, a strong regulating as well as investigating government agency is needed to manage it.

## 3.3. Identified themes for next workshop/seminar

- Year Round Irrigation

- IWRM: New tools and Approaches
- Ground water Irrigation and Lift Irrigation
- Non-Conventional Irrigation Technologies
- Scope and Potential of Multipurpose Projects
- Farmers Managed Irrigation Systems
- Challenges in Irrigation Financing
- Human Resources Management in Irrigation

Irrigation Development and management from Gender Equity and Social Inclusion

# Annex – 1
# Program Schedule

# National Irrigation Seminar, 2070
# **"Challenges and Opportunities in Irrigation Development for Green Revolution"**
## Program Schedule

Venue: Dhulikhel Lodge Resort, Dhulikhel
Date: 2070/2/10-11(2 days)

Master of Ceremony: Er. Basudev Timilsina,SDE,SMTP

| **DAY 1** (Jestha 10, 2070, Friday) | | |
|---|---|---|
| 9:30-10:30 | Breakfast | |
| 10:30-11.00 | Registration of Participants | |
| **Inaugural Ceremony** | | |
| Chairperson: Er. Shiv Kumar Sharma, DG, DOI | | |
| Chief Guest: Hon. Minister, Er. Uma Kant Jha, MOI<br>Special Guest: Mr. Pratap Kumar Pathak, Secretary, MOI | | |
| Special Guest: Mr. Bishwa Prakash Pandit, Secretary, WECS | | |
| Special Guest: Er. Prakash Paudel , DG, DWIDP | | |
| Special Guest: Mr. Pramod Raj Sharma, ED, GWDB<br>Special Guest: Er. Mahindra Bahadur Gurung, President, NEA<br>Special Guest: Mr. Ram Prasad Meheta , President, NFIWUAN<br>Special Guest: IWMI Representative<br>Special Guest: INPIMI Representative<br>Seminar Coordinator: Er. Uttam Raj Timilsina, DDG, DOI | | |
| **Time** | **Activities** | **Resource Persons** |
| 11:00-11:05 | Welcome Address | Er. Uttam Raj Timilsina, DDG, DOI |
| 11:05-11:15 | Introduction to the seminar design and content | Er. Basu Dev Lohanee, Chief, SMTP |
| 11:15-11:25 | Inauguration | Hon. Minister, Er. Uma Kant Jha, MOI |
| 11:25-11:30 | Few words from Special guest | INPIM Representative |
| 11:30-11:35 | Few words from Special guest | IWMI Representative |
| 11:35-11:40 | Few words from Special guest | Mr. Ram Prasad Meheta , President, NFIWUAN |
| 11:40-11:45 | Few words from Special guest | Er. Mahindra Bahadur Gurung, President, NEA |

| | | |
|---|---|---|
| 11:45-11:50 | Few words from Special guest | Mr. Pramod Raj Sharma, ED, GWDB |
| 11:50-11:55 | Few words from Special guest | Er. Prakash Paudel , DG, DWIDP |
| 11:55-12:00 | Few words from Special guest | Mr. Bishwa Prakash Pandit, Secretary, WECS |
| 12:00-12:05 | Few words from Special guest | Mr. Pratap Kumar Pathak, Secretary, MOI |
| 12:05-12:10 | Few words from Chief guest | Hon. Minister, Er. Uma Kant Jha, MOI |
| 12:10-12:15 | Few words from Chairperson | Er. Shiv Kumar Sharma, DG, DOI |
| **12:15-14:00 Launch Break** | | |
| **Technical Session I (Irrigation Modernization for Water Productivity and Crop Production)** | | |
| Chairperson: Mr. Kamal Regmi | | |
| Rapporteur: Mr. Min Raj Dhakal , SDE, DOI | | |
| 14:00- 14:20 | Application of MASSCOTE Tool for Enhancing Water Productivity in Nepal through Irrigation Modernization | Suman Sijapati, INPIM Nepal |
| 14:20- 14:40 | Design of Irrigation Canals for Sediment Transport<br>A Case Study of Sunsari Morang Irrigation Project | Krishna P. Paudel |
| 14:40- 15:00 | Application of the SWAT Model to a assess climate change impacts on water balances and crop yields in the West Seti River Basin | Pabitra Gurung, Luna Bhatati/ IWMI Nepal<br>Saroj Karki/ IOE TU Nepal |
| 15:00-15:20 | Improved food security and income for small farmers through pond irrigation | Susan Shakya, LILI Helvetas Nepal |
| 15:20-15:40 | Discussion on the session | |
| **15:40-16:00 Tea Break** | | |
| **Technical Session II (Economics of Irrigated Agriculture)** | | |
| Chairperson: Mr. Nabin Mangal Joshi | | |
| Rapporteur: Mr.Hari Ram Shrestha, SDE, DOI | | |
| 16:00-16:20 | Micro Irrigation for Rural Development in Nepal<br>(A case study of Micro-Irrigation Piloting under IWRMP) | Krishna Bahadur Kunwar,<br>Mr.Bashu Dev Lohanee,<br>Dr.Kishor Bhattarai |

| | | |
|---|---|---|
| 16:20-16:40 | Economics of Irrigated Crops: Major Indicator for modernization and Commercialization of Irrigated Agriculture | Tulasi Gautam, Agri-Economist |
| 16:40-17:00 | IWRM: Status in some of the river basins in Asia | Ashish Bhadra Khanal ,SDE, DOI |
| 17:00-17:20 | Discussion on Session | |
| **DAY 2** ( Jestha 11, 2070, Saturday) | | |
| **8:30-09:30 Breakfast** | | |
| **Technical Session III (Governance in Irrigation )** | | |
| Chairperson: Mr. Madhav Belbase, DDG, DOI | | |
| Rapporteur: Dr. Kishor Bhattarai, SDE, DOI | | |
| 09:30- 09:50 | Governance through Internal Auditing in Irrigation and Agriculture | Janak Raj Gautam |
| 09:50- 10:10 | Small Scale Irrigation Systems in the context of Irrigation Policy of Nepal | Prachanda Pradhan |
| 10:10- 10:30 | Rethinking Governance Framework in Irrigation Service | Laxman Neupane |
| 10:30-10:50 | Discussion on Session | |
| **10:50-11:10 Tea Break** | | |
| **Technical Session IV ( Groundwater Irrigation in Nepal )** | | |
| Chairperson: Mr. Siddi Pratap Khand, DDG, DOI | | |
| Rapporteur: Andy Prakash Bhatta, SDHG, DOI | | |
| 11:10-11:30 | Analytical Status of Groundwater Irrigation in Nepal | Sagar Kumar Rai |
| 11:30-11:50 | Present Scenario of Groundwater Usages and Role of GWRDB in Development as well as Management of Groundwater Resources | Nir Shakya/ Surendra Raj Shrestha |
| 11:50-12:10 | Discussion on Session | |
| **12:10-13:50 Launch Break** | | |
| **Plenary Session** | | |
| **"Sharing Past Experiences and The Way Forward"** **13:50-15:30** | | |
| Chairperson:Mr. Bhubanesh Kumar Pradhan | | |
| Panel of Experts: Mr. Shiv Kumar Sharma, Mr. Ratneshwor Lal Kayastha, Dr. Umesh Nath Parajuli, Dr. Prachanda Pradhan | | |
| Key note Speaker :Mr. Sheetal Babu Regmi, Som Nath Paudel | | |
| Rapporteur :Mr. Saroj Pandit and Mrs. Sarita Dawadi | | |

| **15:30-16:00 Tea Break** | | |
|---|---|---|
| **Closing Session** | | |
| Chairperson: Er. Shiv Kumar Sharma, DG, DOI | | |
| Chief Guest: Hon. Minister, Er. Uma Kant Jha, MOI | | |
| Special Guest : Mr. Pratap Kumar Pathak, Secretary, MOI | | |
| Special Guest : Mr. Bishwa Prakash Pandit, Secretary, WECS | | |
| Seminar Coordinator: Er. Uttam Raj Timilsina, DDG, DOI | | |
| Time | Activities | Resource Persons |
| 16:00-16:10 | Conclusion remarks of the seminar | Er. Basudev Lohanee |
| 16:10-16:15 | Few words from Seminar Coordinator | Er. Uttam Raj Timilsina, DDG, DOI |
| 16:15-16:20 | Few words from special Guest | Mr. Pratap Kumar Pathak, Secretary, MOI |
| 16:20-16:25 | Few words from special Guest | Mr. Bishwa Prakash Pandit, Secretary, WECS |
| 16:25-16:30 | Few words from Chief guest | Hon. Minister, Er. Uma Kant Jha, MOI |
| 16:30-16:40 | Seminar closing from Chairperson | Er. Shiv Kumar Sharma, DG, DOI |

# Annex –2
# Participant List

| S.No. | Name | Designation | Organization | Address | Telephone | | | Email Address |
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| 3 | Kamal Prasad Regmi | Joint Secreatary | MOI | Singhadurbar | | | | - |
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# Annex – 3
# Full papers

# Application of MASSCOTE Tool for Enhancing Water Productivity in Nepal through Irrigation Modernization

***Suman Sijapati***[1]

**ABSTRACT**

*With rising cropping intensity and more and more adaptation of high yielding varieties, the level of irrigation service demanded by farmers is on the rise. This coupled with greater fluctuations in supply sources due to issues like climate change has been making the task of the irrigation managers / water supply providers even more difficult. In order to meet this rising demand of service level, it is essential to have appropriate infrastructure and matching technology which needs to be established in the case of new schemes and continuously maintained and upgraded in the case of existing irrigation schemes. While new technologies are being developed to meet these requirements the other key challenge lies in making it efficient and cost effective. In this context, there is a pressing need for the irrigation managers in all developing countries including Nepal to use suitable tools that help in identifying the irrigation modernization needs and a systematic approach in developing modernization plans that can lead to overall enhancement of water productivity in the concerned irrigation systems.*

*This paper will present an introduction to MASSCOTE (MApping System and Services for Canal Operation Techniques), which is one of the tools developed by the United Nations Food and Agriculture Organization (FAO) used for developing irrigation modernization plans. It will highlight the relevance of the tool in the context of Nepal. It will also describe past exercises of using the approach and tool and discuss on how Nepal can benefit from it towards the end of identifying and implementing irrigation modernization works in a cost-effective way.*

**Key words:** Irrigation modernization, MASSCOTE, FAO, assessment tools.

## INTRODUCTION

Nepal's resource base for agriculture is severely limited by topographical constraints. The terrain consists of 'Terai' (plain land) in the south, central hilly region and rugged Himalayas in the north with elevations extremes from 70m to 8,850m. Total arable land is about 2.64 million ha (16% of the country) with permanent crops on less than 1% (Figure 1).

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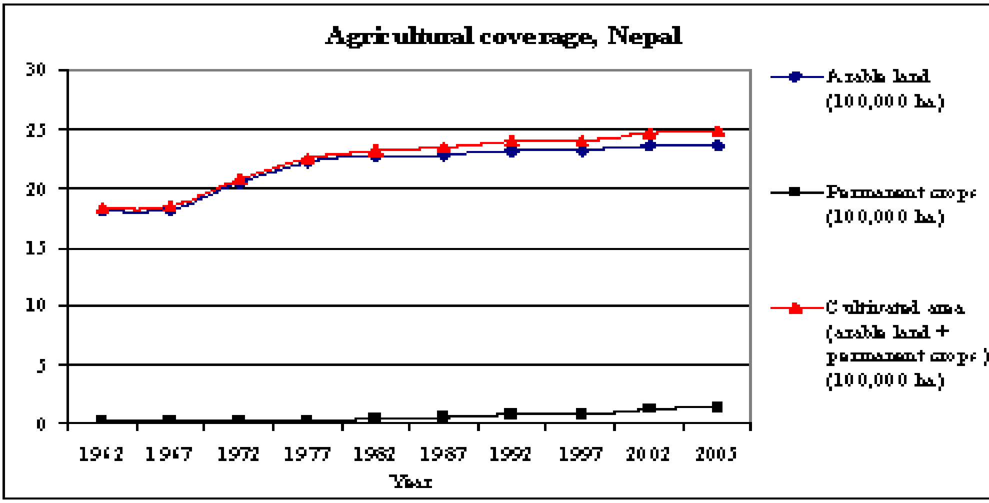


Figure 1: Agricultural Coverage and its Trend, Nepal (Source: FAO Database, 2009)

The country's population is approximately 28 million of which one-third lives below the poverty line. Agriculture provides livelihood for three-fourths of the population and accounts for about 33% of gross domestic product (GDP). Figure 2 shows the trend of increasing population and dependency on agriculture.

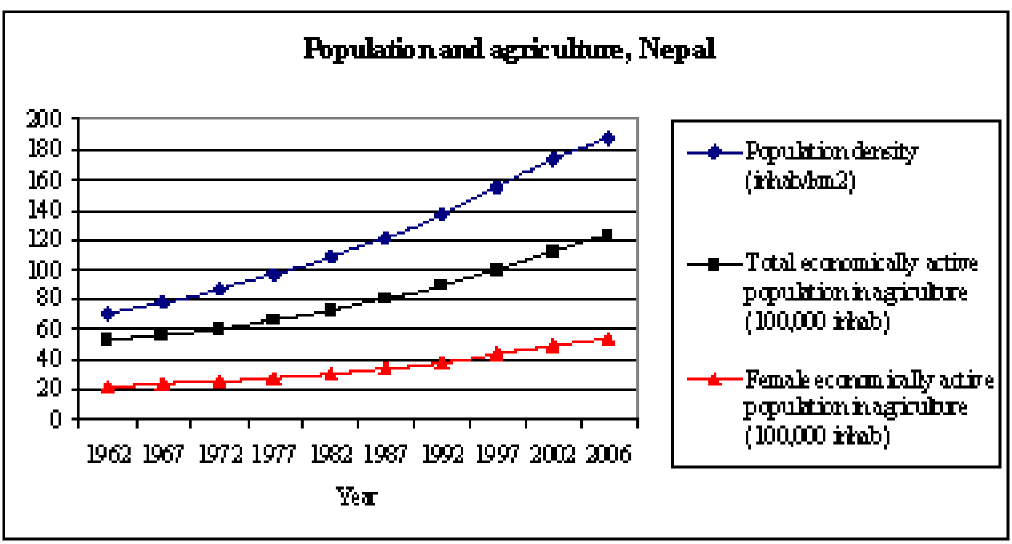


Figure 2: Population and Agriculture, Nepal (Source: FAO Database, 2009)

Agricultural practice is highly dependent on rainfall due to inadequate irrigation infrastructure or facilities. This dependency on rainfall, awaiting monsoon, significantly influences the sowing and harvesting time. Irrigated land makes about 1,170,000 ha and total annual renewable water resource is about 210 cubic km. The majority (96%) of the total fresh water withdrawal (10.18 cu km/yr; 375 cu m/capita) goes to the agriculture sector.

The Government of Nepal, with and without the support of international donors, has made continuous efforts for the development of the irrigation sector of the country over the last five decades. Despite large investments in the sector, only 51% of arable land presently has irrigation facilities while the rest remains rainfed. Furthermore, only 40% of the area having irrigation facilities gets year round irrigation while the remaining 60% receives only seasonal irrigation.

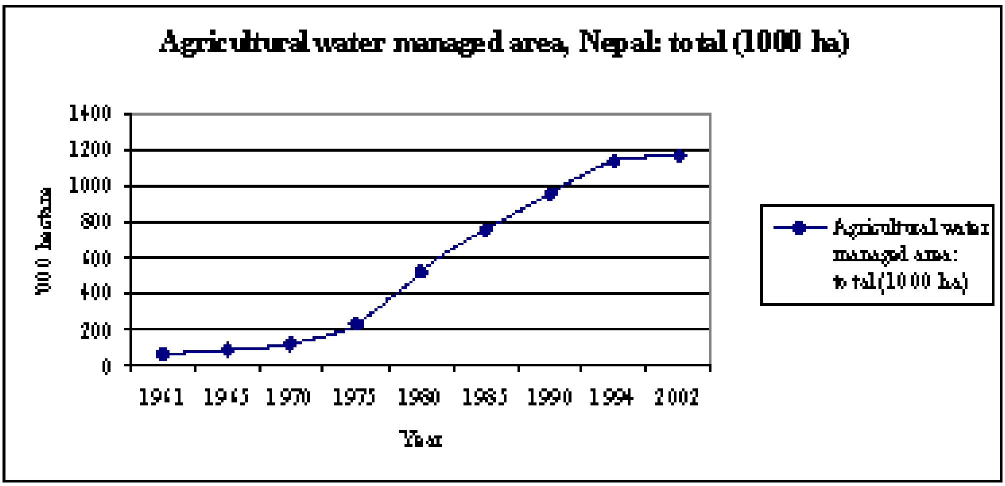


Figure 3: Agricultural Water Managed area, Nepal (Source: FAO Database, 2009)

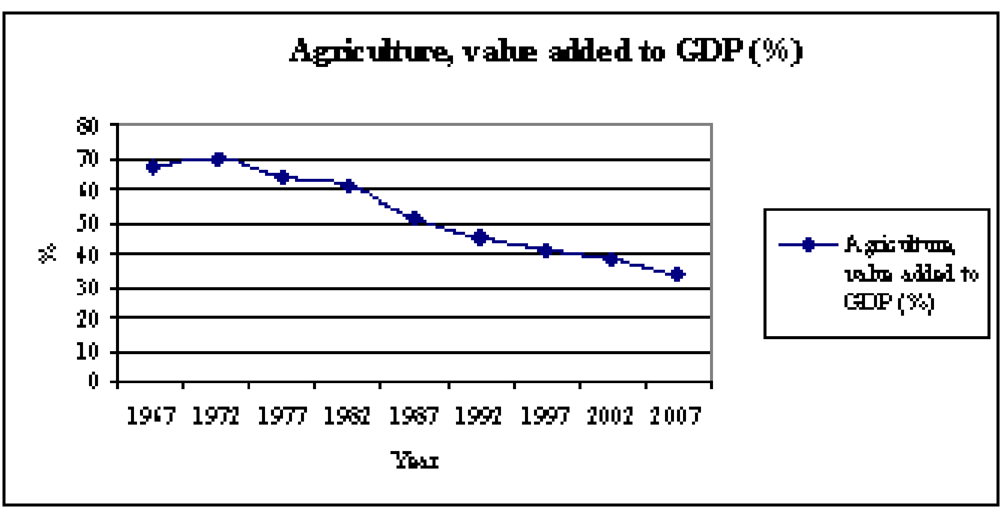


Figure 4: Agriculture, Value Added to GDP, Nepal (Source: FAO Database, 2009)

To sum up, it is evident from the above statistics that pressure on land resources (cropping intensity) is on the rise. Nepal has made notable gains in the extent of water managed area during the period from 1965 to 1995 owing to large investments made in the irrigation sector, but the relative contribution to the agriculture sector proved to be otherwise due to its continually declining share in the total economy as is evident from Figure 4 above. Hence, the country presently faces a stiff challenge of making the agriculture /irrigation sector more efficient.

## INTRODUCTION OF MASSCOTE IN NEPAL

MASSCOTE (MApping System and Services for Canal Operation Techniques) was introduced in Nepal with the idea of evaluating the performances of some of the agency-managed irrigation systems and developing appropriate plans for modernizing them. It was first carried out in Sunsari Morang Irrigation System (SMIS) in May 2003 and later in Narayani Irrigation System (NIS) in November 2003.

MASSCOTE is a methodology developed by FAO on the basis of its own experience on modernization programs in Asia between 1998 and 2008. It aggregates all the pieces into a consistent framework, complementing tools such as Rapid Appraisal Process (RAP) and Benchmarking[2], to allow a complete sequence of diagnosis of external and internal indicators of performance and practical solutions for an improved management and operation of the system.

MASSCOTE aims at organizing the project development into a stepwise revolving frame including:

- mapping system characteristics, water context and all factors influencing management
- delineating manageable sub-units
- defining strategy for service and operation for each units
- aggregating and consolidating canal operation strategy at the main system level

MASSCOTE is an iterative process based on 10 successive steps. Some steps need to be re-discussed and refined several times before reaching consistency. The ten steps are as follows:

2 Rapid Appraisal Process (RAP) is a tool developed by Irrigation Training and Research Center (ITRC) of California Polytechnic State University to quickly assess irrigation system performance while Benchmarking is a similar tool developed through the initiative of the World Bank.

| | |
|---|---|
| ***1. INITIAL ASSESSMENT*** | |
| 1. RAPID DIAGNOSIS | Initial rapid diagnosis and assessment through RAP or others. Objectives:<br>i. to get an initial sense of what and where the problems are, how they should be prioritized, etc.;<br>ii. to start mobilizing the energy of the actors (managers and users) for modernization;<br>iii. to generate a baseline assessment, against which progress will have to be measured. |
| ***2. MAPPING THE SYSTEM CHARACTERISTICS*** | |
| 2. SYSTEM CAPACITY AND SENSITIVITY MAPPING | a) Assessment of the physical capacity of irrigation structures to perform their function of transport, control, measurement, etc.<br>b) Assessment of sensitivity of irrigation structures (offtakes and regulators) and identification of singular points.<br>c) Mapping the sensitivity. |
| 3. PERTURBATION ANALYSIS | Perturbations analysis: causes, magnitudes, frequency and options for copping with it. |
| 4. MAPPING WATER NETWORKS AND WATER ACCOUNTING | a) Assessment of hierarchical structure and the main features of irrigation and drainage networks, on the basis of which partition of the system into sub-systems will be made.<br>b) Water accounting exercise considering both surface and groundwater and mapping their opportunities and constraints |
| ***3. MAPPING THE SERVICE: COST OF OPERATION AND DEMAND PER SUB-COMMAND AREAS*** | |
| 5. MAPPING SERVICE OPTIONS | Mapping options for services to users: farmers, crops and other users. |
| 6. MAPPING THE COST OF OPERATION | Mapping the cost for current operation techniques and services, disaggregating the elements entering into the cost, costing options for various levels of services with current techniques and with improved techniques. |
| 7. MAPPING THE DEMAND FOR CANAL OPERATION | a) Assessing means, opportunities and demand for canal operation.<br>b) A spatial analysis of the entire command area, with preliminary identification of Sub-Command Areas (Management, service, etc). |

| 4. DESIGN SUB-UNITS FOR SERVICE & OPERATION | |
|---|---|
| 8. PARTITIONING IN MANAGEMENT UNITS | Division of irrigation system and the command area into SUB-UNITS [sub-systems and/or sub-command areas] which are homogeneous, and/or separate from one to the other with a singular point or a particular borderline. |
| 9. CANAL OPERATION IMPROVEMENTS | Identification of improvement options for each Management Unit for (i) Water control (ii) Water management and (iii) Canal operation (service and cost-effectiveness). |
| ***5. AGGREGATING AND CONSOLIDATING*** | |
| 10.AGGREGATING & CONSOLIDATING MANAGEMENT | a) Aggregation of options at the system level, and consistency check.<br>b) Consolidating and designing an overall cost-effective Information System for supporting operation and Service Oriented Management (SOM). |
| | |
| A PLAN FOR MODERNIZATION<br>And MON. & EVAL. | a) Modernization strategy and progressive capacity development<br>b) Select/choose/decide/phasing the options for improvements<br>c) Plan for monitoring and evaluation of the project inputs and outcomes. |

MASSCOTE exercises were carried out in SMIP and NIS through which quantified performances in terms of water delivery service at each canal level were determined. Through field rating and analysis, major constraints of both these systems were identified.

## ANALYSIS OF IRRIGATION COSTS AND SERVICES

Another important part of the MASSCOTE exercise in the two systems was the analysis of their irrigation cost and services. Analysis of cost of operation not only revealed the cost-effectiveness of current operation and identified how it is affected by changes in the different inputs (water, staff, energy, office, communication and transportation) but also provided a good basis for cost-effectiveness of the improvements.

The estimated annual O&M cost for most large projects in the Terai was more than 400 Nepalese Rupees per hectare (NRs.400/ha) (US$1 = NRs72), with operation costs as shown in Table 1 (DoI, 1996):

Table 1: Breakdown of Operation Costs for the Level of Infrastructure in SMIS, Nepal

| Component | Operation Cost (NRs./ha) | % of total Cost of Operations |
|---|---|---|
| Headworks | 35 | 10 |
| Main Canal | 50 | 15 |
| Secondary & Sub-secondary Canals | 120 | 35 |
| Tertiary Canals & Water Courses | 125 | 40 |
| Total | 260 | 100 |

At that time, the project operation for the SMIS consumed an annual maintenance budget of NRs. 770/ha (DOI, 2001). According to the then managers, the O&M cost in the SMIS should be NRs. 1,500/ha, with NRs. 500 for operation and NRs. 1,000 for maintenance. This amount would correspond to about 3.3 percent of the gross product in the command area for 2005. According to Pradhan *et al*. (1998), it would correspond to about 10 percent of the net income per hectare provided.

Part of the differences in the figures for O&M costs can be explained by inflation and by the increase in cropping intensity from one irrigated crop per year (rice) to more than two on average (the cropping intensity is currently 215 percent). With year-round irrigation, the service is provided for a much longer period of time and the cost of O&M increases. Therefore, a figure of NRs. 1,500/year for irrigation was considered for O&M.

This figure was compared with the cost to individual farmers of pumping groundwater. The RAP estimated this cost at NRs. 2,000–3,000 per crop/season, meaning that two crops per year would cost NRs. 4,000–6,000 with this type of supply (even more expensive where the farmer has to rent the equipment). This O&M cost corresponded to the then service level, which in many regards is not able to satisfy demand in winter and spring. Responding to the users' demand with more flexible service would demand an increment in inputs and consequently result in higher annual O&M cost.

Many farmers that have poor service from a canal, or none at all, had moved to groundwater pumping wherever it is accessible at a reasonable cost. Thus, they usually pay a high cost for an adequate, reliable and flexible service. The cost of pumping varied with the context. In Terai, Nepal, farmers spend NRs. 3,000 per season for rice. The average cost of energy for pumping groundwater to cultivate sugarcane in one hectare is about NRs. 15,100 which is much higher than the canal water fee of sugarcane in the project (see Figure 5). Therefore, it seems reasonable to consider the option of upgraded service from surface supply allowing two crops at about NRs.1,800/ha/yr (the increase being mainly due to operation). This cost was expected to be acceptable to users provided that the service really improves.

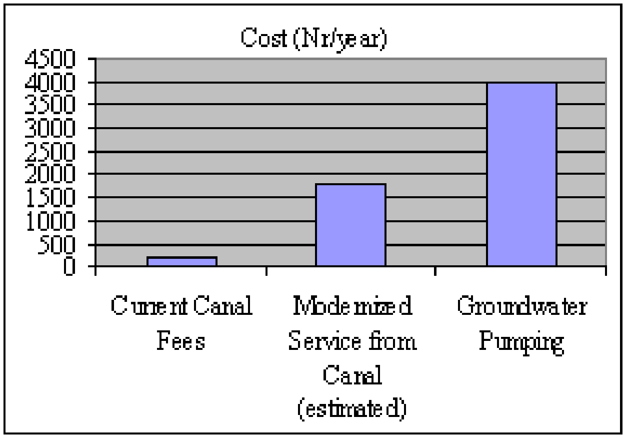


*Figure 5: Comparison of Costs (Cost Analysis during MASSCOTE Exercise)*

Cost analysis was also carried out for NIS. With reference to the irrigated area, the cost of operating the system is NRs. 233/ha. From the breakdown of the actual cost for different levels and items, a rough estimation of the service cost was determined for two options:

Option 1 aimed mainly at improving water management and deliveries along the main canal through tapping additional water from natural surface streams, an improved information system and better operation. This option did not target much improvement within the secondary CAs. The service (in terms of reliability and equity) to farmers would be only slightly improved. The main system level inputs would be increased significantly to face these challenges while some new allocation would be made in order to develop the local management capacity in Block 13–15. Under this option, the cost of operating the system would be about NRs. 244/ha.

Option 2 targeted Option 1 plus significant improvements in the service delivery to farmers, which basically means two crops a year and improved reliability and equity. In order to realize this option, an increase in the staff capacity at main canal level and increase in many more inputs at the secondary canal level would be required. For this option, the cost of operating the system would be about NRs 360/ha.

**CONSEQUENCES AND RESULTS OF MASSCOTE EXERCISE IN NEPAL**

The MASSCOTE exercises conducted in Nepal contributed both in terms of capacity building and in terms of real actions. A total of 80 irrigation related professional (27 during SMIP MASSCOTE, 24 during NIS MASSCOTTE and 29 during the summing up exercise conducted in April 2006) received exposure to the tool. The workshops were very useful in making the participants more analytical in their job assignment instead of the 'business as usual approach'.

Its impact was also in the form of actions in the ground. Modernization plans with different options were developed through MASSCOTE exercises for both these systems. In the consequent years the operation and maintenances works in those systems were carried out very much along the lines of the recommendations of the MASSCOTE results. Due to fund constraints, even though modernization plan could not be fully executed as in SMIS, government made the funds available for NIS and option 1 recommendation of MASCOTTE was executed during 2006 and 2007. The level of service is reported to have significantly increased after the modernization works. Thus, the MASSCOTE exercise and the consequent modernization plans were very useful in providing a guideline for increasing cost-effectiveness of irrigation management in the two large irrigation systems in Nepal

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# Evaluation of Canal Design Methods for Sediment Transport

# A Case Study of Sunsari Morang Irrigation Project

**Krishna Prasad Paudel**[1]

## ABSTRACT

*The design of a canal is a complex process of fixing its shape, slope and size based upon various aspects like volume and quality of water to be conveyed, type of canal to be constructed, the terrain through which it passes, socio-economic setting, climate, soil type, etc. The process becomes more complicated when the boundary of the canal is erodible and when the canal carries sediment with water.*

*In Nepal, the design manuals of the Department of Irrigation recommend Lacey's regime equations and White-Bettess-Paris tables with the Tractive Force equations for the design of earthen canals carrying sediment. But in practice, there is no consistency in the design approaches. The approaches have been found to vary from canal to canal even within the same irrigation scheme.*

*Irrigation canals that carry sediment load are difficult to operate. Hence the design of the canal for sediment transport should be an integrated approach of hydraulic calculations that take care of well defined management plans. It is possible to improve the design, if rational approaches, which explicitly use the influence of canal shape, management plans and sediment parameters, are used. However, it is not possible to have a canal designed for a specific water flow and sediment load to be non-silting and non-scouring for all the discharges and sediment concentrations. Sediment transport modelling is a key tool, which could be used for the precise representation of changes in management, hydraulic and sediment parameters and their effect on the overall performance of the designed canal system.*

## BACKGROUND

For countries like Nepal, with relatively young and fragile mountains, high intensity rainfall patterns, agricultural activities on the sloping and marginal lands and rapidly shrinking

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forest areas, the sediment is an integral part of the river flows, which is difficult to be excluded by the sediment removal arrangements in the headworks. Hence, irrigation canals have to carry the sediment loads. The design of canals for sediment transport, in majority of cases, is limited to using some empirical equations for computing canal geometry. The end result, as expected, is unwanted erosion or deposition in the canal network, thus requiring heavy investment for annual operation and maintenance.

Canal design for sediment transport requires long term and extensive database on sediment inflow rate as well as sediment size distribution. Such data are rare and hence, the designers have to depend on very few data collected during the survey. This may be one of the reasons that the designed canal's performance in terms of sediment transport is generally very poor.

In this paper, an evaluation of the canal design methods that are in use in Nepal and more specifically in Sunsari Morang Irrigation Project (SMIP) are given. A more rational canal design approach is proposed in terms of hydraulic calculations and the management aspect that should be taken into consideration is also presented.

## HYDRAULIC ASPECTS OF CANAL DESIGN

The purpose of the hydraulic design of canals is to determine the flow depth required to pass a known discharge for a given geometry and roughness. Geometry of a canal is defined by the bed width, side slope and bed slope. Hence, theoretically any of the three parameters, i.e., bed width, side slope or bed slope can be varied to obtain a desired depth for a given discharge. Since, it is not practical to construct a canal with varying side slope along its length, it is normally taken constant unless the canal discharge is reduced significantly and steeper slopes are possible to adopt. Hence, for a given condition (soil type, discharge) the side slope is selected and taken as constant, while bed width and bed slope are taken as the design parameters.

Similarly, roughness depends upon the flow conditions as well as on other factors like type of construction material, quality of construction and/or maintenance, canal shape, geometry and vegetation. Although the change in roughness will change the water depth for a given canal geometry and discharge, it is not taken as design parameter. Roughness is related qualitatively to the type and quality of the construction as well as the maintenance work, but quantitatively it is not practical to specify a roughness and ask to construct or maintain a canal accordingly.

## EXISTING CANAL DESIGN APPROACHES IN NEPAL

Based on design considerations, irrigation canals in Nepal can be broadly divided into two groups, canals in the hills and canals in the Terai (alluvial plain in the southern part). In the design manuals for the design of unlined irrigation canals, generally two conditions have been identified (Department of Irrigation, 1990a):

i. *Water flowing without sediment*. For sizing the canals Manning's equation is recommended while for limiting the slope to prevent bed erosion tractive force equations are recommended.

ii. *Water flowing with sediment*. In this case the manual suggests satisfying both the non-scouring and non-silting criteria. For sizing the canals it is suggested to use Manning's equation for all canals in the hills and small canals in the Terai, while Lacey's regime formula (Lacey, 1930) or White-Bettess-Paris tables (White*, et al.*, 1981b) for large canals in the Terai. For limiting the slope or preventing erosion in the bed tractive force equations are suggested. For computing the sediment transport capacity Engelund and Hansen (Engelund and Hansen, 1966) or Ackers and White (Ackers and White, 1973) equations are suggested.

The design manuals recommend that the use of Lacey's equations should be restricted to the areas where the sediment size and concentration is expected to be similar to those implicit in the formulae. It is recommended that for large canals, a more thorough assessment of the sediment balance should be carried out using quantitative formulae. No specific standards have been setup so far, hence the constants and coefficients in the empirical equations are selected on personal judgement.

## CANAL DESIGN METHODS IN SMIP

Similar to other large scale irrigation scheme canals, the canal system of SMIP was also designed using Lacey's regime equations. This irrigation scheme faced severe sediment deposition problems and during modernization the sediment transport aspect was also given due importance in the design of canals. However, in the absence of clear and defined guidelines for the design, different approaches have been used. During earlier phases (stage I and II) of modernization, Lacey's regime method (Method I) was used while later on (stage III) the tractive force method with energy concept for preventing deposition was used (Method II) (Department of Irrigation, 1987, 2003).

### 1. Method I

The set of Lacey's regime equations used in the design and the values of the constants taken are (Department of Irrigation, 1987):

$$V = \left(\frac{Qf^2}{140e^2}\right)^{\frac{1}{6}} = 0.483Q^{\frac{1}{6}} \qquad (1)$$

$$D = 0.525\left(\frac{Q}{e^2 f}\right)^{\frac{1}{3}} = 0.636Q^{\frac{1}{3}} \qquad (2)$$

$$B = 0.8B_s = 2.9\sqrt{Q} \qquad (3)$$

$$B_s = 4.83e\sqrt{Q} \tag{4}$$

$$S_f = \frac{0.00303e^{\frac{1}{3}} f^{\frac{5}{3}} E}{Q^{\frac{1}{6}}} \tag{5}$$

$$E = \frac{P}{B_s} = 0.8 + 0.2\left(\frac{\sqrt{1+x^2}}{x}\right) \tag{6}$$

and x is given by

$$x = 0.1\,B_s / D = 0.57Q^{1/6} \tag{7}$$

where

| | |
|---|---|
| $B_s$ | = water surface width (m) |
| B | = bed width (m) |
| D | = design water depth (m) |
| E | = shape factor |
| e | = width factor (taken 0.75 in SMIP) |
| f | = silt factor (taken 1.0 in SMIP) |
| P | = wetted perimeter |
| Q | = design discharge ($m^3/s$) |
| $S_f$ | = water surface slope (m/m) |
| V | = mean flow velocity (m/s) |

The regime theory postulates – "for a given discharge, sediment diameter and concentration the width, depth, mean velocity and slope of a sediment transporting canal are uniquely determined". This statement is subject to the condition that the sediment is loose, incoherent, the channel is active and the bed is in movement. That is, there is no restriction to the formation of regime conditions. The major issues in the use of Lacey's regime equations are:

i. *Implicit use of sediment parameters.* The sediment size and concentration appear implicitly in the equations. Only the silt factor appears in the equation that is related to mean sediment size ($d_{50}$). There is a common consensus among the researchers that more number of hydraulic and sediment related parameters, other than the sediment size and discharge, have influence in the sediment transport process. The disagreement, however, still exists on how much influence one parameter will have over the others. That is the reason, the sediment transport capacity predicted by the available predictors varies by a large margin for the same hydraulic and sediment related parameters. In the regime equations, all sediment related variables are included in a single parameter, the silt factor.

*ii.* *Concept of incoherent alluvium and bed width.* Most of the irrigation scheme in Nepal pass through the terrain that cannot be considered to have unlimited envelope of sediment identical to the transported sediment as assumed in the regime theory. The regime width is constant for a given discharge and is independent of the type of bank material. In practice, even the natural rivers with strong banks are narrower than the ones with erodible banks. Hence, to achieve the regime conditions, the banks should not offer any resistance. Such conditions are difficult to find in the irrigation canals in Nepal.

*iii.* *Introduction of flow control structures.* For a canal to adjust its slope and width and attain a regime condition an incoherent perimeter and a long reach without any restriction to flow is needed. Such conditions are difficult to find in modern irrigation canals. Even the old irrigation schemes, designed on a supply based concept, are being converted to a demand based concept during modernization. As a result, more of flow control structures are being added to regulate the flow to meet the changing demand. Hence, there is hardly any possibility of attaining the so called regime condition in present day irrigation canals.

*iv.* *Changing water flow.* Regime conditions assume canals to carry relatively constant flows with little variation. The modern irrigation canals are highly demand based and the discharge varies constantly within the irrigation season. It will be difficult to assess sediment transport process in such canals using the regime theory.

*v.* *Roughness implicit in other equations.* The theory assumes that in a self formed channel in loose sediment the roughness is implicit in the values of the hydraulic mean depth and the slope it adopts. It is not clear how to compute the roughness of a canal that is not in regime. Normally the irrigation canals have defined boundary and the side slope and different protection and repair works are done to maintain the side slopes that will definitely affect in the equivalent roughness of the canal section. The effect is more pronounced in case of non-wide canals.

*vi.* *More equations*. As discussed above the hydraulic design of a canal is basically to find the three variables; bed width (B), water depth (h) and bed slope ($S_0$). Hence, three equations are needed to find a unique solution. But, Lacey's regime theory provides more than three equations. This creates confusion which of the three equations should be taken in the design.

In Nepal, so far no studies have been made on how much deviation there is between the predicted and actual stable canal parameters. However, in India the predicted values deviated from actual stable canal values by 11 to 84%. Some adjustments have been made in the regime equations to make them compatible with the local conditions. Examples of such equations are that of Chitale's best fit equations (Chitale, 1966) and the Irrigation Research Institute, Roorkee equations for northern India (Varshney, *et al.*, 1992). There are so many variables involved in the sediment transport process and the Lacey's regime equations use so little parameters that it becomes difficult to make any tangible comparison, between the conditions of the place of interest and the conditions where these equations have been claimed to be successful.

Despite all the limitations in the equations, the design engineers in Nepal use the Lacey's regime equations for the design of canal mainly because they are simple and easy. Design discharge and the mean sediment size are the only information needed to start the design.

## 2. Method II

The second approach used is based on the energy concept that states that the sediment transport capacity (stream power) should be constant or non-decreasing in the downstream direction. The basic principle of this method is that any sediment entering into the system should be transported to the end without deposition in between. For the control of erosion in the bed the shear stress is restricted to a certain safe limit.

In this approach, one of the three resistance equations (Chézy, Manning or Strickler) makes the first equation. The bed width to water depth ratio (B-h ratio) makes the second equation. In SMIP the values as shown in Table-1 have been used.

Table-1: B-h ratio and side slope for different discharges.

| Flow range (Q $m^3/s$) | V:H | B-h ratio |
|---|---|---|
| 0.1 to 1.0 | 1:1 | 1 to 4 |
| 1.0 to 15.0 | 1:1.5 | 2.7 to 7 |
| 15.0 to 100.0 | 1:2 | 5.5 to 10 |

i. *Check for erosion*. For a given/assumed bed slope, the two equations are used to find the water depth and bed width. The slope is then checked for erosion using the following condition:

$$\tau_b = \rho g h S_0 \qquad (8)$$

where

$g$ = acceleration due to gravity (m/s$^2$)

$h$ = water depth (m)

$S_0$ = bed slope (m/m)

$\rho$ = density of water (kg/m$^3$)

$\tau_b$ = maximum tractive force (<3-5 N/m$^2$)

ii. *Check for suspended load*. For controlling the deposition of suspended sediment, the Vlugter (1962) energy concept has been used. It states that sediment particles will be transported in any concentration by the flowing water when the fall velocity ( $w$ ) is less than a certain threshold, given by:

$$w_s \leq \left( \frac{\rho_w}{\rho_s - \rho_w} \right) VS_0 \qquad (9)$$

Shoemaker (1983) used this concept and proposed the concept of stream power for designing a canal with suspended sediment. The stream power is given by:

$$E = \rho g V S_0 \qquad (10)$$

where

$E$ = stream power (W/m$^3$)

$S_0$ = bed slope (m/m)

$V$ = mean velocity (m/s)

$\rho$ = density of water (kg/m$^3$)

The energy of the main canal at the head of the off-take is computed and the off-take canal is designed such that it would have energy at least equal to or more than the energy of the main canal to ensure no sediment deposition. The criterion used to test this condition is:

$$VS_0 = \text{constant or non-decreasing} \qquad (11)$$

Comparatively, the energy approach is better as compared to the regime equations. In this approach all the canals downstream of a point under consideration are related with each other. The secondary canal's transport capacity is determined by the transport capacity of the main canal near the intake of the secondary canal. Similarly, the capacities of the sub-secondary canals are related to the capacity of secondary canal and so on.

There are, however, some limitations of this approach in the design of canals that carry appreciable amount of sediment:

i. *Sediment transport rate only a function of velocity (V) and bed slope ($S_0$)*. The majority of irrigation canals are non-wide and trapezoidal in shape with the exception of small and lined canals that may be rectangular. In a trapezoidal section the water depth changes from point to point in the section and hence the shear stress. The effect would be more pronounced if the bed width to water depth ratio (B-h ratio) is small. The change in velocity distribution in a canal in view of the change in boundary shear and water depth along the cross section will influence the sediment transport capacity also. Hence, by relating the transport capacity with the velocity and bed slope only, the major characteristics of an irrigation canal are ignored and the sediment transport process is not completely described.

ii. *Non-decreasing energy not the sufficient condition*. The sediment transport predictors are more sensitive to velocity as compared to the bed slope. Taking other variables constant the exponent of velocity is equal to 5 for Engelund-Hansen, greater than 3 for Brownlie and greater than 4 for Ackers-White predictors. The slope parameter does not appear explicitly in Ackers-White and Engelund-Hansen predictors while in Brownlie the exponent to slope is 0.6. Hence, the transport capacity may not change proportionally with change in $VS_0$ for sediment load outside the De Vos assumptions (fine sediment of size less than 70 μm). Discharge in irrigation canals decreases in downstream direction, hence the roughness increases for the same canal shape and bed material size and the velocity ($V$) decreases. The product $VS_0$ can be maintained constant or non-decreasing by three different methods:

   – by changing the bed width while keeping the bed slope constant;

   – by changing the bed slope while keeping the bed width constant;

   – by changing both the bed width and bed slope.

   The practical difficulty lies on the correct selection of method/option to get the constant $VS_0$. Sometimes, the topography restricts the change in slope while sometimes the bed width has to be kept constant. Moreover, for a canal with the same constant energy achieved by three different methods, the actual sediment transport capacity of the canal will not be same. Hence, the non-decreasing energy criteria may be necessary but not sufficient for preventing deposition in the canals.

iii. *Extrapolation of the method for larger sediment size*. The De Vos statement was for very *fine* sediment ($d \leq 50 - 70$ μm) and the assumption that it will be equally applicable to larger sized sediment is not yet justified.

Apart from the limitation in the approaches used in the design, some canal systems that were less problematic from sediment transport aspect are performing with less reliability after modernization/rehabilitation. The major reasons are alteration of hydraulic behavior of the canal due to the introduction of flow control structures to increase the flexibility of the scheme.

## RECOMMENDED CANAL DESIGN APPROACH

i. *Holistic design concept*: It is seldom possible to have the same sediment transport capacity for all the canals in an irrigation scheme. One or more canals or one or more reaches of a canal may have more sediment deposition problems as compared to others for the given sediment load. One of the major problems in existing design approach is to treat each canal as separate entity with no relationship with each other from sediment transport capacity aspect.

   Moreover, the design manuals suggest to design the main and secondary canals using tractive force or regime concepts while lower order canals by simple Manning's or Chézy's equations (Department of Irrigation, 1990a). This gives an impression that the objective in the design from the sediment transport perspective is to transport the sediment up to the end of the secondary canals. Since the design approach does not include any specific plans and methods how the transported sediment is to be managed after that point, the operation of such schemes is difficult.

   The lower order canal should be linked with the higher order canal not only in terms of hydraulic but also in sediment transport aspects. In the above methods, the sediment parameters are implicit in the formulae; hence it is not possible to relate this aspect during design. A rational approach that uses sediment characteristics explicitly will have to be used.

ii. *Prediction of roughness*: The alluvial canals with sediment load will have bed forms once the threshold of initiation of motion of bed material is reached. The present approaches use constant roughness along the canal with single roughness value. The reliability of design in terms of sediment transport increases, if the roughness to be used for the design is estimated considering the bed forms for the designed hydraulic conditions.

iii. *Adaptation of sediment transport predictors*: The sediment transport predictors assume uniform velocity distribution and sediment transport across the cross section, similar to that of the wide rivers. While using them in irrigation canals, two aspects should be considered; the side slopes and the bed width to water depth ratio (B-h ratio). The majority of the canals have a trapezoidal shape. Hence, the changing water depth on the sides will have influence in the overall shear distribution along the perimeter. This effect is more pronounced if the B-h ratio is small. Irrigation canals are non-wide in nature, in the majority of the cases the ratio of bed width to water depth is less than 8 (Dahmen, 1994). Hence, a correction should be made before using these equations for irrigation canals to improve their predictability.

iv. *Integration of water management plan*: Irrigation schemes that carry a sediment load need extra efforts to operate them properly. Two objectives have to be met simultaneously, firstly to supply the water as per the demand or as per the previously agreed schedule and secondly to ensure that the effects due to sedimentation/erosion are minimal. Delivery of water as per the demand requires adjustment in the water level and flow rate. The operation of control gates to manipulate the water level and discharge makes the flow in the canal system unsteady and non-uniform and will affect in the sediment transport behaviour. It is not possible to operate the scheme in a flexible way and also to reduce the sedimentation problem at the same time. Hence a compromise has to be made between the flexibility in water delivery and sediment deposition. The limitations of such irrigation schemes in terms of service delivery have to be understood at the time of design and accordingly operational plans should be prepared. Simply using sediment transport formulae and determining best canal geometry without considering water delivery plan and the resources and skills of the available management team and its effect in the hydraulic behaviour, does not solve the problem.

v. *Sediment Management*: The sediment management aspect should be fully understood and incorporated in the design. The design of a canal or reach of the canal for a certain transport capacity may solve the problem of that reach but from management aspect it is simply the shifting of the trouble from one place to another. It should be clearly indicated what is the objective in terms of sediment transport. If the objective is to transport the sediment down to the field then all the canals in the network should be capable of transporting the sediment load.

To address the above mentioned issues, a rational canal design approach for sediment transport has been proposed (Depeweg and Paudel, 2003). The proposed approach was evaluated with the water delivery plan and sediment inflow data of two secondary canals (S-9 and S-14) of Sunsari Morang Irrigation Project and was found that this approach results in a efficient canal section as compared to the existing design approaches (Lacey's regime approach for S-9 and Energy approach in S-14) (Paudel, 2010). A simple computer program DOCSET (**D**esign **o**f **C**anal for **Se**diment **T**ransport) has also been prepared based on the suggested approach that is being used for education purpose and is available for free.

## CONCLUSION

The design of a canal is a complex process that has to satisfy different operational requirements. Hydraulic calculations are based on a specific design discharge and sediment characteristics for uniform flow. The design information are derived considering the water requirement, sediment load in the river and the provisions of sediment removal facilities, expected maintenance conditions and the proposed operation plan. The proposed design approach, if used could produce more efficient and reliable canal in terms of hydraulic and sediment transport aspects. However, it is not possible that a canal designed for a specific water flow and sediment load to be non-silting and non-scouring for all the discharges and sediment concentrations. Since the water flow and sediment concentration keep on changing, it is unavoidable to have some deposition in one part of the irrigation season and some erosion in the other. Hence, the design should be able to produce a system that has a minimum net erosion/deposition at the end of the season. Hence, the design values of water and sediment concentration may not be the maximum values that the canal is expected to convey but those that produce minimum net erosion or deposition during one crop calendar year.

For a given discharge and geometry the actual water depth in a canal under uniform flow condition is decided by the roughness. Roughness keeps on changing throughout the canal operation. The roughness in the bed will change with the change in flow conditions. The roughness in the sides might change due to the growth of vegetation, weathering of canal slopes and periodic maintenance activities. However, the canals have to be designed by taking the average roughness expected during the irrigation season. Modelling provides an option for a precise representation of these changes during the irrigation season that will increase the reliability of predicted morphological changes and help in a better design from sediment transport perspective.

A flow control system is needed in an irrigation scheme to manage the water flows at bifurcations to meet the service criteria and standards regarding flexibility, reliability, equity and adequacy of delivery. A flow is regulated through water level control, discharge control, and/or volume control that make the flow non-uniform. For flows other than the design values, the gates are operated to maintain the set-point and diverting the desired water to the laterals. This will create drawdown or backwater effects and non-equilibrium sediment transport conditions. The canals are designed assuming a steady and uniform flow and an equilibrium sediment transport condition. The sediment transport equations used in the design are not capable of predicting the sediment transport behaviour under non-equilibrium conditions. Sediment transport models provide an option for predicting the sediment transport process in time under changing flow conditions. Hence, a design should be evaluated by using a sediment transport model and necessary changes should be made to reduce the erosion/deposition. Hence, modelling should be the integral part of the design, especially for major irrigation schemes and it will be helpful to:

- select the design discharge and sediment concentration that will give minimum net erosion/deposition;
- incorporate in the design the changing nature of roughness due to changing hydraulic and management conditions;
- include the effect of water delivery schedules and flow control in the design; and
- Prepare and propose the irrigation management plans.

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# Assessment of climate change impacts on water balances and crop yields

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**Abstract:**

*The West Seti River basin is located in the far western region of Nepal and has a catchment area of 7,438 km$^2$ and annual rainfall of approximately 1921 mm. According to Siddiqui et al., (2012) this basin is one of the most vulnerable in Nepal. The average elevation of the basin is 2505 m but can vary from 314 m to 7043 m in the Api and Nampa high mountain ranges. Agricultural land in this basin is categorized into three types: level terraces; slope terraces; and, valleys. The major summer cereal crops in the basin are rice, maize and millet and the major winter cereal crops are wheat and barley.*

*The Soil and Water Assessment Tool (SWAT) is used to simulate water balances in different cropping patterns under current and future climates. The results show that total precipitation over rice, maize, millet, wheat and barley fields are 1002 mm, 818 mm, 788 mm, 186 mm and 169 mm respectively whereas total simulated actual evapotranspiration (ET) are 534 mm, 452 mm, 322 mm, 138 mm and 177 mm respectively under current climate. Actual ET will change by +0.7% in rice, +3.4% in maize, -3.4% in millet, +41.2% in wheat and +36.2% in barley under future climate projections. Results show that yield of rice, maize and millet will decrease by 10%, 7.9% and 26.1% whereas yield of wheat and barley will increase by 7.8% and 5.8% respectively. Therefore, the impact of climate change shows that summer crop yields will decrease and winter crop yields will increase.*

**Key Words:** Water Balance, Hydrological Modeling, Climate Change, Crop Yields, SWAT

## INTRODUCTION

The Himalayan region is considered sensitive to climate change (CC), and developing countries, such as Nepal, are more vulnerable to CC because they have limited capacity to adapt to it (IPCC 2001). The Fourth Assessment of the Intergovernmental Panel on CC (IPCC 2007) states that due to increasing concentration of greenhouse gases in the atmosphere, a warming of about 0.2°C per decade is projected for the next two decades for a range of Special Report on Emissions Scenarios (SRES). The mountain regions of Nepal

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are the major source of water storage in the form of ice and snow. Between 1977 and 2000, the mean maximum temperature of Nepal increased by 0.06°C per year (Hua, 2009). The rise in temperature will affect the hydrological cycle, which in turn will have an impact on water availability, evapotranspiration, runoff and the discharge regime of rivers (Sayari et al., 2011).

Water has been identified as the key resource for development and economic growth of Nepal (WECS, 2011); therefore managing spatial and temporal water resources variability is critical in river basins that are vulnerable to climate change. In Nepal, most of the agricultural land in the hills and middle mountains depends on the rainfall and only few lands have irrigation access from local streams. The irrigation water management should be balanced with soil fertility management to increase the monsoonal crop yields and increasing soil fertility without considering the irrigation could result in crop failure (Shrestha et al., 2013). Consequently, agricultural production depends on the water availability in the local streams; and on the amount and timing of rainfall. Therefore, the central idea of this paper is to evaluate the impact of climate change on the soil water balance in the agricultural lands of the West Seti River sub-basins and subsequently to measure change in the yields of cereal crops. The spatially distributed agro-hydrological models are widely used to simulate hydrological parameters and crop yields in the river basin scale. Thus Soil and Water Assessment Tool (SWAT) is used to simulate water balance and crop yields in this study.

## STUDY AREA: THE WEST RIVER SUB-BASIN

According to a study on climate change vulnerability in the middle and high mountain regions of Nepal (Siddiqui et al., 2012), the West Seti sub-basin was identified as one of the most vulnerable sub-basins in relation to climate change. The West Seti River Sub-basin is located in the far western region of Nepal (Figure 1) and has a catchment area of 7,438 $km^2$ and has confluence point with the Karnali River as the basin outlet. The sub-basin originates from the snow fields and glaciers around the twin peaks of Api and Nampa in the south facing slopes of the main Himalayas. The average elevation of the sub-basin is 2505 m but it varies from 314 m at sub-basin outlet, to 7043 m of Api and Nampa high mountain ranges. The West Seti River is one of the major tributaries of Sapta Karnali River (the longest river of Nepal). In the period of 1981 to 2010, the average annual rainfall within the sub-basin was 1921 mm whereas seasonal precipitation was 137 mm in the winter; 261 mm in the pre-monsoon; 1449 mm in the monsoon; and, 74 mm in the post-monsoon seasons. Therefore, in this sub-basin almost 75% of annual rainfall occurred during the monsoon season. In the period 1981-2010, the daily maximum temperature varied from -17.3°C to +46.7°C and minimum temperature varied from -23.4°C to +31.3°C. The projected climate result shows that the average daily maximum temperature will change by -0.62°C to +0.66°C per decade and minimum temperature will change by -1.14°C to +0.03°C per decade in this study area. This shows an average day becomes hotter and night becomes colder.

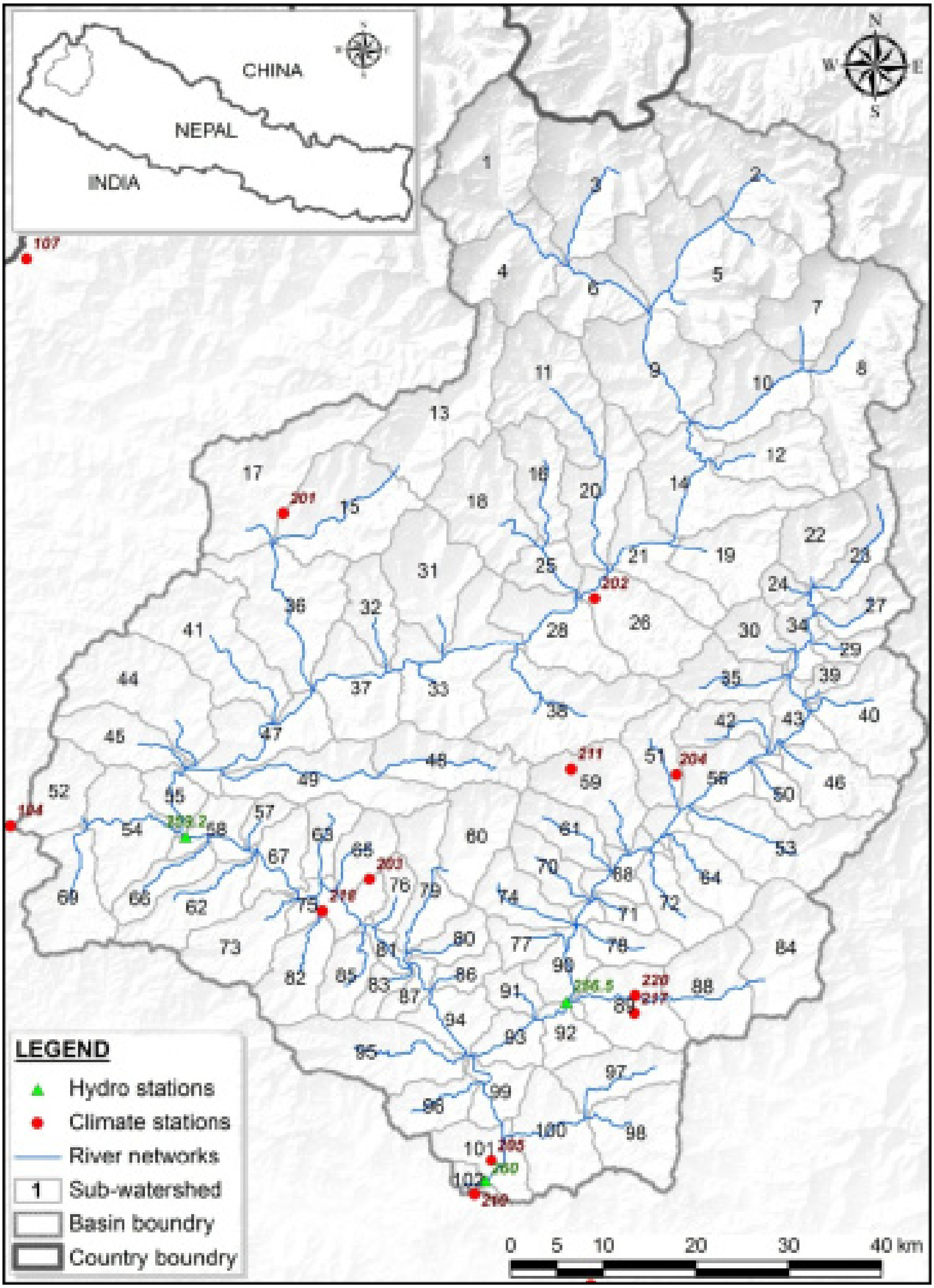


*Figure 1: West Set River Sub-basin/Sub-watersheds with location of hydro meteorological stations*

## DATA AND SOURCES

### Hydro-Meteorological Data

SWAT requires time series of observed climate data i.e. rainfall, minimum and maximum temperature, solar radiation, wind speed and relative humidity. In this study, time series climate data from 1981to 2010 from Department of Hydrology and Meteorological (DHM) of Nepal was used for model input. In addition, daily observed hydrological data obtained from DHM was used to calibrate and validate the model output. Altogether, data from 15 climate stations and 3 hydro stations was used for this study.

In this study, projected climate data from DHM (downscaled from PRECIS, and WRF regional climate models) were used to model future scenarios. The downscaled climate variables were based on the five global climate models (GCMs): ECHAM5, and HadCM3 in PRECIS; and, Era40, CCSM, ECHAM5, GFDL, and HadCM3 in WRF. The average of projected climate data from these seven projections, under A1B scenario, was used to assess climate change impacts. The projected climate time series data covered the periods from 1971 to 2000 as base line and 2031 to 2060 as the future projection.

### Spatial Data

SWAT requires three basic files for delineating the basin into sub-basins and hydrologic response units: Digital Elevation Model (DEM); Soil map; and, Land Use/Land Cover (LULC) map. The Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model Version 2 (GDEM V2) with 1-arc second (approximately 30 m at the equator) resolution is used for the DEM in this study. This ASTER GDEM was jointly developed by the Ministry of Economy, Trade, and Industry (METI) of Japan and the United States National Aeronautics and Space Administration (NASA). The sources of the land cover map and soil map are from National Land Use Project (NLUP), Ministry of Land Reform and Management (MoLRM), Nepal.

### Agricultural Data

Based on MoAC (2005), the crops considered in this study are: rice, maize, wheat, barley, millet, potato, oilseed, sugarcane and vegetables. Agricultural fields in level terraces are classified into rice (19%), millet (16%), sugarcane (1%) and vegetables (64%) whereas agricultural fields in slope terraces are classified into maize (36%), oilseeds (6%), potato (8%) and vegetables (50%). All the agricultural fields in river valleys are classified as rice fields. Wheat and barley are considered as winter crops in rotation with summer crops such as rice, maize, millet, oilseeds and vegetables; whereas sugarcane and potato do not contain a second crop.

## METHODS

### Soil and Water Assessment Tool (SWAT)

SWAT is a process-based continuous hydrological model that predicts the impact of land management practices on water, sediment and agricultural chemical yields in complex sub-basins with varying soils, land use and management conditions (Arnold et al., 1998; Neitsch et al., 2011; Srinivasan et al., 1998). The main components of the model include: climate, hydrology, erosion, soil temperature, plant growth, nutrients, pesticides, land management, and, channel and reservoir routing. Conceptually SWAT divides a basin into sub-basins. Each sub-basin is connected through a stream channel and further divided in to Hydrologic Response Unit (HRU). HRUs are a unique combination of a soil and a vegetation type in a sub watershed, and SWAT simulates hydrology, vegetation growth, and management practices at the HRU level.

The hydrologic cycle as simulated by SWAT is based on the water balance equation:

$$SW_t = SW_o + \sum_{i=1}^{n}(R_{day} - Q_{surf} - E_a - w_{seep} - Q_{gw}) \quad (1)$$

Where,

| | | |
|---|---|---|
| $SW_t$ | : | Final soil water content (mm) |
| $SW_o$ | : | Initial soil water content (mm) |
| $t$ | : | Time (day) |
| $R_{day}$ | : | Amount of precipitation on day $i$ (mm) |
| $Q_{surf}$ | : | Amount of surface runoff on day $i$ (mm) |
| $E_a$ | : | Amount of actual evapotranspiration on day $i$ (mm) |
| $w_{seep}$ | : | Amount of percolation on day $i$ (mm) |
| $Q_{gw}$ | : | Amount of return flow on day $i$ (mm) |

Since the model maintains a continuous water balance, the subdivision of the basin enables the model to reflect differences in ET for various crops and soils. Thus, runoff is predicted separately for each sub-basin and routed to obtain the total runoff for the basin. This increases the accuracy and gives a much better physical description of the water balance. More detailed descriptions of the model can be found in Arnold et al. (2011) and Neitsch et al. (2011).

The SWAT model partitions crop yield from the total biomass on a daily basis (Arnold et al., 2011). The partitioning is based on the fraction of the above-ground plant dry biomass removed as dry economic yield and this fraction is known as harvest index (Neitsch et al., 2011). The harvest and kill operation is enabled to evaluate the crop yields in the modeling. The equations for the crop yield are;

$$YLD = bio_g \times H \qquad \text{when } H \leq 1 \tag{2}$$

$$YLD = bio \times \left(1 - \frac{1}{1+H}\right), \qquad \text{when } H > 1 \tag{3}$$

Where,

$YLD$ = Crop yield (kg/ha),

$bio_g$ = Above-ground biomass on the day of harvest (kg/ha),

$H$ = Harvest index on the day of harvest, and

$bio$ = Total plant biomass on the day of harvest (kg/ha)

In this study, the harvest index considered for optimal growing conditions are: rice, 0.50; maize, 0.50; millet, 0.25; wheat, 0.40; and, barley, 0.54. Whereas the harvest index considered under highly stressed growing conditions are 0.25, 0.30, 0.10, 0.20, and 0.20 for rice, maize, millet, wheat and barley respectively. The potential harvest index for a given day is depend of the harvest index for the plant at maturity given ideal growing conditions and the fraction of potential heat units accumulated for the plant (Neitsch et al., 2011). Thus SWAT takes into account the change in harvest index for the crops when there is water stress at certain phases of the crops. The equation for the actual harvest index in water stress condition is;

$$H_{act} = (H - H_{min}) \frac{\gamma_w}{\gamma_w + \exp[6.13 - 0.883\gamma_w]} + H_{min} \tag{4}$$

$$\gamma_w = 100 \frac{\sum_{i=1}^{m} E_a}{\sum_{i=1}^{m} E_o} \tag{5}$$

Where,

$H_{act}$ = Actual harvest index,

$H_{min}$ = Harvest index for the plant in drought conditions,

$\gamma_w$ = Water deficiency factor,

$E_a$ = Amount of actual ET on day $i$ (mm),

$E_o$ = Amount of potential ET on day $i$ (mm),

$i$ = Day in the plant growing season, and

$m$ = Day in harvest

## MODEL CALIBRATION AND VALIDATION

The stations and period considered for model calibration and validation are described in Table 1. The model performance is determined by Nash-Sutcliffe Efficiency (NSE) with respect to the daily and monthly observed flow data (Karki, 2012). The performance (Table 1) is acceptable as described by Liu and De Smedt (2004); and, Moriasi et al. (2007). Whereas, the simulated crop yields are not validated due to lack of data therefore only changes in crop yields are presented in this study.

**Table 1: Hydrological Stations in the West Seti River Sub-basin and Model Performance (Karki, 2012)**

| Station | Period | | Model Performance (%) | | | |
|---|---|---|---|---|---|---|
| | Calibration | Validation | Calibration | | Validation | |
| | | | Daily | Monthly | Daily | Monthly |
| Budhi Ganga, Chitreghat | 2001-2003 | 2004-2006 | 73 | 90 | 60 | 78 |
| Seti River, Gopaghat | 1986-1990 | 1991-1995 | 67 | 86 | 54 | 90 |
| West Seti, Banga | 1981-1985 | 1986-1990 | 74 | 93 | 68 | 85 |

## RESULTS AND DISCUSSIONS

### Trend of Actual Evapotranspiration (ET) and Crop Yields

Figure 2 represents the correlation between simulated annual actual ET and crop yields for the period from 1981 to 2010. This study considers three scenarios of crop rotations in a year. They are;

Rice-Wheat-Vegetables rotation scenario,

Millet-Wheat rotation scenario, and

Maize-Barley rotation scenario

The study shows a positive correlation between actual ET and crop yields however, the correlation coefficients are less than 0.50 in all crop rotation scenarios. In scenarios (a) and (b), crop yields gradually increase with respect to increase in actual ET. Linear trend lines show that the ratios of actual ET by crop yields are 0.95 and 0.84 in scenarios (a) and (b) respectively. In contrary, the scenario (c) shows crop yields increase slightly with respect to an abrupt increase in actual ET. Hence, the linear trend line shows that the ratio of actual ET by crop yields is 3.52 in scenario (c).

Figure 3 illustrates the trend of change in actual ET and crop yields under the selected crop rotation scenarios in the period from 1981 to 2010. Results show a declining trend of both actual ET and crop yields in the simulation period. The trend of changes in crop yields is following the trend of change in actual ET in all crop rotation scenarios.

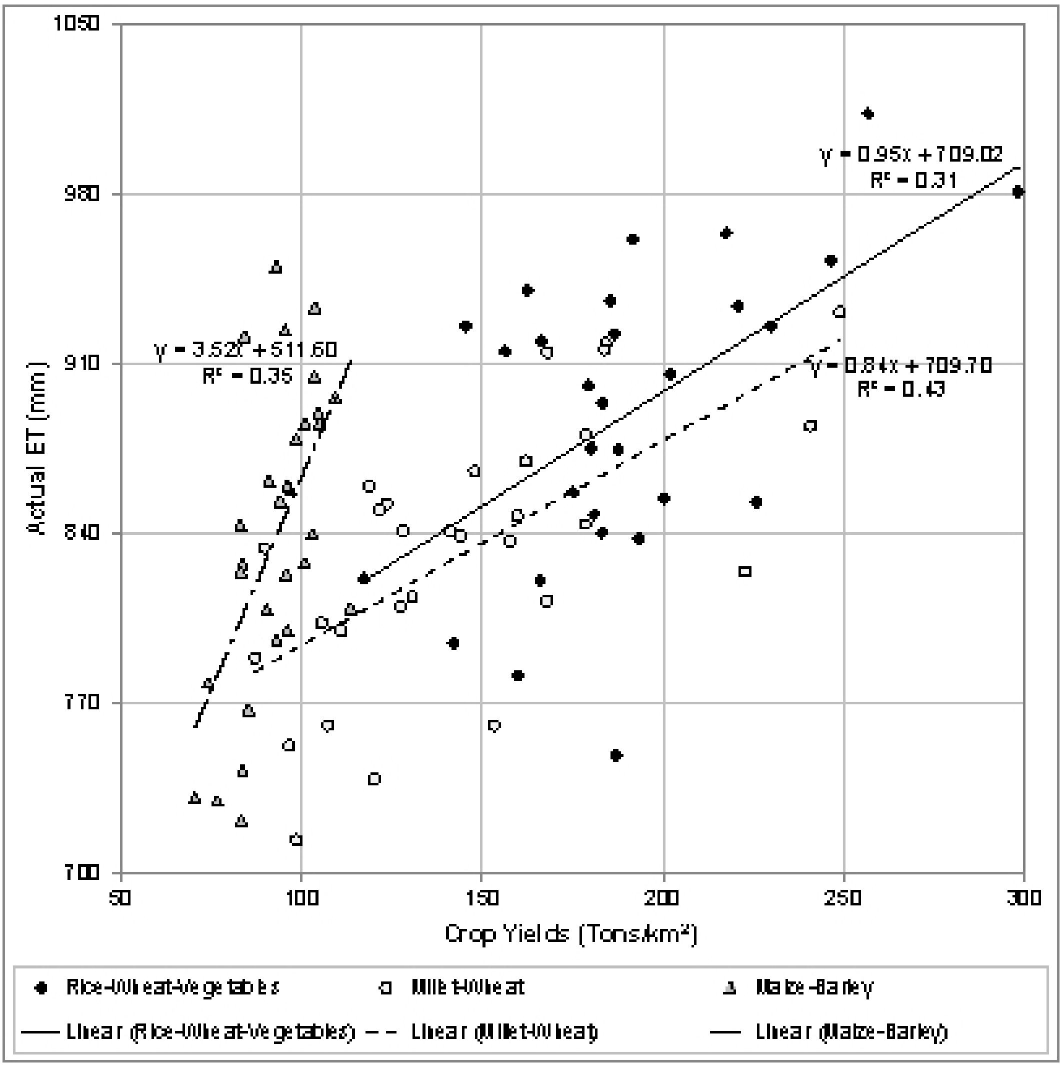


*Figure 2: Correlation between Simulated Annual Actual Evapotranspiration (ET) and Crop Yields under Selected Crop Rotation Scenarios for 1981-2010 Periods*

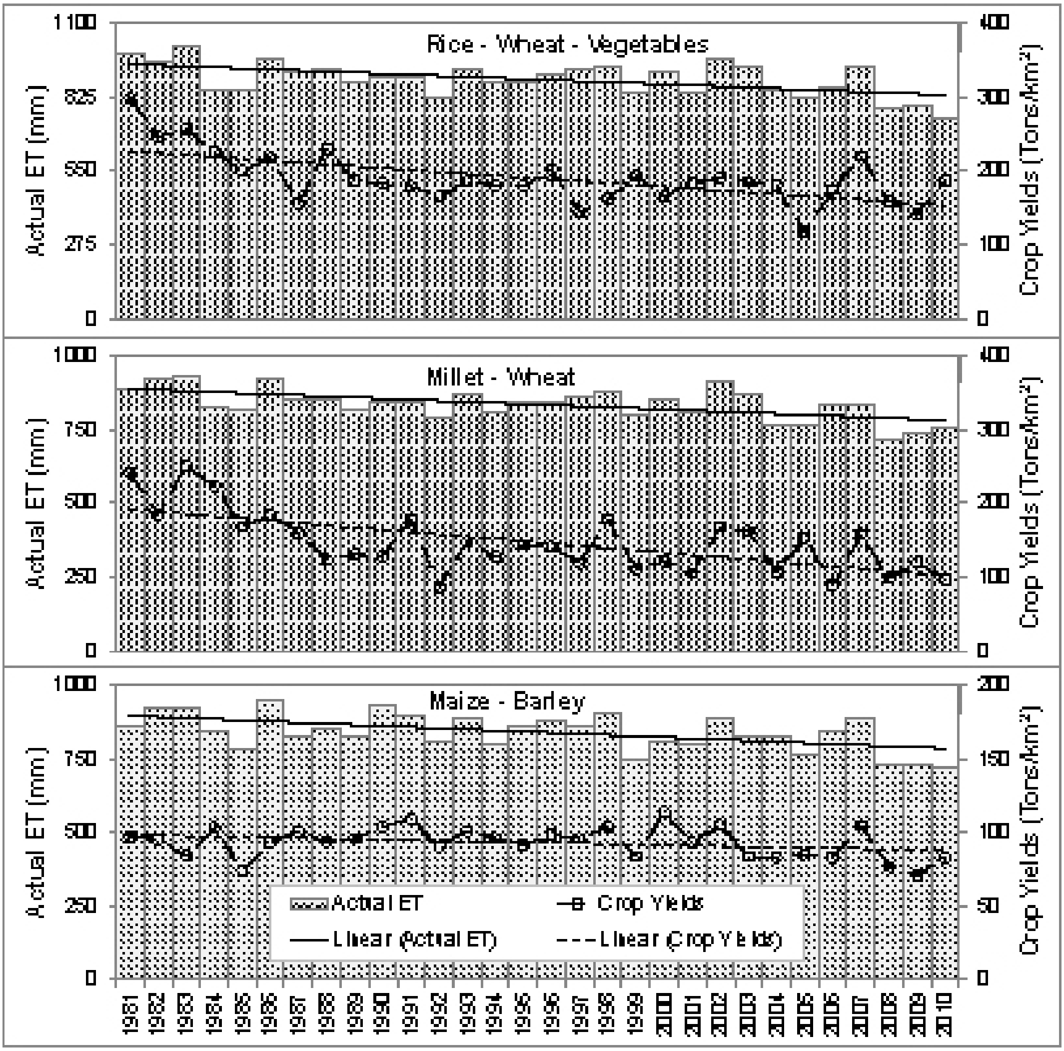


*Figure 3: Actual Evapotranspiration (ET) and Crop Yields Trend under Selected Crop Rotation Scenarios for 1981-2010 Periods*

**Water Balance and Crop Yields**

As afore mentioned, the model runs from 1981 to 2010 with daily climate data and the outcome of this study represents average results over a 30 year period as a current climate scenario. The model result shows that total precipitation over rice, maize, millet, wheat and barley fields are 1002 mm, 818 mm, 788 mm, 186 mm and 169 mm respectively whereas total simulated actual ET are 534 mm, 452 mm, 322 mm, 138 mm and 177 mm respectively under the current climate (Table 2). Similarly, simulated surface runoff from the crop fields and crop yields are presented in the Table 2. In the study, the total surface water yields are validated with the observed river flows however the simulated crop yields are not validated as there are no available data which spatially covers over the study area. All the crops are considered as rain-fed and the auto-irrigation option of model is enabled in the simulation. In auto-irrigation option, the model will automatically apply water up to a maximum amount whenever there is water stress in crops (Neitsch et al., 2011). Hence this study only looked into how climate change will impact on the crop yields with default parameters of the model and by auto-application of irrigation.

**Table 2: Simulated Water Balance and Crop Yields under Current Climate**

| Variables | Summer Crop | | | Winter Crop | |
|---|---|---|---|---|---|
| | **Rice** | **Maize** | **Millet** | **Wheat** | **Barley** |
| Precipitation (mm) | 1002 | 818 | 788 | 186 | 169 |
| Actual ET (mm) | 534 | 452 | 322 | 138 | 177 |
| Surface Runoff (mm) | 235 | 175 | 170 | 7 | 10 |
| Crop Yields (Tons/km$^2$) | 54 | 83 | 15 | 45 | 29 |

## Impact of Climate Change on Water Balance and Crop Yields

The climate change impact study is assessed by comparing between the model results of baseline (from 1971 to 2000) and future projections (from 2031 to 2060). The model results show that the total precipitation will change by -4.4% in rice, +0.5% in maize, -9.5% in millet, +37.3% in wheat, and +30.6% in barley fields. Similarly, actual ET will change by +0.7% in rice, +3.4% in maize, -3.4% in millet, +41.2% in wheat, and +36.2% in barley, under future climate projections. Actual ET will increase in all crops except in millet because water availability will decrease in the millet fields. The linear correlation will occur in the percentage change between precipitation and actual ET; and, between crops yield and actual ET (Figure 4). However, the correlation equations between actual ET and crop yields are different between summer and winter crop (Figure 4). The change in surface runoff on the crop fields is presented in the Table 3. Whereas the impact of climate change results show that crop yields from rice, maize and millet will decrease by 10%, 7.9% and 26.1% respectively, the yield of wheat and barley will increase by 7.8% and 5.8% respectively under future climate. The precipitation on the summer crops will decrease, except in maize which will impact negatively on the crop yields (Table 3). Whereas, precipitation on the winter crops will increase and this will lead to an increase in crop yields. Hence, the impact of climate change shows that summer crop yields will decrease and winter crop yields will increase. Therefore, the changes in amount of precipitation will impact on the actual ET, and then on the crop yields.

Table 3: Percentage Change in Simulated Water Balance and Crop Yields under Future Climate

| Variables | Summer Crop | | | Winter Crop | |
|---|---|---|---|---|---|
| | Rice | Maize | Millet | Wheat | Barley |
| Precipitation | -4.4% | +0.5% | -9.5% | +37.3% | +30.6% |
| Actual ET | +0.7% | +3.4% | -3.4% | +41.2% | +36.2% |
| Surface Runoff | -12.6% | -6.3% | -16.9% | +21.9% | +18.1% |
| Crop Yields | -10.0% | -7.9% | -26.1% | +7.8% | +5.8% |

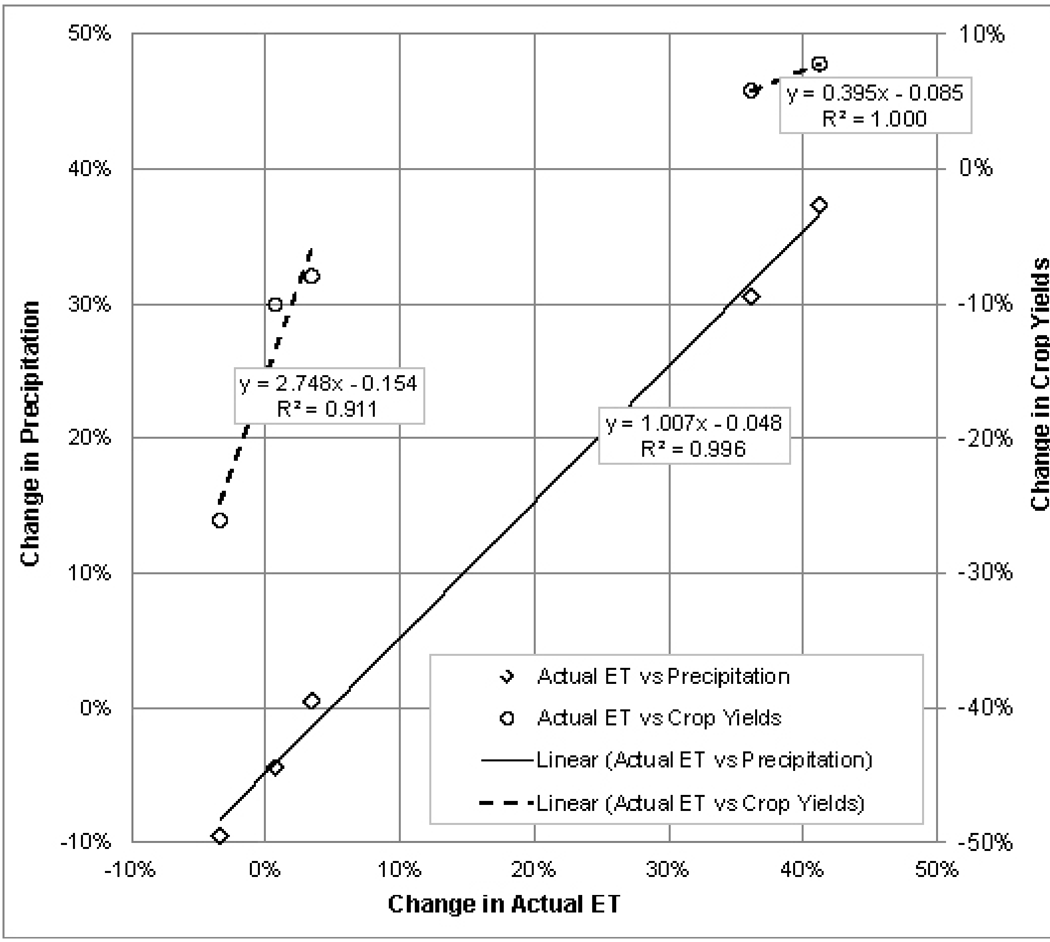


*Figure 4: Correlation of Percentage Change between Precipitation and Actual ET, and between Crop Yields and Actual ET under Future Climate Scenario*

## CONCLUSION

The result of the model simulation under current climate conditions shows declining trends of actual ET and crop yields in this study area. The projected model results show that summer precipitation will decrease except on the maize fields and winter precipitation will increase; whereas actual ET will increase for all crops except in millet under future climate scenario. As a result, summer crop yields will decrease and winter crop yields will increase under projected climate change scenarios. However, there is large degree of uncertainty in the simulated results due to disagreement among the projected future climate scenarios (Bharati et al., 2012) and this uncertainty can reliably be reduced by using only a selection of GCMs that shows high inter-model similarity for the current and future climate (Sperna Weiland et al., 2012).

The SWAT model is found to be a good tool to simulate the water balances and crop yields under current and future climate scenarios. However, the model's performance will depend on the model inputs and availability of observed data to validate output. In this study, simulated water balance components are more precise due to the availability of observed river flow data. Whereas, due to unavailability of spatially coverage of crop yields data, the study is confident to present only changes in crop yields under future climate scenario.

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# Improved food security and income for small farmers through pond irrigation

***Er. Susan Shakya*[1]**

*Pond irrigation systems: These are new irrigation systems which are usually situated in comparatively higher and colder areas (~ 1600 masl in average), highly potential for fresh vegetable farming. Fresh vegetables are cash crops that can increase income of farmers by far more that of cereal crops in a given area of land compared to cereal crops like wheat, maize, millet or paddy, provided market linkages are established. In this type of system water is collected in pond which is lined and sealed with sheet membranes. The sheets are water proof, resilient to harsh weather conditions; less affected by earth-movements, affordable for small farmers and can be easily repaired in case of small tears and replaced in case of damage. The water is conveyed to pond from springs or streams by means of pipes through gravity flow. Once the water is brought to farmers' land from distant water sources, the farmers are usually smart to utilize water efficiently. Since this type of system is often built in water deficit areas, farmers need to distribute water on equal basis, provide labor force equally for construction and contribute to operation and maintenance fund equally.*

*The pond irrigation system is implemented in selected food deficit areas in Nepal's rural central-eastern and mid- & far-western regions in seven districts as mentioned above through HELVETAS Swiss Intercooperation Nepal with financial support of Swiss Development Cooperation. They are hill areas, altitude ranging from 500 m to 2000 m above sea level. The size of pond practiced are 15, 30, 45 and 60 cubic meters which depends upon available water and proposed command area.*

*The potentiality of replication is proven as the pond irrigation technology is recognized by government bodies and "one village one pond" programme announced. The technology is also adapted by Community Irrigation Project (CIP) which is funded by ADB and is active in 12 other districts of Nepal.*

*Since the technology is simple, affordable and can bring significant difference in the livelihood of small farmers, local government bodies have shown interest to adapt pond technology. Some farmers have been practicing the technology for 5 years and have become one of the major sources of income.*

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1 Technical Coordinator, LILI HELVETAS Swiss cooperation Nepal

*The main factors of success are:*

- *The technology is simple to understand and implement by local technicians and farmers.*
- *It is a low-cost technology having a high probability of economic benefits.*
- *The technology is suitable for hill areas which account for more than 50% of the land area in Nepal.*
- *The technology is appropriate for small farmers striving for additional income from their small land.*
- *The technology is environment friendly.*

## INTRODUCTION

The Nepalese economy is dominated by agriculture as the main source of food, income, and employment for the majority in the country. To increase agricultural production, the Nepalese Government promotes irrigation, the use of fertilizers and insecticides, the introduction of new seeds of better adapted and high-yield varieties, and the provision of credit. A considerable gap exists in the provision of irrigation facilities in the hill areas, where only about 27% of irrigable land is irrigated. In rural areas, the prevailing socio-economic exclusion and inappropriate land use combined with discriminatory land tenant systems have a negative impact on the livelihood conditions of marginalized and small farmers[2]. In order to address the increased pressure on rural livelihoods and some of the issues raised above, LILI[3] (Local Infrastructure for Livelihood Improvement Project) was conceived in 2004 by HELVETAS Swiss Intercooperation Nepal with the objective to improve food security and income by providing better access to water for irrigation to poor farmers with predominantly marginal landholding in selected food deficit areas of Nepal's rural central-eastern and mid- & far-western regions in seven districts.

### Pond Irrigation System:

Pond irrigation systems are non conventional type of Irrigation system practiced in water scarce area of mid hills focusing high value crops eg seasonal/off-seasonal vegetables. The system comprises intake at the water sources (mostly perennial spring source), pipe lines and pipes from intake site to near the pond sites, flow regulating chambers to distribute the water proportionately to different ponds, ponds 2-5 in number as per the need, water distribution post as outlets for irrigation.

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2 Small Farmer: Farmer having land less than 0.5 ha

3 LILI: Local Infrastructure for Livelihood Improvement Project, Project funded by Swiss Development Cooperation (SCD Nepal)

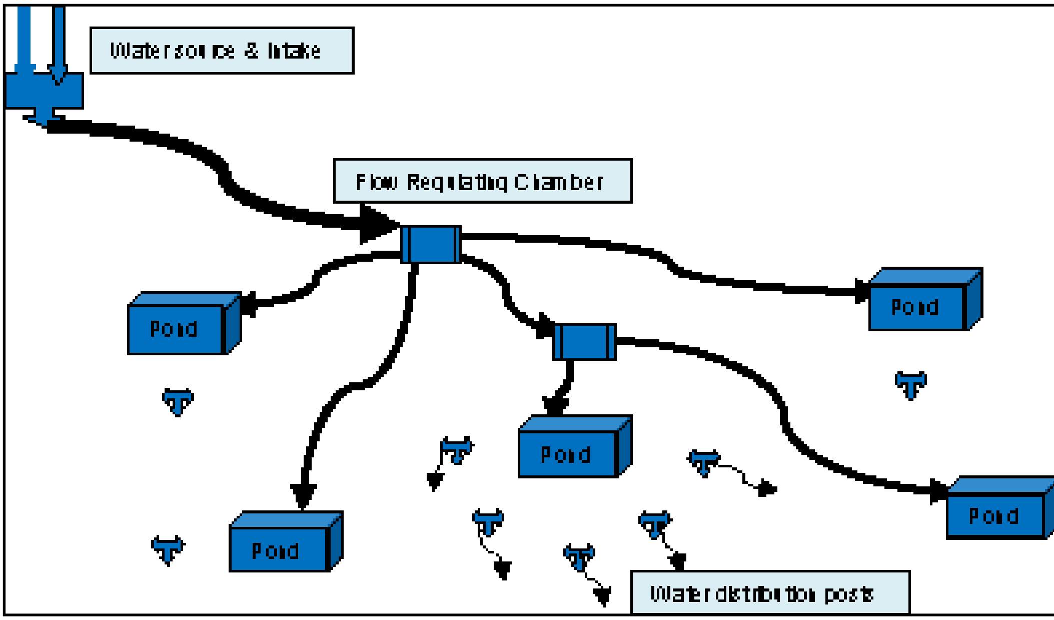


*Figure 1: A typical layout of Pond Irrigation System*

In pond irrigation system water is collected in ponds excavated at the field and lined with water-resistant membrane (200 GSM SILPAULIN sheet membranes). The water is conveyed to pond from spring or stream as gravity flow by means of HDE pipes. Once the water is brought to farmers' land from distant water sources, the farmers can utilize it as per their agricultural plan and water sharing policies. The pond irrigation systems can be easily constructed at the regular but small water sources exist above the farm land. The size of pond practiced are 15, 30, 45 and 60 cubic meters which depends upon available water and proposed command area.

*Figure 3: Pond with soil cement jute bag lining*

*Figure 2: Excavated Pond with Lined*

The excavated pond is lined with 200 GSM[4] Silpulin sheet. The Silpaulin sheet is water proof, resilient to harsh weather conditions, less affected by earth-movements, affordable for small farmers, easy to repair in case of small tears and replaceable in case of damage. Life of the Silpaulin membrane sheet is generally claimed to be at least 10 years with the exposed of sun. Although, certain cautions are needed to care from damage of Silpaulin sheet caused by hitting the solid objects to the empty pond and firing. However, the punctured silpaulin membranes can also be repaired by sticking pieces of similar sheets with adhesives supplied, Soil Cement Jute bag[5] lining over Silpaulin sheet is more safe and favored by farmer.

## FOOD SECURITY AND INCOME

Nepal being predominantly agricultural country with subsistence types of agriculture, above 65% of the farmers adopt traditional agricultural pattern with traditional water management practices. Meantime Nepal has huge discrepancy in land occupation by the peasant farmers. More lands are occupied by less people, i.e. about 5% farmers owing 37% of total agricultural land against 47% of the farmers owning just 15 % of land (http://www.ngofederation.org/index ), similarly, the major water sources are well captured and utilized by the rich farmers. Thus land and water availability is highly skewed fostering inequality among the Nepalese Society. The poor and small land holding farmers are often suffering from social and cultural conflicts on water right issues. There are various efforts made from public and other development agencies to increase the irrigation water availability with harmonized social harmony in a participatory way. The Pond Irrigation system is focusing to small farmers residing hilly areas in scattered way. The system is highly potential for fresh vegetable farming, seasonal and off-seasonal. Fresh vegetables are cash crops that can increase income of farmers by far more that of cereal crops in a given area of land compared to cereal crops like wheat, maize, millet or paddy, provided market linkages are established

The study report of LILI HELVETAS Swiss Intercooperation Nepal revealed that the Pond Irrigation Systems are more favorable in comparison to conventional type Canal Irrigation system for small farmers in terms of increase in cropping intensity, farm income and beneficiaries coverage. This paper highlights the success of small land holding farmers in managing scarce water sources through pond irrigation system and increase their food security and income.

This study is the analysis of 308 small irrigation schemes completed in different region of Nepal with the support of LILI HELVETAS Swiss Intercooperation Nepal within the period of three years (2009 to 2012). Total out 308 small irrigation schemes 112 schemes are Canal Irrigation system and remaining 196 schemes are Pond Irrigation system. The study showed that the coverage of DAGs[6] as beneficiaries in pond irrigation system is more than

4 GSM: Gram per square meter (represent the thickness of Silpaulin sheet)
5 Soil Cement Jute bag: Jute bags filled with mixture of soil cement in about 1:12 ratio to protect Silpulin
6 *DAG: Disadvantaged Group*

in Canal Irrigation System. In Pond Irrigation System about 58% beneficiaries are belongs to DAG but in Canal Irrigation system only 47% beneficiaries are DAG. Likewise the beneficiaries having less land are more in Pond Irrigation System than in Canal Irrigation System. The average size of land per households in Pond Irrigation system are about 2.2 Ropani but in the case of Canal Irrigation System the average size of land is about 4.12 Ropani.

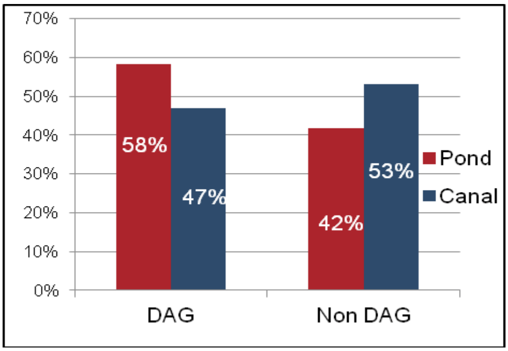


*Figure 5: Land Holding per HHs (Ropani)*

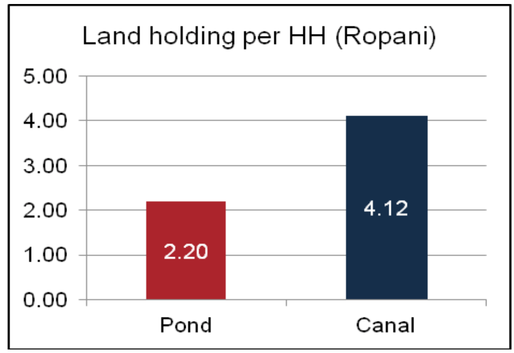


***Figure 4: Beneficiaries coverage (HHs)***

The study also revealed that the increase of cropping intensity in comparison with the base line survey (without irrigation facility) is almost same about 40 % in Pond and Canal Irrigation system. In spite of almost same increase of cropping intensity the farm income in the case of Pond Irrigation system is much higher than in Canal Irrigation system. The regular irrigation water availability at *bari* land nearby resident supported to adopt new cash crops mainly off season vegetables to increase their income per Ropani land by NRS 630/- in average than in Canal Irrigation system.

| Year | Types of schemes | Cropping intensity | | Net Income (Rs/ Rop.) |
|---|---|---|---|---|
| | | Baseline survey | Outcome Monitoring survey | |
| 2011/12 | Pond | 162% | 216% | 4320 |
| | Canal | 150% | 195% | 3867 |
| 2010/11 | Pond | 187% | 227 % | 2'191 |
| | Canal | 150% | 200% | 1,779 |
| 2009/10 | Pond | 218% | 250 % | 3,047 |
| | Canal | 196% | 222 % | 2,018 |

Figure 6: Cropping Intensity & Net Income per Ropani land

## CONCLUSION AND RECOMMENDATION

The Pond Irrigation system may be the best option in hill areas because the flow of water from source to pond is gravity-flow and is conveyed by means of pipe. The climate in these areas of Nepal is suitable for both season and off-season vegetable farming. The farmers of these areas work extremely hard to earn their living and also opt for seasonal migration to India for earning. With the available small land, usually less than half a hectare, the technology would be a boon for making a better living for small farmers, provided agricultural services are imparted for initiating optimal cropping pattern and higher yields. Market linkages are crucial for ultimately improving livelihoods.

Pond Irrigation system serves the most vulnerable groups of the society mainly, women, *Dalit* and *Janjati* community who otherwise have no other livelihood options than the agriculture in their settlement. To upscale this solution, the technology should be incorporated in governments' plan and policy. Trainings related to technology should be provided to authorities of government bodies at local and national level but also disseminated with farmers, other governmental and non-governmental organizations and donor agencies world-wide. A harmonized planning process and implementation modality should be agreed among major stakeholders to ensure that supports are received by the needy ones.

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# Economics of Irrigated Crops: Major Indicators for modernization and commercialization of Agriculture

***Tulasi Gautam* [1]**

***Abstract***

*This paper assesses economics of irrigated crops comparing traditional Vs high value crops. Profitability is the main indicator for commercialization and shifting from traditional practices into new technology can be termed as the modernization. For the technology adoption, irrigation is vital component. Realizing this fact, Nepal government has allocated more budgets in irrigation to enhance both agriculture production and productivity in Nepal. However, Year Round Irrigation covers only 18 per cent despite the seasonal irrigated area. This seasonal irrigated area is reported to be 1254000 hectare. By ecological distribution, Terai shares 81 per cent followed by mid- hills (15%) and High- hills (4%). This is because of limited low land area for surface irrigation. For these mid-hills and high-hills, Non Conventional Irrigation Technology (NCIT) is more suited. Such irrigation technology should be expanded in upland hills while integrating market oriented agriculture products based on climate changing environment. Farmers of Okhreni VDC of Ramechhap district and Panena VDC of Arghakhanchi district are shifted from maize to vegetable and mandarin–orange production through pond and sprinkler irrigation .These are illustrative examples of modernization and commercialization. Such practices are found in other hill areas too. The efficient use of scarce water in the hills can be taken as a lesson for Terai and other Valley areas of hills. The economics of irrigation has been assessed analysing benefit cost ratio and crop productivity along with market prices. These could be taken as the major indicators for the modernization and commercialization of agriculture sector. However, these needs mandatory in irrigation and improved agriculture programs for more productive investment in these sectors. Indeed, irrigation can contribute to enhance agricultural production if it is properly integrated as a part of agriculture development package. This statement envisaged in Nepal Agriculture Sector Strategy 1982 is still valid. Policy recommendations are implementation of land use policy( Irrigated land should not be used in housing, industries, other settlements and fish pond construction), there needs strong mandatory of integration of irrigation and agricultural extension technology program, Need to establish one apex body to look for irrigation system by restructuring the existing organizational structures. And need to update statistical information on irrigation coverage, cropping intensity, productivity, food security and livelihood issues based on irrigation.*

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1 Agri economist

एही ठाममे अध्ययन जरूरी नही थी क । यी सब बेकार थिक आवश्यकता अछी त केवल सिचाइके । अध्ययन मे जतेक खर्च लागत ततकमे त एही ठाममे सिचाइ भ जायत ।

२०३९ मा धनुषा इटहरवा १ का किसानको भनाई

किसानको आस, बिकासे प्रयास , तुलसी गौतम कान्तिपुर , २०६३.१२.१७

## INTRODUCTION

Irrigation is considered as the pre-condition for agricultural prosperity as strongly felt by farmers and government. This is because of the fact that it allows agriculture for the intensification and diversification through technology transformation. Realizing this fact, government has taken responsibility to provide irrigation facilities to the farmers as a public good. The reason behind this is that agriculture is the way of life for the majority of population in terms of livelihood, employment and income. These are small farmers having poor infrastructure of irrigation. They need strong support in the construction of irrigation cannels and dams, which requires heavy investment. The total irrigated area is estimated to be 1254000 hectare land in 2012, this is some lower than targeted coverage-1400000 hectares under Three Years Plan in 2012/13. The potential irrigated area is estimated to be 1700 thousands ha. However, the irrigation and agricultural updated statistics are questionable requiring correction. Housing construction, fish pond construction, other settlements, establishment of industries etc have further encroached irrigated areas ignoring land use policy of Nepal. The seasonal and year-round irrigation coverage, area covered by crops is often questionable statistics. Yet, there is no other option for the correction at present. For this, statistical correction techniques should be explored while sharing the ideas and use of satellite. In the present available information basis, Terai shares highest coverage i. e 81 per cent followed by Mid-Hills 15% and High-hills 4% respectively. Reasons for low irrigated land area in the Hills and Mountain Region are due to limited low land area for surface irrigation. For these mid-hills and high-hills, Non Conventional Irrigation Technology (NCIT) is more suited.Such irrigation technology can be expanded in upland hills while integrating market oriented agriculture products based on climate changing environment.

In the basis of development region, Eastern region shares 33 per cent of the irrigated land, which seems highest compared to other regions. The Central region shares 32%, Western region 16%, Mid Western 11% and Far Western region 9% respectively. This paper highlights irrigation contribution to agriculture for modernization and commercialization. There are some macro level indicators in terms of economics of irrigation.

## INVESTMENT ON IRRIGATION AND AGRICULTURE

Irrigation, being the major input for crop production, it has received more budgets compared to agriculture in Government plans and programs. The following table itself depicts the volume of Government expenditure on irrigation and agricultural programs.

Table 1: Government Expenditure on Irrigation and Agricultural Programs during 1984/85 to 2010/11

| SN | Sector | Amount(Million Rs) |
|---|---|---|
| 1 | Irrigation | 78982.3 |
| | Agriculture | 71448.3 |

Source: Agricultural Statistical Information on Nepalese Agriculture, Ministry of Agriculture Development, Government of Nepal.

## MODERNIZATION AND COMMERCIALIZATION OF AGRICULTURE: A CASE OF VEGETABLE PRODUCTION IN NEPAL

Agriculture technology is highly responsive to irrigation. The shift from traditional to modern agriculture mostly depends on irrigation. In this respect, farmers are growing improved crops. Cropping intensity has been increased up to triple crops from mono crops. Also crops are replaced based on comparative advantage given market assurance. Now, vegetable area is increasing, where irrigation facilities are available. The area under vegetables is increasing steady in Terai compared to Mid-hills. Least expansion is found in the high hills constraint to mainly irrigation and climatic conditions. The following Chart illustrates the expansion of vegetable area by ecological reason over the time period.

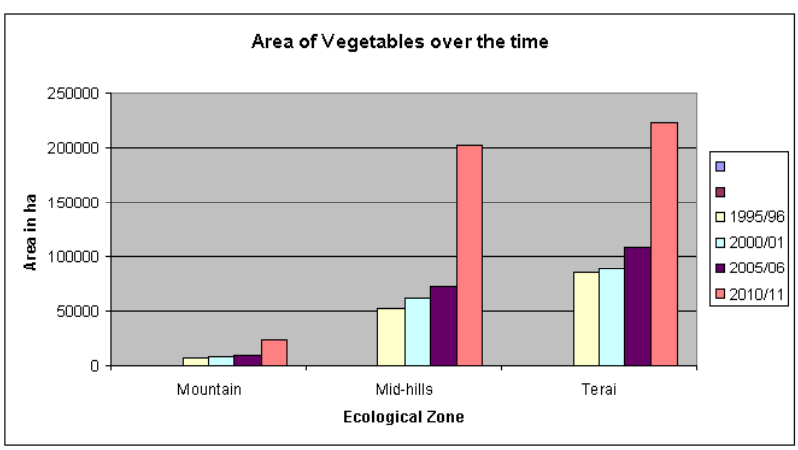


*Figure 1: Vegetable Area Expansion by development region over the period*

In those areas, where surface and ground water irrigation is not feasible, NCIT is introduced. The sprinkler and pond irrigation in the hills has direct impact on modernization and commercialization of agriculture. For instance, farmers in Panena VDC of Arghakhanchi district are shifted from maize to vegetable and mandarin –orange production using sprinkler irrigation. According to key informants, out of 42 households, 38 households have replaced mandarin–orange and vegetables instead of maize crop in their uplands. Similarly, in Okhreni VDC ,Katunje of Ramechhap district, pond irrigation has modernized traditional agriculture into the commercial one. The farmers of this area grow three times vegetable crops in a year based on market situation. Sweet- orange is another perennial crop for them. In both areas, maize became secondary crop. Thus, in both areas, commercialization has been taking place and socio-economic improvement has been clearly observed. These are some illustrative examples of modernization and commercialization through the provision of irrigation facility. Such practices are found in other hill areas too. The efficient use of scarce water in the hills can be taken as a lesson for Tarai and other Valley areas of hills.

Impact Study on small irrigation managed by farmers under Department of Agriculture (DOA) in 2010/11 shows increase frequency of crops for a year and enables farmers to use agriculture technology. As the result, average household (HH) income has increased by 30 per cent. Similarly, the average number of food availability in a year had been changed from 7.79 to 11.51 months and about 7 per cent of the HHs was not sending any children to school has started to send school.

Similarly, cost of production of major crops conducted by the Marketing Research and Statistics Management Program of DOA shows profitability level of different crops at farmers' practice. Benefit-cost ratio analysis known as B/C Ratio gives return to investment. This ratio shows that a rupee invested today yields worth of rupee. If there is 3.5 B/C ratios, this means, a rupee invested yields Rs.3.5. Higher the ratio, higher the return to the investment is denoted. Thus, irrigation is important for productivity and technology adoption. In other words, more productivity means lesser cost of production, and more income. So farmers are saying to the state ″Give irrigation and technology and take the production". However there are three Ministries in Nepal looking for irrigation; large and medium irrigation by Ministry of Irrigation (MOI), small by Ministry of Local Development (MOLD), and farm level by Ministry of Agriculture Development (MOAD). In some cases, there seems duplication of the activities and lack of coordination between agricultural extension technology and irrigation program. It should be mandatory. In Sunsari- Morang irrigation command area, shallow tube wells in Sunsari district are installed. This should be considered as the policy issue. Yet, irrigation is the most for farmers for the intensification and modernization of farm practices.

Table below shows vegetables yields more return to investment compared to cereal crops. Even in the vegetables, off-season carrot in Rupandehi district paid highest return to the investment.

Table 2: B/C Ratio of Different Crops

| Crops | B/C Ratio |
|---|---|
| **Paddy Terai** | 1.38 |
| **Paddy Hill** | 1.31 |
| **Wheat Terai** | 1.36 |
| **Wheat Hill** | 1.29 |
| **Carrot off-season (Rupandehi)** | 8.60 |
| **Carrot main season** | 3.96 |
| **Pea main season** | 2.20 |
| **Tomato** | 3.78 |
| **Cauli main season** | 3.01 |
| **Cauli off-season** | 3.78 |
| **Capsicum** | 3.31 |

The impact of irrigation can be judged from the productivity and market value measures. More production per unit of land means lesser cost of production. Table below illustrates both productivity and market values even in irrigated conditions indicating technological intervention options under the given environment. Here is the case of choices of crops to be grown.

**Table 3: Productivity and Price**

| Crops | Production (Kg/ha) | Price (Rs./Kg) |
|---|---|---|
| **PaddyTerai** | 3910 | 15 |
| **Wheat Terai** | 3301 | 18 |
| **Paddy Hill** | 3465 | 15 |
| **Wheat hill** | 3253 | 18 |
| **Carrot Off Season** | 15945 | 39 |
| **Carrot main season** | 15914 | 18 |
| **Pea main season** | 15785 | 16 |
| **Tomato** | 20631 | 21 |
| **Cauli Main Season** | 18763 | 17 |
| **Cauli offs** | 29418 | 12 |
| **Capsicum** | 18946 | 16 |

## CONCLUSION

These analyses strongly show economics of irrigation to modernize and commercialize agriculture sector. However, these needs mandatory in irrigation and improved agriculture programs for more productive investment in these sectors. "Indeed, irrigation can contribute to enhance agricultural production if it is properly integrated as a part of agriculture development package." This statement envisaged in Nepal Agriculture Sector Strategy 1982 is still valid.

## POLICY RECOMMENDATIONS

1. Land use policy: Irrigated land should not be used in housing and fish pond construction.

2. There needs strong mandatory of integration of irrigation and agricultural extension technology program.

3. Need to establish one Apex Body to look for irrigation system by restructuring the existing organizational structures.

4. Need to update statistical information on irrigation coverage, cropping intensity, productivity, food security and livelihood issues based on irrigation.s

# IWRM: Status in some of the river basins in Asia

***Ashish Bhadra Khanal*** [1]

**Abstract**

*Modernization and rise of the population globally in twentieth century putting pressure on the fresh water resources of the earth. Many dams in different rivers around the world are developed to harness water resources optimally. In the course of rapid urbanization and modernization, water demand in the city and town are soaring. In order to fulfill the demand and supply gap, water experts developed the idea of Integrated Water Resources Management (IWRM) in river basins. Based on the principles of IWRM, river basins development have been taking place in various countries of Asia too. This paper has attempted to present one of the each successful river basins development experience from Laos and Indonesia. Similarly it highlights the status of river basin development in Nepal. Despite accepting the fact that IWRM is the best mantra for water management, debate also exists about its perfection in Sri Lanka. Also in Southern India owing to polity, interstate water disputes are continuously undermining the principle of IWRM. Taking into account of these lessons, principles of IWRM can be improved so that water conflict can be avoided within a river basin.*

*Key Words: IWRM, River basin, water resources*

## BACKGROUND

An early example of an integrated approach took place in the 1930s in the United States of America (USA), with the development of comprehensive watershed plans for natural resource usage e.g. Tennessee Valley Authority (UNESCO, 2009). However in the global level, Integrated Water Resources Management (IWRM) emerged around the 1980s in response to increasing pressures on water resources from competition amongst various users for a limited resource, the recognition of ecosystem requirements, pollution and the risk of declining water availability due to climate change. A central goal of IWRM at the river basin level is to achieve water security for all purposes, as well as manage risks while responding to, and mitigating, disasters. The path towards water security requires resolving tradeoffs to maintain a proper balance between meeting various sectors' needs, and establishing adaptable governance mechanisms to cope with evolving environmental, economical and social circumstances (ibid).

1 SDE, DoI

**Definition**

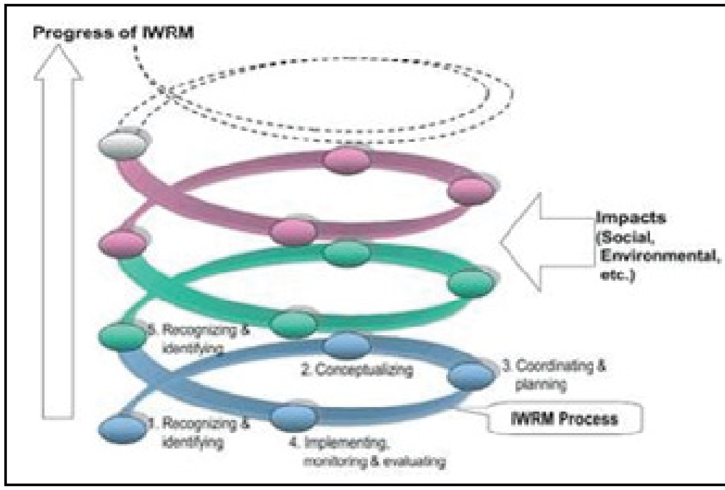


*Figure 1: IWRM Spiral*

Integrated Water Resources Management (IWRM) is explained by the Global Water Partnership (GWP) as "a process which promotes the coordinated development and the management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems." IWRM strives for effective and reliable delivery of water services by coordinating and balancing the various water-using sectors – this is an important part of sustainable water management. As water is mainly managed locally, the river basin approach is recognized as a comprehensive process for managing water resources in a more sustainable manner.

IWRM is a step-by-step process and takes time. By responding to changing social, economic and environmental needs or impacts, one can gradually achieve better and sustainable water resources management as if moving up a spiral as shown in Figure 1, through such means as progressively developing water resources in the river basin, building a more integrated institutional framework, or improving environmental sustainability (UNESCO, 2009).

However, well-developed, well tested, scientifically robust, socially acceptable and economically viable approaches to implement IWRM at the river basin level are still not widely available

**STATUS OF IWRM IMPLEMENTATION**

Experience in various countries has shown that IWRM is an essential prerequisite for effectively coordinating water development strategies across diverse sectors, political jurisdictions and geographical regions within a river basin. However, progress towards implementing IWRM in developed and developing countries have varied widely. According to UN-Water Status Report, 2008, lack of progress is characteristically associated with the need to improve public awareness amongst the hierarchy of political jurisdictions and overlapping management institutions. In developing countries, progress can be hindered by additional obstacles related to the region, such as technical capacity, political will and understanding of IWRM concepts and implementation. The Status Report also revealed the existence of diverse interpretations among countries of IWRM planning and management processes and their frameworks. These differences may even exist within one country or between different stretches or sub-basins of the same river.

**Nam Ngum Basin, LAOS**

The Nam Ngum River Basin (NNRB) is one of the most significant and important river basins in Laos. The area of the basin is 16,841 Sq. Km and the length of river is 354 Km. The river is second largest by annual discharge having 21 billion $m^3$ which is 14.4% of the flow of Mekong river. Laos Government has been carrying out the NNRB development sector with the assistance of the Asian Development Bank (ADB) and Agence Francaise de D'eveloppment since 2009 (ADB, 2009).

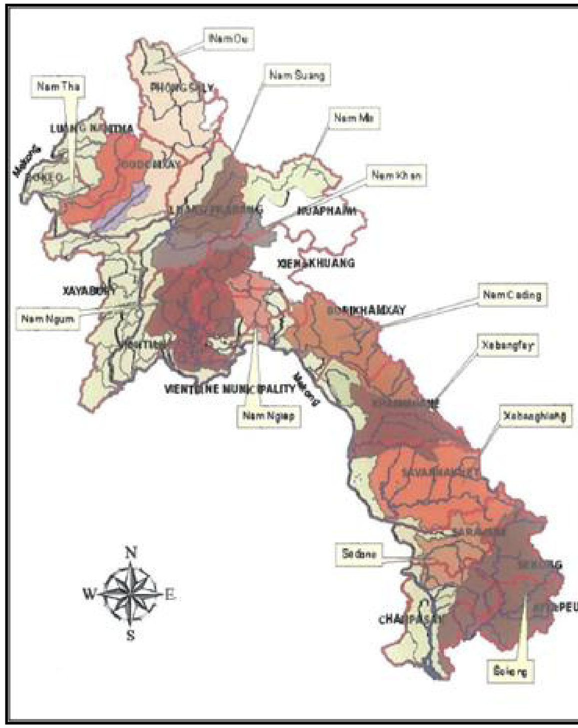


*Figure 2: River Basins of Laos*

National Water Resources Profile report 2008 of Laos mention that in the past the Water Resources Coordination Committee (WRCC) and the Lao National Mekong Committee (LNMC) is responsible for leading the development of river basin planning process and river basin plan. The WRCC mandate was directed toward national water resource management while the LNMC dealt more with international aspects, although this was not a clear separation. Both agencies were small and had inadequate legal powers and poor capacity to carry out coordination of other ministries. In order to improve and empower IWRM concept the Government has established a Water Resource and Environment Administration (WREA) under the Prime Minister's office. The WREA includes the Department of Environment and Environment Research Institute, the Department of Meteorology and Hydrology and WRMC an LNMC secretariats. The WREA should be fully established and strengthened to carry out its important role in leading IWRM activities. Provincial WREA department should be set up to carry out water resources, environment and hydrometeorology management at the provincial level. Provincial water resources committee may be needed to strengthen the coordination of water resources and environment management among provincial department. River basin committee should be established for NNRB and other priority river basin.

The strategic framework set out for NNRB plan is as follows (ADB, 2009);

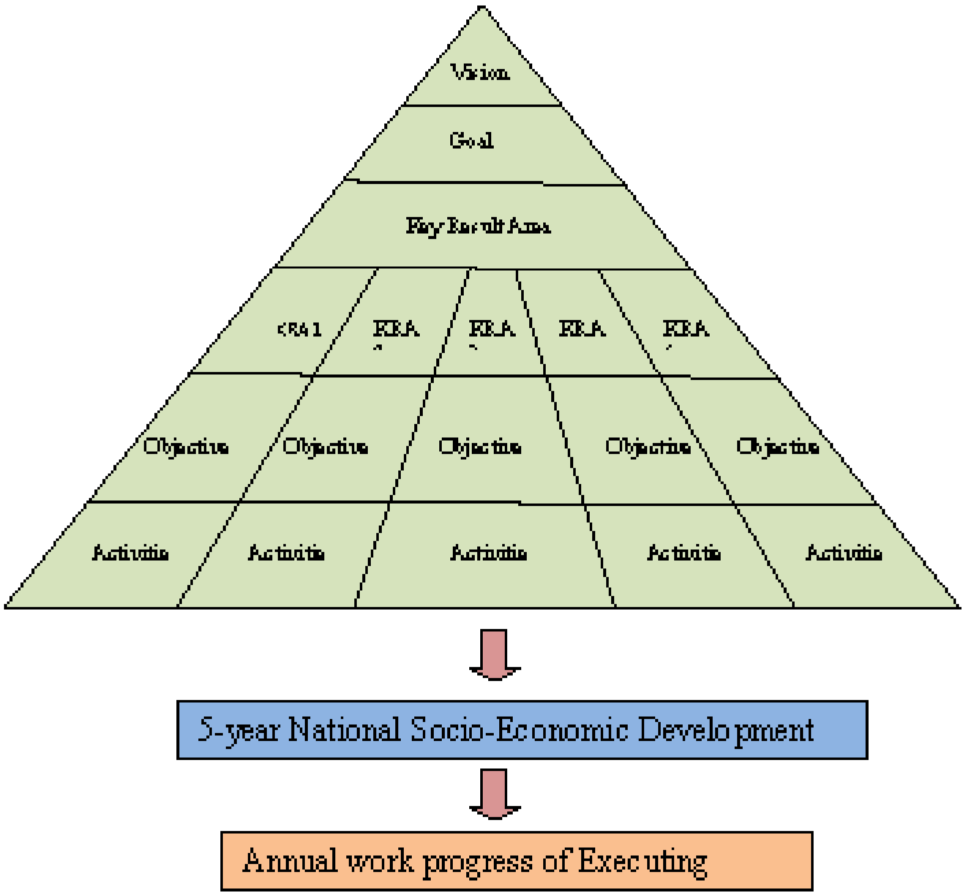


*Figure 3: Strategic Framework*

**<u>Vision</u>**

The vision is for an economically prosperous, socially developed and environmentally sustainable NNRB.

**<u>Goal</u>**

The Nam Ngum river basin plan is to facilitate the sustainable use of the water and related resources of the NNRB for the welfare and economic benefit of the National and basin's people while protecting, and where possible, improving the environmental condition of the basin and downstream communities.

Various KRAs are given below in Table 1.

Table 1: KRAs of NNRB

| Key Result Area | Objective | Activities |
|---|---|---|
| KRA-1: Building the capacity to manage the Nam Ngum RB | Strengthen organizational arrangements in the Nam Ngum basin to enable integrated planning and management of the basin's water related resources and to work with the community and private sector. | 1. Strengthen Nam Ngum River Basin Organizational Arrangement |
| | | 2. Knowledge Management Research |
| | | 3. Stakeholder Engagement an Awareness Raising |
| KRA-2: Sustainable Water Use | Strengthen the management of the water resources in the Nam Ngum River Basin so that the water resource can be used sustainable and meet social, economic and environmental needs | 1. Strengthen the Management of the Basin's surface water resources |
| | | 2. Plan for sustainable management of the basin's groundwater resources |
| | | 3. Strengthening management of water quality |
| KRA-3: Optimizing hydropower outcomes | Strengthen the coordinated management of the hydropower sector in the Nam Ngum River Basin so as to improve overall out comes and impacts on other sectors, the environment and social conditions | 1. Convene the Cooperative group of hydropower operators |
| | | 2. Prepare and implement the hydropower cooperative |
| | | 3. Sustainability reporting to NNRBO |
| KRA-4: Developing the sustainable irrigation potential of the basin | Strengthen arrangements and practices for stainable irrigation in the river basin and undertake further sectoral studies for irrigation expansion | 1. Feasibility studies for increased irrigation on the Vientiane plains |
| | | 2. Prepare environmental best practice guidelines for sustainable irrigation |
| | | 3. Assess the impacts of hydropower water releases on irrigation |
| KRA-5: River Sub-basin management | The key result area strategy involves developing sub-basin management plans in priority river sub- basins of the NNRB in order to improve living conditions and livelihoods while sharing the water resource between users, protecting and where possible improving local and downstream water quality, and improving aquatic and water related ecosystems eco systems | 1. Convene an interdepartmental task force to coordinate and oversight management of sub-basins in the NNRB |
| | | 2. Prepare sub-basin management plans in priority basins |
| | | 3. Implement sub-basin plans in the NNRB |
| KRA-6: Reducing risks and imports from water induced disaster | Review, and as necessary, strengthen the approaches for managing major water related disasters in the NN basin | 1. Appraisal of flood management for the Vientiane plains of the NNRB |
| | | 2. Appraisal of dam safety in the NNRB |
| | | 3. Appraisal of mining water pollution risks and management |

## Hydropower development in NNRB

Particularly in hydropower sector Nam Ngum river has got series of dam as given in Fig. 4 and Table 2 below.

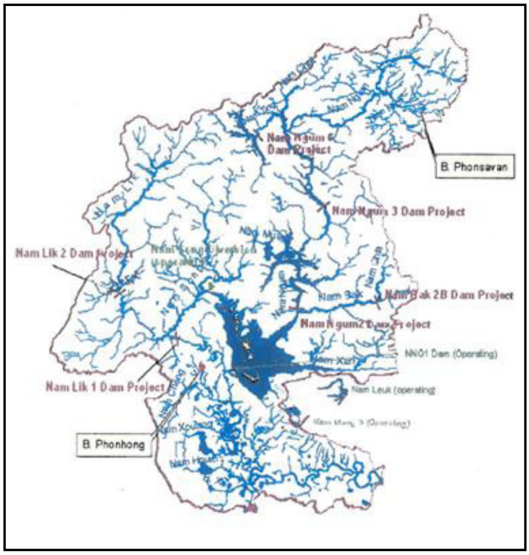


*Figure 5: Nam Ngum River Basin*

### Table 2: Hydropower projects

| Dam name | Status | Storage (MCM) | Wall height | MW | Operation dates |
|---|---|---|---|---|---|
| Nam Ngum 1 | Existing | 7000 | 75 | 155 | 1974-80 |
| Nam Ngum 2 | Under Construction | 6774 | 181 | 615 | 2010 |
| Nam Ngum 3 | Planned | 1320 | 210 | 460 | 2013 |
| Nam Ngum 5 | Under Construction | 318 | 97 | 100 | 2015 |
| Nam Bak 2B | Planned | 185 | 85 | 112 | 2011 |
| NAM Lik 2 | Construction | 1095 | 101.4 | 100 | 2011 |

*Loas is a landlocked, mountainous Country, widely covered largely unspoilt tropical forest and is one of East Asia's poorest countries. Less than 5 % of the land is suitable for subsistence agriculture, which neveretheless provides around 80 % of employment. This Country has very favorable conditions for hydropower development. Rainfall is considered high. It has 26,000 MW of theoretical potential. In 1970, it rarely generated hydropower. Currently it generates 2000 MW hydro-electricity and four other projects totaling 1200 MW are under construction. The Laos Government has strategy to use hydropower to eradicate poverty. It has continuously made numbers of agreements with the neighboring country Thailand, Vietnam and Cambodia for increase power export. The companies developing and exporting hydropower also has a system to include importing company as equity share holder of the company. It will supply 7000 MW and 5000 MW to Thailand and Vietnam respectively by 2020. It has set a target to increase domestic electrification from present 60 % to 90 % by 2020. The participation of private sector is sought and promoted through Build-Own-Operate-Transfer approach. The exports of power sector amounts to 30 % of all Laos export levels.*

## Bengawan Solo river Basin, Indonesia


*Figure 6: Bengawan Solo river basin encompasses central and east Java province*

The Bengawan Solo River has been important to the welfare of the people, since ancient times. The river basin that is located in central and eastern part of Java, needs a comprehensive development and management plan to provide the valuable resource of water – increasingly necessary – for support to the present economic and social growth at Java, the most populous island in Indonesia.

The Bengawan Solo River system, 600 km long has a total catchment area of 20,125 $km^2$. The Bengawan Solo River Basin has a precipitation potential of 2100 mm/year, of which close to 1040 mm or equivalent to 16.7 $km^3$ surfaces as overland flow. The surface water in the river discharge fluctuates during the year. Groundwater potential is estimated to be 2.1 $km^3$.

## Development of River Basin

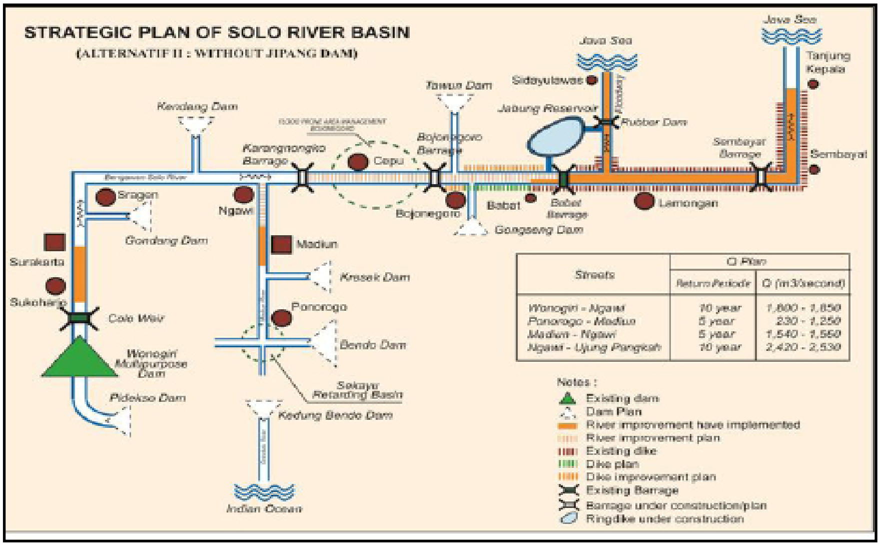


*Figure 7: Solo River Basin (source: Bengawan River Solo Basin)*

Development of Bengawan Solo River Basin has been undertaken by an agency responsible for developing the entire basin, namely the Bengawan Solo River Basin Development Project (in Indonesian: Proyek Bengawan Solo, abbreviated as PBS) in 1969. The objective of the Project is an overall basin development comprising river improvements for flood control and drainage, watershed management and water resources development.

Project activities in the river basin are directed towards improving public welfare and accelerating economic development both nationally and regionally. Through a number of changes in the 1990s, Bengawan Solo River Basin Development Project was converted into PIPWSBS (Proyek Induk Pengembangan Wilayah Sungai Bengawan Solo) and made fully responsible for the implementation and operation of all water resources development projects within the Bengawan Solo river basin.

Recently, in 2007 the PIPWSBS was transformed into the River Basin Development Agency, in Indonesian, Balai Besar Wilayah Sungai (abbreviated as BBWS) Bengawan Solo through a decree from Ministry of Public Works. Most of the former responsibilities remain within this agency but additional tasks, such as conducting hydrological monitoring and surface water quality monitoring were added.

An overall development master plan for the Bengawan Solo River Basin was formulated under technical assistance from the Overseas Technical Cooperation Agency, Japan (OTCA) in 1974. The 1974 OTCA's master plan emphasizes water resources development for irrigation, flood control, and hydroelectric power generation. In line with this overall plan, various projects have been realized by PBS, as shown in Table: 3.

### Table 3: Various projects

| No. | Name of Project | Stage | Period | Foreign Agency |
|---|---|---|---|---|
| 1 | Wonogiri Multipurpose Dam | F/S | 1974/75 | JICA |
| | | D/D | 1976/78 | OECF |
| | | C | 1979/82 | OECF |
| 2 | Wonogiri Irrigation (Including Irrigation extensions) | F/S | 1975/76 | JICA |
| | | D/D | 1977/79 | OECF |
| | | C | 1980/90 | OECF |
| 3 | Upper Solo river improvement | F/S | 1974/75 | JICA |
| | | D/D | 1983/85 | OECF |
| | | C | 1987/94 | OECF |
| 4 | Madiun River Urgent Flood Control | F/S | 1980 | JICA |
| | | D/D | 1983/85 | OECF |
| | | C | 1987/91 | OECF |
| 5 | Lower Solo River Improvement | LF/S | 1983/86 | CIDA |
| | | D/D | 1991/93 | OECF |
| | | C | 1994/2001 | JIBC |

The river infrastructure has contributed much to the water system in the basin, for electricity, irrigation; municipal and industrial bulk water supply. As the total investment for water resources infrastructures in Bengawan Solo River Basin is recently about Indonesian Rupiah(Rp) 1.3 trillion, at year 2000 prices (excluding land compensation), Bengawan Solo River Basin Development Project currently encounters the problem of funding the cost of operation and maintenance, which is assumed to be 1% to 2% of water resources infrastructure investment.

### Institutional Arrangement

Bengawan Solo Water Council has 64 members out of that 50% from government organization and 50% from public users. The structural organization of the council is as follows;

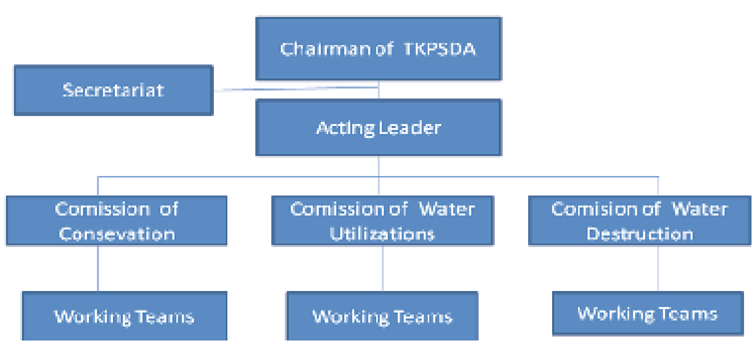


*Figure 8: Organizational Structure of Bengawan Solo Water Council (Source: Bengawan River Solo Basin)*

Principal Duties Bengawan Solo Water Council in order to help Ministry of public works in concern;

1. Arrange to Road Mapping on level River Basin;
2. Arrange to action Program and activity of Water Resources Management;
3. Arrange to Plan of Allocation of water on level River Basin;
4. Manage of System Information Data (Hydrology, Hydrometeorology, etc ) on level River Basin;
5. Arrange to Allocation of Water in concern to Water Resources Management.

It also carries out

1. Consultation with other sectors in order to coordinate plans, programs and other activity with purpose to reach comprehension between sectors and inter region in Water Resources Management;
2. Coordination with other sectors for arranged in a Road Map on level River Basin;
3. Coordination with other sectors for arrangement of program and action on level River Basin;
4. Coordination with other sectors and stakeholders that concern in conflict of interest, etc for integration and harmonization in Water Res. Management;
5. To give consideration for Ministry of Public Works about Water Resources Management and other issues on level River Basin;

Water Council activities

1. Full Session Meeting (4 times/year);
2. Commisions Meeting;
3. Team work Meeting ; part of members, expert, consultans, etc;
4. Leaders Meeting ; Chairman of TKPSDA, and Chirman of Commisions;
5. Visiting problem in river basin location ; water alocation, mining in river basin, irigation, etc.

## IWRM AND NEPAL


*Figure 9 : Major River Basins of Nepal*

The concept of IWRM was first officially documented in the National Water Plan (NWP) of Nepal in 2005. It says "Optimum utilization of water for the benefit of all stakeholders in the particular river basin couldn't be achieved in terms of efficiency, equity and environmental considerations." It has developed the river basin management tools in which it has identified the following key activities to be carried out for mainstreaming of IWRM.

- Introducing the IWRM and river basin management principles in water resources policy(ies) and legislation;
- Developing programs to raise awareness of the advantages of IWRM among all stakeholders, general public, legislators, political activists, civil societies and professional societies;
- WEC collecting, collating and segregating all relevant data and information on a river basin basis;
- Encourage all data generators and providers to publish data on river basin basis; and
- NPC and WEC requiring statements from sector program developers to produce 'river basin water balance' prior to getting administrative approval for all projects and programs.

Literally no conspicuous development has been realized in river basin development of Nepal although two major donors are engaged in this regard. The World Bank has been supporting to develop Babai basin, West Rapti basin and Gandak basin under component 'C' of Irrigation Water Resource Management Project (IWRMP) which is looking after by Water and Energy Commission Secretariat (WECS)[2]. Likewise ADB has been carrying out Bagmati River Basin Improvement Plan. Apart from these, a Koshi River Basin Project activity is being conducted by collaborative effort of WECS and WWF.

## FORMATION OF RIVER BASIN COMMITTEE

Babai and West Rapti Basin Committees[3]

Two River Basin committees namely Babai River Basin Committee and West Rapti River Basin committee have been formed. The process of formation in brief is as follows:

- Three sub-basin committees that is Jhimruk, Madi and Rapti (downstream of Jhimruk and Madi confluence) are formed in West Rapti. Similarly Sarada, Upper Babai and Lower Babai (downstream of sarada and upper babai confluence) sub basin committees are formed in Babai basin. Each sub-basin committee consists of nine members representing from the existing water users committees of various sub-sectors such as irrigation, water supply, forest, micro-hydro etc.

- Twenty seven members from the three sub-basin committees have selected eleven members among themselves for basin committee. Thus, each basin committee for Babai and Rapti has eleven members.

- The role of the basin/sub-basin committee is to prepare integrated water resources plan, suggest implementation arrangement and monitor the implementation.

- The existing water user committees are responsible for implementation of the activities.

- There is no legal mechanism as such to guide the basin committee. Therefore, at present, the basin committee will work closely with District Water Resources Committee chaired by Chief District Officer, and support in planning and designing the implementation mechanism.

Planned Activities for Fiscal Year 2070/071: (Considering continuation of IWRMP)

Support to Babai and West Rapti basin committees for preparing integrated river basin plans;

2 Source : WECS

3 Source: WECS

Formation of sub-basin/basin committee for Gandaki basin and prepare integrated river basin plan;

**Bagmati Basin**

Bagmati River Basin improvement Project is the project supported by ADB. The PPTA (TA 8050-NEP) has been hired by ADB and the feasibility study of Bagmati basin is completed. The PPTA has finalized the project design in the following three components;

1. Towards Integrated and Participatory River Basin Management;
2. Upper Bagmati River Improvement;
3. Integrated River Training and Irrigation for Marin Khola.

The Bagmati River holds a special place in the national identity of Nepal as it is related to the mythological birth of civilization in the Kathmandu Valley. It is also considered as a holy river and counts many cremation ghats and temples of great cultural value along its banks that attract scores of Hindu devotees from all over the world who traditionally purify themselves in the holy Bagmati waters. Apart from its cultural and religious significance, the Bagmati River Basin also has great economic importance as it plays a crucial role in meeting the water supply requirements of the country's capital city and downstream communities, as well as in sustaining irrigated agriculture in the Kathmandu Valley and throughout the basin[4].

**Impact and Outcome**

- The expected impact of the Project is to improve sustainable economic development and poverty reduction in Bagmati River Basin.
- The expected outcome of the Project will focus on improving water security in the Bagmati River Basin as a whole.

At present one can hope early implementation of this project to improve the quality of life in Kathmandu valley.

**UPDATING OF IRRIGATION MASTER PLAN AND RIVER BASIN PLAN;**

Recently kicked off study project "Water Resources Project Preparatory Facility (WRPPF)" has envisaged of updating irrigation master plan and river basin plan in its package four. By doing water budgeting and allocating water for different use will facilitate the planner to develop different water related projects in future[5].

4 Source: Bagmati River Basin Improvement Project, DoI unit

5 *Source: DoI*

**DEBATE ON IWRM**

There exists another school of thoughts that IWRM tends to be driven not by indigenous need but rather by foreign intervention and is enforced “through international organizations, loan conditionality, expert consultations, and economic as well as political pressure” (Laube, 2007: 421), often at the expense of alternative solutions and paths.

Giordano and Shah agree with above statements and illustrate the example of Sri Lanka; In 1993, the Government began a process of implementing water policy reform under a technical assistance activity of the ADB in association with the ISPAN/USAID. Some 115 stakeholder consultation meetings were held involving government agencies at the national and provincial levels, policymakers, water managers, the private sector, professional bodies, NGOs and all major water users. Working groups were set up involving NGOs to discuss and identify the major problems, suggest policy prescriptions and propose appropriate institutional arrangements to implement the policy. The result was a package of reforms mimicking the IWRM ideal described above. A water policy and water law were established, existing water organizations were to be replaced by river basin organizations; water use rights were established through withdrawal permits, permits were made transferable to encourage water trade towards high valued uses and all water was priced. Despite following an apparently open process, the reform program was heavily criticized and thought the program was implemented to satisfy donor interest rather than cater to national needs.

In the wake of intense agitation by the public and the media against the proposed national water policy, the government first distanced itself and then withdrew the proposals. The result was not simply that the process failed, but also that the opportunity for any reform was greatly reduced. Open discussions of even some of the principles of IWRM, such as cost recovery, have become politically impossible. Outside organizations trying to help with the water sector are frequently accused of trying to buy up or privatize Sri Lanka’s water. Almost 20 years after the reform process started, there has been little change and when a drought hits the country, as is the case now, there is no way to coordinate a response. The process of establishing IWRM set back progress in tackling Sri Lanka’s real water challenges (Giordano and Shah, 2012).

However it was strongly criticized by Dr. Danka and Stevan in Global Water Partnership's blog. They say that the failure cited was not really a failure of IWRM but it was a failure of polity; or of some stakeholders hijacking the process. They further defended saying that it require a deeper analysis than simply saying IWRM failed and blamed poor governance, harmful subsidies, and lack of participation for the causes.

Furthermore they compared IWRM with democracy by giving the examples of many countries that have problems applying democratic principles (for many of the same reasons they have problems applying IWRM). But the conclusion isn’t that ‘democracy doesn’t work’. It is that certain conditions and processes have to be in place before democratic principles can succeed (though never perfectly).

## FAILURE OF IWRM DUE TO POLITY

While appealing in principle, practical implementation of IWRM has often been problematic. For example a case study of the Krishna basin in South India highlights that interstate water conflicts remain largely unresolved in India despite such long-held calls for IWRM and the existence of basin water allocation mechanisms. Framing the river basin as a social and political space sheds light on the root causes of continued interstate water disputes in India and allows opportunities for sustainable water management to be identified (Venot et al, 2010).

Another example of interstate water dispute is the Kaveri Basin. This too has been the source of a serious conflict between the Indian states of Karnataka and Tamil Nadu. The 802 kilometres Kaveri river has 32,000 $km^2$ basin area in Karnataka and 44,000 $km^2$ basin area in Tamil Nadu. The state of Karnataka contends that it does not receive its due share of water from the river as does Tamil Nadu. Karnataka claims that these agreements were skewed heavily in favour of the Madras Presidency, and has demanded a renegotiated settlement based on "equitable sharing of the waters". Tamil Nadu, on the other hand, pleads that it has already developed almost 1.2 million ha of land and as a result has come to depend very heavily on the existing pattern of usage. Any change in this pattern, it says, will adversely affect the livelihood of millions of farmers in the state. After decades of negotiations between the parties, bore no fruit. So on 20 February 2013, based on the directions of the Supreme Court, the Indian Government has notified the final award of the Cauvery Water Disputes Tribunal (CWDT) on sharing the waters of the Cauvery system among the basin States of Karnataka, Tamil Nadu, and Kerala and Union territory of Pondicherry (Wikipedia, 2013).

The aforementioned cases of India have illustrated that without resolving inter-state polity, principles of IWRM remains in shadow.

## CONCLUSION

The integrated approach involving RBO like setup has been successfully applied in many river basins worldwide. Tennesse Valley Authority and Murray Darling Basins are worth emulating examples of IWRM approach with appropriate Institutional Mechanism. In Asia, Mekong Basin and Bengawan Solo river basin of Indonesia are good examples following the principles of IWRM.

The pressing need of water in various sectors is a challenge to cope with for developing countries. As, most of the easy storage sites have already been identified and executed, the future lies in Integrated Water Resources Management for sustainable development of water resources along with preservation of ecosystems.

Learning the lessons from the successful examples of RBOs, South Asian countries could benefit more and suffer less. In Nepal, benefits from potential hydropower development and agricultural modernization remain untapped, while flood and drought management systems are inadequate to protect lives and livelihoods. Better management of the basin – to sustain the river ecosystem, capture its potential benefits, and mitigate its mounting costs – requires enhanced regional knowledge and cooperation.

Even in the transboundary river basin, the development trend is through incremental, project-by-project activities within each of the riparian countries. There has been surprisingly little systematic regional research on the basin's development options and challenges using modern analytical tools that go beyond sector, country, or state analysis to examine the systemwide strategic questions that the basin faces. In addition, long-held perceptions of the current condition and the future development path of the any river basins vary dramatically within and among different stakeholder groups, institutions, and countries.

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# Governance through Internal Auditing in Irrigation and Agriculture

***Janak Raj Gautam*** [1]

**Abstract**

*Sustainable operation of contemporary activities in irrigation and agriculture is essential for employment and growth. Efficient management of irrigation is able to coordinate and provide regular service of its output to agriculture sector for the national requirement of farming products and cultivators, making the constructional structure and maintenance of irrigation system well. Therefore, prevailing periodic plan has envisioned that the administrative, management and development mechanism should be reliable, transparent, result-oriented, accountable and legitimate in the operation of development affairs.*

*The arrangements of internal audit is to review the application of capital expenditure budget, foreign assistance, cash, stores and other governmental property, whether they are in the grip of any mismanage, malpractice, damage and abuse . The rules for collection, deposits and custody of revenue, other income and retention money are complied with and recorded in the books of accounts with correctness and adequacy.*

*The duties and responsibilities of internal auditors are to identify, verify, evaluate, analyze, inspect and observe the budget execution, financial statements, financial transactions, operational activities, performance of programs, and non-financial activities of an entity . Their functions may extend to review the same considering efficiently, effectively and economically. Eventually, they have to prepare the report to the management for mid-course correction and recommendations for improvements thereto if the financial transactions are out of financial discipline and not in tune with governance principles.*

## INTRODUCTION

Good governance can be in motion when government of Nepal can make public service delivery effective through transparency, participation, accountability, and legitimacy particularly in development affairs. In this context, the efforts have been continued to translate the basic principles and provisions of Good Governance (Management and

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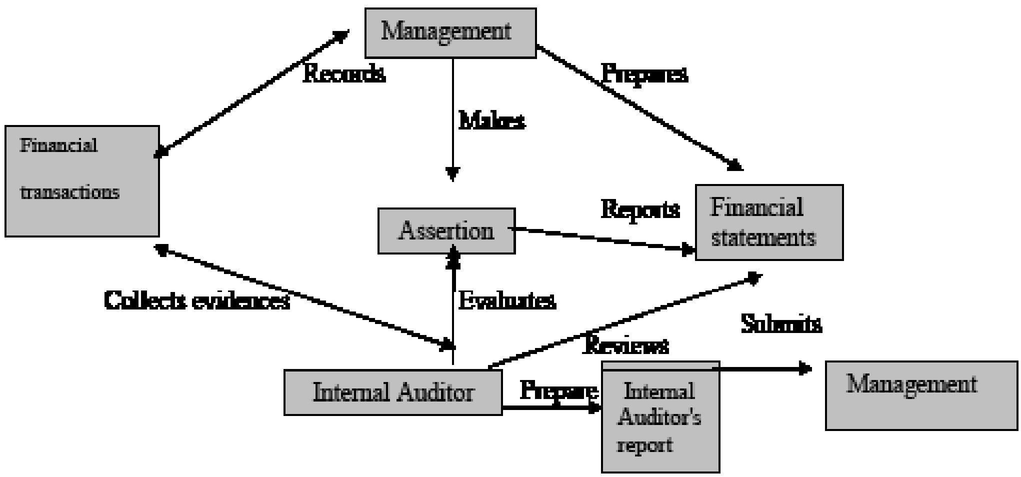
Operation) Act, 2007, Civil Service Act, 1993, Local Self-Governance Act, 1998, Public Procurement Act, 2007, Fiscal Procedures Act, 1998 and rules, regulations of the same.

Historically, through 1940 to 1950 internal auditing was heavily involved in the analysis of financial management solely for meeting point of financial auditing. Modern internal auditing has begun to be an integral part of a control system of any entity since 1941. It is a saying that “Nobody can deny the fact that effective internal auditing protects an organization from fraud and financial irregularities".

In this way, to-day internal auditing accepts much broader range of responsibility maintaining proximate relationship with management. Basically, the internal auditor can also assist the line management by ensuring that adequate financial and management controls have been implemented and are operating effectively by identifying weaknesses in the system. Although, management appoints internal auditor, but internal auditors are not assistant of the management but are as a part of top management level. Therefore, internal auditing is critical examination of books of accounts with a view to establish their accuracy and correctness through the verification and cross-checking of the books of accounts by a person engaged by management for the job. However, the duties of internal auditors are not only limited to the verification of arithmetical accuracy, but ascertaining the validity and reliability of accounting information, financial data, records, statements and performance results and also provide an assessment of a system of internal control of a person, organization, system, process, project or product.

**OBJECTIVES**

'Transparency and accountability are not government’s gracious concessions; instead, they are the legal, ethical and moral obligation that no one can overlook’ according to Arturo Gonzdleg Aragon, former chairman of International Organization of Supreme Audit Institutions (INTOSAI) Governing Board. In tuning with the same line Mr Claes Norgen, Auditor General of Sweden has expressed that 'Supreme audit institutions (SAIs) help their governments improve performance, enhance transparency, ensure accountability, fight corruptions, promote public trust and foster efficient and effective receipt and use of public resources for their citizens. In this respect, the vision of government auditing as used by the Office of the Auditor General of Nepal is, 'an independent, efficient and effective audit institution to promote good governance'. The following diagram gives an idea about the relationship among financial transactions, management records, financial statement and internal auditor's report .




The purpose of an internal audit is to help to management for making mid–course correction in any financial transactions, to help to final auditors providing the report, to give opportunity to the incumbents prevent their individual images if they have committed any mistakes and misutilized in the irrigation agricultural and entities. Therefore, internal audit draws attention to go ahead mostly in following matters:-

- **Evaluate the system**- To increase agricultural production and productivity through efficient, sustainable, effective and reliable distribution system for providing irrigation facility to the agricultural land throughout the year.
- **Eliminate poverty** — to assist in alleviating poverty with the creation of employment through preservation of human settlements, irrigation system and agricultural land.
- **Resources mobilization** —to mobilize foreign-aid in irrigation and agriculture sectors to fulfill the deficit on the internal financial resources to obtain national development goals.
- **Delegate authority** — To delegate the administrative, financial, technical and procurement authority to the local level entities for such a variety of functions to implement the process be more effective.
- **Monitoring** -To make the monitoring and evaluation process of management, financial and development functions workable and credible.

## SCOPE

Management can determine the scope of internal audit regarding the increasing scale of internal audit for achieving maximum organizational effectiveness. It considerably comprises the nature, time, extent, depth of coverage and procedures from financial to non-financial activities. Internal auditors require a good eye for details, a closer scrutiny and a concern for accuracy on financial information, evidences, books of accounts and data. They are expected to deal mostly with individual, financial figures, systems and structures keeping them within the scope.

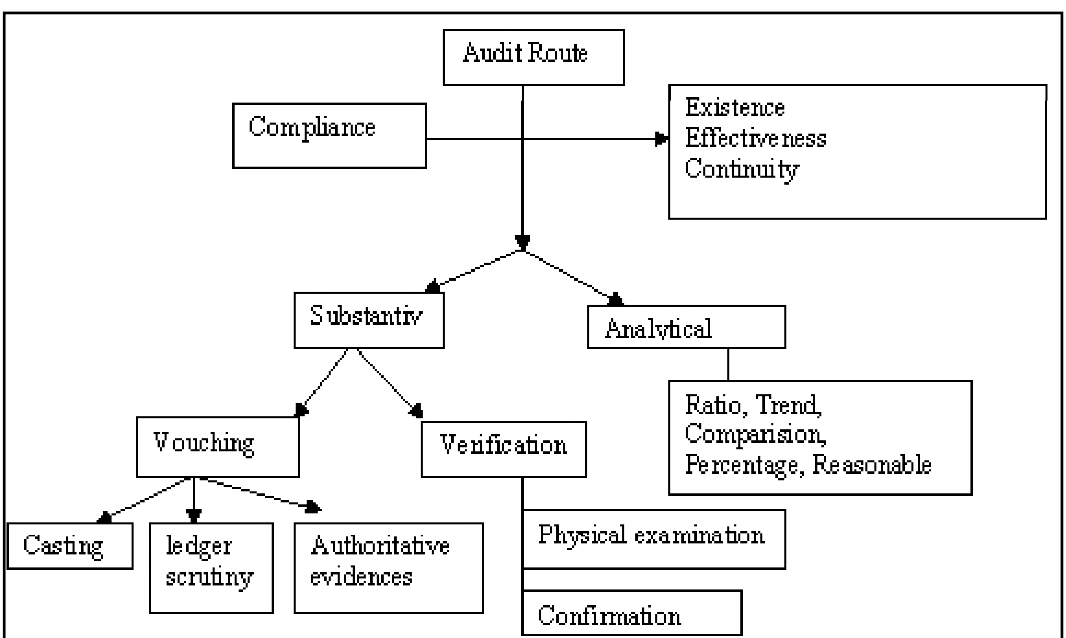
**METHODS**

The choice of route and techniques is a matter of professional judgment. The audit evidences may be gathered from within (internal) or from outside (external) the organization. Internal auditing can help the governance of the irrigation entities which are providing irrigation facility in 162,075 ha agriculture land and preservation of physical structure and human settlements after the construction of 300 km dam through ground water irrigation projects within 2012-13. Following are the nature of evidences to examine and verify for moving forward that internal auditors conduct the their tasks to achieve the above the objectives:-

a) Normally evidences, to be influential, must be sufficient appropriate that is obtained to a reasonable basis:-

| | |
|---|---|
| Timely and Substantial | Reliable and documented |
| Valid and relevant | Useful and objective |
| Sufficiency and appropriate | Sensible and cost effective |

a) Route to move forward



## DUTIES AND RESPONSIBILITIES

According to the Institute of Internal Auditors, government auditing is a cornerstone of good public sector governance. The objective of internal auditing is to assist members of the organization in the effective discharge of their responsibilities." A major responsibility of an internal auditor is to ascertain the extent of entity compliance with established management policies, strategy, plan and procedure. Its focus is on rule, norms, internal control system, directions, and internal regulations are in functions as designed. Therefore, an internal auditor in an irrigation and agriculture sector has to examine the propriety of the following financial transactions of each entity with due regard to:-

- **Objectives**– Have clear objectives and policies
- **Accountability**– Conduct the projects in tune with cost recovery system by making the irrigation facilities sustainable and reliable to the agriculture sector.
- **Appropriation**– Does not exceed the ceilings of expenditure heads and subheads that has to be incurred for their respective purposes. Strengthen the multi-year allocation system of capital expenditures budget.
- **Compliance** –Adequately support the financial transactions and they are in compliance with existing laws. The accounts have been maintained in the prescribed form in a correct, satisfactory, acceptable and reliable manner. The accounts of expenditure of irrigation and agricultural services and their balance of cash and other assets are adequate.
- **Revenue** –Supervise the collection, deposit and custody of revenue, other incomes and retention money are in adherence with rules and regulation. The arrangements and rules relating to their financial transactions are being observed.
- **Assets** – Up to-date keep correct the inventory of irrigation and agricultural entities and the assets are properly utilized, maintained and secured against loss or damage;
- **Operation** – Operate satisfactorily the organization because of sound management system and job allocation of projects being reasonable and proper.
- **Participation** – Make the programs implemented through people's participation more result-oriented, transparent and accountable by making it cost effective within approved limits.

- **Duplication** − Find out any duplication of work, or that any function is being performed unnecessarily or any necessary task has been omitted; the progress of work is on schedule and the quality and quantity of the work produced is satisfactory.

- **Internal control -** Review the internal control playing a significant role in the accountability process. The study and evaluation of internal control has become a standard audit procedure for satisfactory discharge of auditing responsibilities. It is the duty of internal auditors to examine whether a system of internal control has been a safeguard against the losses, misappropriation, fraud and intentional errors.

## PERFORMANCE AUDIT

Internal audit function is more than just transaction based and cost driven. Therefore, performance audit is the next step of internal auditing. Performance audit, according to International Standards of Supreme Audit Institution (ISSAI) often ask two questions,

- Are the right things being done?

- Are things being done in the right way?

Economy ⟶ Spending less for Input

Efficiency ⟶ Spending well process

Effectiveness ⟶ Spending wisely for outcomes

| | |
|---|---|
| 1.**Criteria** | What the auditee should have done |
| 2.**Condition** | what the auditee did or did not do ,it is the situation actually existing in the audited entity |
| 3.**Causes** | Why the auditee did not meet the criteria, likely reason for audit result. |
| 4.**Consequences** | What results from the auditee not meeting the criteria, it is the impacts. |

## RESULT AS DISCREPANCIES

According to Kirsten Astrup, INTOSAI Director of Strategic Planning, "I believe that working in an internal audit environment is a valuable experience for any external auditor".

Audit objections are the auditors' findings that are unmatching between the criteria and condition that really exists in the implementation. However, auditors need not write any queries on a second guess. In order to make management of irrigation and agriculture service effective, legal provisions will be undertaken for Irrigation Development Fund on the basis of feasibility. Working procedures will be developed considering the aid agreement in order to implement Paris Declaration, 2005, Accra Agenda for Action 2008 and Bushan Conference, 2011.Normally the examples of authority, responsibility, accountability, functions, duties and assignments of office-bearers which should be exposed in the auditors' reports. However, internal audit reports are not made public. Office of the Auditor General studies the internal audit report and, if found any significant ones, may incorporate in the annual report. In this connection, it will be useful to know the status of unsettled final audit queries in a concise form. If there is sound internal audit and management has made correction, rectification, action taken and improvement to the internal audit report accordingly for maintaining financial discipline, then the following figures irregularities wouldn't have been in the Auditor General's Report, 2013 (50th),

**Rs. ( in lakh)**

| Statements | Total of all ministries | Irrigation | Agriculture |
|---|---|---|---|
| Total amount of Audit discrepancies yet be cleared up to this year | 2,04,25,74 | 2,25,52 | 1,66,78 |
| Advance amount to be settled from individuals and institutions | 72,87,13 | 1,62,14 | 13,36 |
| Total audited amount of the fiscal year 2011-12 i.e. Annual Report-2050 | 7,42,59,43 | 10,16,29 | 11,25,08 |
| Irregularities amount to be covered from individuals and institutions in 2011-12 | 3,89,97 | 1,61 | 5,45 |
| Total irregularities of the fiscal year 2011-12 | 35,07,51 | 1,18,56 | 31,06 |
| Advance amount to be settled from individuals and institutions of the fiscal year 2011-12 | 14,70 | 99,52 | 3,62 |

**PROBLEMS AND CHALLENGES**

Following are the major problems prevailing in internal audit while taking steps towards good governance.

- Lack of effective mechanism to discourage the financial irregularities
- Lack of knowledge and skill for professional development to internal auditors.
- Lack of effective monitoring of internal auditors' report issued.

- Internal audit function has been misunderstood, misused or simply ignored.
- Internal audit has not been completed and not reported within stipulated time.
- Internal audit directive should be followed in an auditing situation

**CONCLUSION, RECOMMENDATIONS AND SUGGESTIONS**

Management of an entity receives an assurance from internal sources that the processes have minimized the probability of the occurrence of fraud, error, inefficient and uneconomic practices. Internal auditors should not confine to what has been done 'but also examine what not has been done' to meet the policy and objectives. Internal auditors recommend for remedial steps and actions, where necessary**.** Timely reform and capacity enhancement of the Financial Comptroller General Office will be made by conducting their organization and management study in order to complete public expenditure management tasks for maintaining financial discipline. Then the governance through internal audit can be achieved in agriculture and irrigation sector with sustainability.

a) **Correction**—Public expenditure management requires effective monitoring and evaluation system that can be fruitful with the reference of internal audit report making correction timely.

b) **Professional**—internal audit work is performed by persons having adequate training, proficient, experienced, and professionally qualified persons.

c) **Co-ordination**—Co-ordination between institutional capacity developments will be enhanced to increase capacity, transparency and accountability in aid mobilization committed bilateral and multilateral assistance to meet the increasing expenditure needs,

d) **Action plan**- Public Expenditure and Financial Accountability Action Plan will be implemented according to rules and regulation.

e) **Spectrum-** The area of audit may cover the entire spectrum of control. Eventually, the external auditors should cover few elements to ascertain and evaluate whether the internal audit work appears to be in consistent and reasonable.

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# Rethinking on governance of irrigation service

***Laxman Neupane*[1]**

***ABSTRACT***

*Water resources is important natural resources, it has played a vital role for socio-economic development, building capability, enhancing the livelihood opportunities, generating hydropower, and irrigation etc. Water resources management, utilization and development are becoming more complexes and challenging tasks that it involves emerging uncertainties at different levels. Further water management increases and accelerates different water demand areas and is doubled with increasing population, urbanization, emerging and economic grow and climate change. Hence, water resources need to sustainably managed and steer it properly. Water resource is as taken as common property resources whereas Integrated Water Resources Management (IWRM) is gaining universal paradigm of sustainable and inclusive water resources management and use. However, integrating water functions is a very complex and daunting task as it involves diverse actors and stakeholders that they have multiple interests to use it. This nature of application and involvement make it fertile case for water crisis that it is essentially a crisis of governance (UNDP 2004; United Nations (UN, 2005, 2006). In water services and its sustainability manifests itself in the fragmented institutional structures, absence of clarity on roles and responsibilities, questionable allocation and distribution patterns, wicked financial management, poor capacity of implementing agencies both private and public levels including NGOs/civil society organizations; and in the pervasive leakage of resources, weak accountability of politicians, policy-makers and implementing agencies, unclear or non-existent regulatory environments, and unpredictability in the investment climate for private sector actors (UN 2006). Many of these problems are rooted in a general lack of knowledge and awareness of rights and responsibilities of societal institutions. This paper brings governance perspective and political economy that analysis on application of the IWRM approach and the related principles of governance for sustainable water resources water regime.*

## SCHEMATIC

Developed, developing and under developed worlds; in general the globe community have been experiencing to water crisis. Population growth, land use changes, expanding and creating new economic opportunities has been heightening various forms of water scarcities in every part of the human society.

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Water in fact is the essential for survival, it tads entire gamut of human life, ecological, economic, and social/cultural. Water resources management lies on broad spectrum social ecological system (SES) (Ostrom 2007 &1997) in the contemporary time that it must addresses each of all sectors as well as the linkages and trade-offs among ecological needs and services, human well being. The framework of sustainable water resources management that integrates to many competing facets of water access, use and distribute so that water can be managed as a sustainable manner. Unfortunately, modern water resource management endeavors have not scientifically addressed to the SES framework and methodological processes that necessarily integrates plural sectors and their cumulative effects. Recognizing to this urgency, this paper deliberates to the Rethinking on Governance of Irrigation Service that integrates to social phenomena that shapes to Sustainable Water Resources Management.

Author of the paper came to realize that governance requires for sustainability of irrigation service that is an outcome of deploying to the SES framework to monitor, assess, and adaptively managing to irrigation services as broad aspect of water resources management without compromise to future generation's need.

Vedeld (1996) argues that the devolution process of resources management involves to programs that shift responsibility and authority from the state to non- governmental bodies—a "rolling back the boundaries of the state". Devolution processes could go by a range of models or names that when control over resources is transferred more or less completely to local user groups, it is often called to as Community-Based Resource Management (CBRM). In CBRM regime, state/government principally pull down her role (s) by (either) cuts or redeploys her agents or staffs; in joint management or co management process, when state/government retains a large role in resource management, in conjunction with an expanded role for users, it may be referred to as joint management or co-management. In this model of management, the roles are often not clear-cut, with most cases involving some form of interaction between the state and user groups. These form of process or model have specific terms depend to community, sector and country. In irrigation service, irrigation management transfer generally recognizes to programs that go farther in divesting government/ state agencies of their roles that Participatory Irrigation Management programs (PIMP) seek to increase user engagement that is usually as a supplement to the state/government's role. Like joint forest management is an example of program that transfer some management responsibilities to user groups, in conjunction with state agencies. The following paragraph in the paper explains on devolution, de-concentration, decentralization and privatization etc.

- ***Devolution*** process is a part of a number of related policy reforms, in which central government agencies transfer rights and responsibilities to more localized institutions. Ribot (1999) be fluent on devolution further focuses to the transfer of rights and responsibilities to user groups at the local level. These forms of organizations are accountable to their membership and user members usually those who depend on the resource, but do not represent others in the local community, nor society at large.

- In a ***de-concentration***, the decision-making authority is transferred to lower-level units of a bureaucracy, or government line agency, represents the least fundamental change, because authority remains with the same type of institution, and accountability is ultimately still to the central government

- ***Decentralization*** in which transferring both decision-making authority and payments responsibility to lower levels of government is made. This model provides a stable and stronger role to local bodies. This is presumed to have greater accountability to the local populace, including both users of the resource and others who live in the area.

- Dick & Knox (1999) provides broad perspective on ***privatization*** that refers to transfer from the public sector to private groups or individuals. This can include non-profit service organizations (grassroots or external NGOs) and for-profit firms (Uphoff 1998). The private sector can be taken to include user groups.

Behind all these process or models, the broad principle of governance is about decision making by addressing to concerns and aspirations of multiple social phenomena that should be devolved to the lowest appropriate level. Within this, transfers of authority to lower level of government (de-concentration and decentralization) represent vertical subsidiarity, while transfers to non-governmental institutions (user groups or private firms) represents a horizontal dimension of subsidiarity (Doring, 1997).

The concern of this paper is with rethinking on governance of irrigation services that requires for creating new economic opportunities by addressing to SES sustainability. To this aspect, number of institutional actors, community groups, norms & values as well as culture are involved in framing and designing irrigation services which falls under resources system. International agencies, government, local government bodies, civil society, non state actors and the private sector, as well as user groups keep their eyes on the resources system that shape their well being. The structure and dynamic interactions between these forms of organizations or institution is important. In this paper, governance, sustainability, and capability approach, and conclusion have been discussed. These discussions have been relied from literatures survey that attempts to elaborate on typology of governance.

## GOVERNANCE

Past several decades, traditional governance instruments had failed to address the concerns of social, economic and environment as well as political system etc. This had yielded much turmoil around the world. Many forms of governance had emerged to settle chaos that were impacted severely to both human wellbeing and made irreversible destruction of natural resources. Such shift in governance has occurred in private, semi private, and public spectrum at local, county, province, district, regional, national, transnational and global levels. Changes have taken place in the forms and mechanisms of governance, location of governance, governing capacity, fashion & style of governance. Such changes have been the subject of a variety of literatures, and disciplines like political science, sociology, economics, law, public administration & business administration, natural resources, environment, history and geography etc. Such wide disciplines give the term 'governance' different meaning. Governance in fact is a systems of rule, as the purposive activities of any collectivity, that sustain mechanisms designed to ensure its safety, prosperity, coherence, stability, and continuance. These mechanisms, usually the core businesses of government are increasingly found in international collectivities (Rosenau, 2000). The credit goes to the World Bank that the first prominent usage of 'governance' while its investing fund or resources for economic development. The World Bank and other international development organizations have been stressing efficient or good governance (Janning, 1997). Principle of economic governance argues to so called second generation reforms' that this approach triggers of discouraging wasteful public sending; spending primary health, education, social safety net, promoting private sector, reinforcing banking sector, reforming tax system and creating transparency, accountability within government and corporate affairs (Rosenbaum & Shephered, 2000; Wood, 2000; Philip, 1999; Kiely 1998; cited by Kersbergen, K. V. and Waarden, V. F. 2004).

In the context of economic governance, this approach is refined along with other disciplines of economic history, institutional economics, economic sociology, comparative political economy, labor economics that societies have varieties of institutions to govern economic activities, assist reduce the cost and increase their likelihood of visibility; government is only one institutions. Contracts, firms & their hierarchies, voluntary association, and users groups etc. are other form of institutions. So, these types of governance are broader category of governance other than government.

These forms of governance have greater role for efficient and sustainability in developing new or strengthening existing irrigation schemes. Without considering to societal concerns, interests and roles; society in this case would hesitate to take ownership of schemes that rises to a question of sustainability. Considering to technicality of schemes like designing and developing, maintenance or operation etc. is not sufficient where as all forms of social, economical, environmental or political phenomena requires to internalize from early stage of inception. Nepal carries very unique experience from Chandra *Nahar* (Canal) up to Sikta or Rani Jamara irrigation project etc.; glory of our irrigation experiences is distressful that like Rajkulo, traditional farmers managed schemes etc. were annihilated in the name of modernity or sustainability. It is a failure of governance to address existing dimensions of schemes that fail to deliver required level of services. This form of governance equally consume huge amount of means which governance unable to operate in the long term. Engaging diverse actors and stakeholders to a large extent form of hybrid governance institutions that successful governance systems in irrigation sector could be framed that both bottom-up input and top-down initiatives could be realized. Promoting awareness, build political commitment and trigger action on critical irrigation issues at all levels, including the highest decision-making level, to facilitate the efficient conservation, protection, development, planning, management and use of irrigation water in all its dimension and environmentally sustainable basis for the benefit of all life on earth are the crucial elements that fairly demands to internalize.

Bringing to all into a platform to encourage debates, exchanges of experience, ideas etc.; this facilitates to reach a common strategic vision on irrigation services and management. Their action will recognize from fulfilling basic human need of access to clean water and sanitation and calls for effective mechanisms for the management of shared waters, to support and preserve ecosystems, to encourage the efficient use of water, to address gender equity issues in water use, and to encourage partnership between the members society and governments. This is possible for yielding a strategic vision through a participative governance process for solving twin issue of water crisis, and crisis of governance. Funding, capacity, policy, administrative, information, accountability and information are considered major gaps likely mitigate in timely.

## CAPABILITY APPROACH (CA)

The capability approach developed by Amartya Sen; further Martha Nussbaum contributed to expanding it in multiple levels that response to the conventional welfare economics. The approach is a broad normative framework for evaluating and assessment individual wellbeing and social arrangements, design policy strategies, and proposals for social change in society. It is used a wide range of fields; most prominently in developing thinking, welfare economics, social policy and political economics etc. It aids to evaluate several aspects of people's well being- such as in equality, poverty, and wellbeing of an individual or aggregative wellbeing of a group community or society. This approach is also used an alternative evaluative tool for social cost benefit analysis or to design and evaluate policies, ranging from welfare state design in affluent societies; or to development policies by government and non governmental organization. The CA has also provided the foundations of the human development paradigm (Fukuda-Parr, 2003). It must note that the CA is not a theory that can explain poverty, inequality or wellbeing; instead it only provides a tool to conceptualize and evaluate these phenomena. The CA core concern is on wellbeing and development thus evaluates policies according to their impact on people's capabilities. It seeks whether people are being healthy, educated, and capable, empower and whether the means or resources necessary for this capability, such as clean water, access to health facility. It also asks whether people are well nourished, well education, political participation, sufficient food supplies, and food entitlements are met. All these plays vital role to foster real friendship, for some of these capabilities, the main input will be financial resources and economic production, but other it can also be political practices of effecting guaranteeing protection of freedom, social cultural practice, social structures, social institutions, public goods, social norms, traditions and habits. The capability approach covers all spectrum of human wellbeing. The approach basically conceptualizes welfare as life quality that measures in capability and functioning instead of economical term as income and utility. Capabilities are freedom or individual scope of actions or opportunities to attain valuable doing and beings- the functioning. To operationalize this approach in irrigation sector, the question would be why farmers want irrigation service, a valuable functioning are considered drives for implementation irrigation schemes to irrigate their crops. In the irrigation perspective, the CA facilitates as an instrument to open up to motivating for constructing, operating, maintain etc. to irrigation schemes and optimal use of available irrigation water by protecting watershed catchment. While developing or investing on irrigation scheme, all these phenomena require to analysis that predicts intended interventions' level of contribution for human wellbeing. It is, therefore, this approach is very important in irrigation services, which aim to excel human wellbeing.

## SUSTAINABLE DEVELOPMENT[2]

Evolution of sustainable development can be tracked down from Hardin (1968) seminal work on Tragedy of Common, 1972 and 1992 years' series of international conferences and initiatives. In 1972, the UN Conference on the Human Environment, held in Stockholm could be the first major international gathering to discuss sustainability at the global level. The conference stressed to establish to the UN Environment Program (UNEP), and the creation of numerous environmental protection agencies at the national level. The recommendations from Stockholm Conference were further elaborated in the 1980 by World Conservation Strategy: collaboration between the International Union for the Conservation of Nature (IUCN), the World Wildlife Fund (WWF), and UNEP: which aimed to advance sustainable development by identifying priority conservation issues and key policy strategies.

In 1983, the UN administrated to the World Commission on Environment and Development (WCED), chaired by Norwegian Prime Minister Gro Harlem Brundtland, and assembled representatives from both developed and developing countries, the Commission focused on growing concern over the "accelerating deterioration of the human environment and natural resources and the consequences of that deterioration for economic and social development". In 1987, the commission brought the landmark report of Our Common Future or the Brundtland report that provided a stark verdict to the state of the environment. The report popularized the most commonly used definition of sustainable development: "Development that meets the needs of current generations without compromising the ability of future generations to meet their own needs" (WCED, 1987, p. 45). Further the Brundtland report on sustainable development steered for the landmark 1992 Rio Summit that laid the foundations stone for the global governance for sustainable development. On the occasion of the twentieth anniversary of the Stockholm Conference, the Earth Summit adopted the Rio Declaration on Environment and Development and Agenda 21, a global plan of action for sustainable development. The developed countries acknowledge the

2 This part of work is drawn from the author own work on Transitioning to A Green Economy: policy orientation for sustainable development. Published in A Journal of Public Finance and Economy, Ministry of Finance, Singh Durbar, Kathmandu in 2013. Author

responsibility that they bear in the international pursuit of sustainable development in view of the pressures to their communities on the global environment and of the technologies and financial resources they command.

The Rio Summit successfully established global environment governance by establishing three important environmental institutions; these are the UN Framework Convention on Climate Change (UNFCCC), the Convention on Biological Diversity (CBD), and the non-legally binding Statement of Forest Principles. From the recommendation of Agenda 21, the UN General Assembly officially created the Commission on Sustainable Development (CSD). The Rio Summit was very successful that it had successfully sensitized on issue of environmental deterioration from the world to national level that this brought world's attention, attracted world leaders' active engagement and their meaningful attendance on many facets of environmental issues. Since that time, series of international conferences and meetings on sustainable development have been held like the 1997 Earth Summit+5 in New York and the 2002 World Summit on Sustainable Development (WSSD) in Johannesburg etc. These international gatherings were primarily reviews of progress; and reported that a number of positive results had been achieved, but implementation efforts largely had been unsuccessful at the national and international level. The UN General Assembly noted in 1997 (paragraphs 4 and 17) that "the overall trends with respect to sustainable development are worse today than they were in 1992" and "much remains to be done to activate the means of implementation set out in Agenda 21, in particular in the areas of finance and technology transfer, technical assistance and capacity-building." In 2002, United Nations Secretary-General Kofi Annan confirmed that "progress towards reaching the goals set at Rio has been slower than anticipated" and "there is undoubtedly a gap in implementation" (United Nations Economic and Social Council, 2002, p. 4). Regrettably, initiatives following the seminal Rio Summit have not attracted the attention, commitment, and resources required for effective implementation of sustainable development in water resources and irrigation sector. This is a problem with multilateral agreements that commitments at the international level do not reflect the processes and realities in a country, where multiple stakeholders including government, businesses, and non- governmental organizations (NGOs) need to be engaged in the action.

## NATIONAL PERSPECTIVE ON SUSTAINABLE DEVELOPMENT

In Nepalese context, with motivation from international development pacts and agreements, and be the party of international conventions, Nepal shows her commitments, obligations; crafted national policy strategies, rules and regulations etc. in the line of sustainable development, these pacts and agreements have been directly or indirectly contributing sustainable development in the country. Level of technology, size of economy and poor in human development could not afford to internalized or operationalized to these loaded international agendas.

Since sixth five-year plan (1982-1987) Nepal had concentration to internalizing its policies, programs and institutions for the sustainable development. In sixth five-year plan, Nepal introduced sustainable development in its national planning context that was fully translated into actions in the Eighth Plan (1992-1997); this plan was committed to achieve sustainable economic growth, poverty alleviation and reduction of regional imbalances. During the ninth five-year plan (1997-2002), the plan was concentrated on the need for development activities to be sustainable and for establishing links between environment and poverty. Further, the implementation of Agriculture Perspective Plan (1996-2015) and revised the Forest Sector Master Plan, giving communities a greater role in natural resources management.

In 2003, Nepal adopted Sustainable Development Agenda for Nepal (SADN); the SADAN was a policy strategy for promoting environmental management and sustainable development. Further, it emphasized for effectively integrating the sustainable development approach in planning with people's participation, and set direction for long-term targets in infrastructure, social and environmental sectors to be attained by 2017.

In coming to the tenth year five plan (2002/2007), it operationalized the SDAN strategies. In the same five-year plan, Nepal adopted the Leasehold Forestry Policy Guidelines, 2003; Collaborative Forest Management Guidelines, 2003-2004; and revised the Water Resource Policy 2003; these policies strategies were shown the commitment toward the SADAN. All of these policy strategies valued of community participation, resource sharing, sustainable use of resources, and privatization of services, good governance, and transparency.

In fiscal year 2007/2008; Nepal adopted to the three year interim plan (2007/08–2009/10), the plan emphasized protection, restoration and sensible use of natural resources, and promoting sustainable development through people's participation in campaigns to mitigate urban pollution, to make rural areas clean and green to ensure an individual's right to live in a clean environment, and to effectively implement commitments on environmental management.

In the recent development, Nepal is ready to bring new three year plan of 2013-2015, the three year plan (2010/11-2012/13) completed, this recent completed plan had aim to promote green development, make development activities climate-resilient society, mitigate the adverse impacts of climate change, and promote adaptation. This plan focused on the mitigation to urban pollution and protects natural landscapes. Within this plan period NAPA (National Adaption Plan for Action) finalized. The NAPA focused on identifying agencies and ensuring their roles and responsibilities for NAPA's meaningful implementation. This can be summarizes that Nepal has good stock of policy strategies and provisions of laws (Total 31 policy strategies and law provisions) regarding sustainable development, but shaky state governance and wicked institutions are key factors that these policy strategies and laws could not properly implementation. This has trend to drive nation toward unstained and weak nation in steering to sustainable affairs. Further, in the name of implementing international agendas or commitments, various form of aids and means entered into the country, nevertheless their contributions have hardly address to the core national development issues and challenges and enhance country's capacity that needed for sustainable development. Further, ongoing political morass in the country, this has been further deteriorating to mission of sustainable development. This havoc successfully undermines to national strengths, capabilities and fails to mobilize domestic resources for the sustainable development. Further, recent years' budget programs and sectorial policy strategies seem weak to address core issues of sustainable development. In order to maneuver country toward sustainability by adopting knowledge, skills, and technologies that were brought from international experiences, but it fails that the entire nation has been fully engaged to settle political impasses. These impasses have no starting or ending point. Most of mean has been pouring into settling to these political chaoses but end solution has not yet been proper direction. From this system a key agenda of national level is network, informal public private communication through which nation imposes its will on its external environment that is essential to contemporary governance for sustainable development. Absence of governance model (NewGov), entire state mechanism is dragged by party political games that the system has a question of legitimacy. In conclusion, without economic, environmental and social sustainability, the nation cannot be sustained and strong. There must not be any dispute (s) on the sustainability.

## CONCLUSION

While discussing on governance, capability approach and sustainability in the irrigation service context, it presents many challenges and opportunities in philosophical conception. Irrigation water flowing to the farm field and plant received, this mode of water deliver can easily be said as resources. Irrigation water is only available that technology has been supported to it and ensuring delivery of water. Contemporary Nepalese governance system perceives that technology physically controls to channelize the water but experts fail to fully internalize that it also shapes social construct under, which water is received by users or farmers. Vincent (1997) debates that is irrigation is a technology or a resource? How these two different perspectives affect to the sustainability of irrigation service. Further Vincent (ibid) elaborates that irrigation is as social and socio technical system. Irrigation service is extremely important of social, economic and environmental facets. Governing to irrigation service is extremely difficult task that it has many complexities from all facets of the societies including environment, now we could add one more of climate change issue. Without considering to new mode of governance, the expected outcomes could not be received. This paper call for rethinking on governance of irrigation services that contemporary practices in this sector have many faulty elements and less focused on emerging issues. The Governance' must be efficient that steer to practicing though the societies which deals with managing, guiding action in the realm of public and economic affair, especially needs to focus on public policy decision making. Rethinking on governance for sustainability of irrigation service takes place in the context of the reciprocal interaction within and between multi level social, economic and ecological system across temporal and spatial scale.

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# Small Scale Irrigation Systems in Nepal:

# Its role and contribution in the livelihood of the local community in the context of Irrigation Policy of Nepal

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***ABSTRACT***

*Small scale irrigation systems have been a major contributor for food security in Nepal but its importance, economic value and role in the socio-cultural development and poverty alleviation have yet to be considered within the challenging context. Categorization of size of irrigation systems as given in the Irrigation Policy of Nepal, 1992 and subsequent amendments are systems less than 25 ha in the hills and less than 200 ha in terai are small scale irrigation systems. There are thousands of small scale irrigation systems than in the middle hills and mountains of Nepal supporting the subsistence livelihood of millions of people. These systems are outside the main stream of formal irrigation policy and institutions like the Department of Irrigation and Ministry of Irrigation of Nepal.*

*These systems are either built by the community of users or by the family of the land owners close to the water sources. Therefore, they are either private or family own systems or community owned systems depending on the source of financing of the system development. The category is also dependent on the ownership of water source of the system. If the water source is categorized as community ownership, it becomes community ownership of the system. If the water source is registered to the private party, the irrigation system becomes private or family owned irrigation systems.*

*Recently, small irrigation systems got attention of the policy makers, external donors, INGO and NGOs. Government agencies such as Ministry of Federal Affairs and Local Development through DOLIDAR, Ministry of Agriculture through the Department of Agriculture and Ministry of Poverty Alleviation and Cooperatives have supported these small irrigation systems. Asian Development Bank ( Community Irrigation Project), Helvetas assisted Irrigation Project under Local Infrastructure Support for Livelihood Improvement Program ( LILI Program), Western Upland Poverty Alleviation Program (WUPAP) funded by IFAD support small scale irrigation systems. Ministry of Agriculture implements through DADO the World bank funded small scale irrigation systems through*

1 Patron, FMIST
2 IWMI-Nepal
3 IWMI-Nepal

*the Investment Support Grant (ISG).*

*There is need to rethink about the small irrigation policy. Institutional reforms of irrigation development agencies should imbibes the new values of socio-economic change of (a) inclusiveness, (b) gender concern, (c) self-governing local water institutions (d) promotion of self-supporting institutions and(e) poverty alleviation. Since many agencies have been providing assistance to SSISs, there has not been uniform and consistent policy on intervention.*

## INTRODUCTION

Small scale irrigation systems are not just a means to increase food production for food security but offer many development opportunities for the rural population and therefore significantly contribute to poverty reduction, social and economic development and to the creation of sustainable rural livelihoods (T.Brabben.et.al.2004).Small irrigation systems have in the past been considered by government agencies and donors as infrastructures but in fact represent the embodiment of local knowledge, local technology and skills, and reflect the system of social relations, resource mobilization and institutions for natural resource management of the community.

The importance of small-scale irrigation systems in Nepal, their economic value and role in the socio-cultural development and poverty alleviation have yet to be acknowledged by policy-makers and located within the challenging context of Nepal. The latter includes a) soft state syndrome, b) absence of elected functioning government, c) post-conflict uncertainty and political instability and d) entrenched socio-economic inequality among the community members in the rural areas.

This paper is addressed to decision–makers within development agencies and policy initiators and aims at highlighting the important role of small irrigation systems in sustaining food security, improved nutrition and rural prosperity and providing guidance to design appropriate strategies for rehabilitation interventions in the context presented in the earlier paragraph.

## EXTENT OF SMALL SCALE IRRIGATION SYSTEMS IN NEPAL

There are thousands of small scale irrigation systems ranging between 1 ha to less than 25 ha in the middle hills and mountains of Nepal supporting the subsistence livelihood of millions of people.

Small scale irrigation systems of less than 25 ha are scattered all over Nepal, yet they are prominently found in the middle hills and upland areas. These systems are either built by the community of users or by the family of the land owners close to the water sources. Therefore, they are either private or family own systems or community owned systems depending on the source of financing of the system development. The category is also dependent on the ownership of water source of the system. If the water source is categorized as community ownership, it becomes community ownership of the system. If the water source is registered to the private party, the irrigation system becomes private or family owned irrigation systems.

It will be useful to estimate the share of the small scale irrigation systems in the total 12 million ha irrigated area in Nepal. An overview of the status of small scale irrigation systems can be found from the irrigation systems inventory of 4 districts of middle hill regions. The study was commissioned to the District units of National Federation of Water Users Association of Nepal (NFWUAN) by Farmer Managed Irrigation Systems Promotion Trust in 2001.

Table 1: Irrigation Inventory of Four Districts

| District | Total | Less than 25 ha | % of small scale system |
|---|---|---|---|
| **Kathmandu** | 238 | 131 | 55% |
| **Bhaktapur** | 91 | 37 | 40% |
| **Dolakha** | 237 | 139 | 58% |
| **Okhaldhunga** | 292 | 219 | 75% |
| **Total** | 858 | 526 | 61% |

*Source: FMIST (2001), Kathmandu*

Similarly, the assistance to FMIS was provided by WECS and IIMI in 1980s to 19 irrigation systems in Indrawati Watershed area of Sindhupalchowk district. Out of 19 systems, 12 systems had less than 25 ha, approximately 63 % of the total. In the same area within 200 sq. km, 119 systems were recorded with total command area of 2100ha. Those 119 systems were bigger than 5 ha. There were still many small systems of less than 5 ha unaccounted. These systems are important for the livelihood of many people. The average command area per system comes about 17 ha. If we apply the trend of the size of the command area, it is estimated that out of 119 systems identified, 74 units are expected to be of less than of 25 ha system which is categorized as small scale irrigation system. It comes out to be approximately 66%. Out of 15000 units estimated irrigation systems in Nepal, if we assume that 66% of them are less than 25 ha, it comes out to be about 9900 units commanding about 1, 68,300 (14% of total irrigated area of surface irrigation providing food security to over 2 million people) ha which are categorized as small scale irrigation systems in the middle hills and upland area of Nepal. This figure excludes the irrigation systems in the terai area.

## INSTITUTIONAL ARRANGEMENTS FOR IRRIGATION DEVELOPMENT AND MAINTENANCE

The National Statute of Nepal (MulkiAin, 1853, and subsequent amendments) states in the Land Cultivation Section of MulkiAin that the community or individual can construct irrigation system to cultivate the new land. Those systems are to be maintained annually by the users themselves. In case of big disaster caused by slides or flood, the local official (jimawal or Jamindar) informs with request for assistance to the district administration. The district administration arranges assistance for repair of the system. Similar provision is continued in the National Statue of Nepal (MulkiAin, 2010) amended in 2010. It is also stated that other system above the existing system can be constructed making sure the amount of water being used by the old system should not be affected. This provision talks about prior appropriation right as well as the water right establishment based on investment. So it is stated in the National Statute that other people can get water for irrigation only after the use of water by the first party having investment to bring irrigation water for irrigation. The National Statute of Nepal (MulkiAin) states that those irrigation systems are to be maintained and managed by the irrigators themselves. Private sector is encouraged to develop irrigation systems both in hills and terai in Nepal. Provisions were also made in the statute that land revenue exemptions specified period will be provided to the irrigation developers. This was the tradition of community engagement in local water resource management continued from the King Ram Saha's statute which states that the conflict relating to water should not be brought for arbitration in the court (Riccardi.1977)

The Irrigation Policy, 1992 and subsequent amendments state that medium and small scale irrigation systems feasibility study; design will be the responsibility of the implementing agency like DOI. Manpower required for these systems will be trained by the concerned agency. Data base of all irrigation systems and their performance will be the responsibility of the DOI. However , the categorization of size of irrigation systems as given in the Irrigation Policy of Nepal, 1992 and subsequent amendments define small scale irrigation systems as systems with a command area smaller than 25 ha in the hills and smaller than 200 ha in terai. These systems are under the purview of local governing agencies and user groups and therefore do not come within the jurisdiction of Department of Irrigation (Irrigation Policy, 2004). This institutional gap has hindered the development of a coordinated and sound strategy.

## INVOLVEMENT OF MULTIPLE AGENCIES AND DONORS

Of late, the concern for enhanced food security, poverty alleviation and increased cash crop production and market linkages have brought the small and non-conventional irrigation systems to the attention of the policy makers, external donors, INGO and NGOs. Government agencies such as Ministry of Federal Affairs and Local Development through DOLIDAR, Ministry of Agriculture through the Department of Agriculture and Ministry of Poverty Alleviation and Cooperatives have supported these small irrigation systems. Asian Development Bank (Community Managed Irrigated Agriculture Sector Project CMIASP), Helvetas assisted Irrigation Project under Local Infrastructure Support for Livelihood Improvement Program (LILI Program), Western Upland Poverty Alleviation Program (WUPAP) funded by IFAD support small scale irrigation systems. Department of Agriculture also extends assistance to the small irrigation systems through District Development Agriculture Development Offices (DADO). Ministry of Agriculture implements through DADO the World Bank funded small scale irrigation systems through the Investment Support Grant (ISG). DOI has a unit on non-conventional irrigation to develop sprinklers and drip irrigation systems. Under Irrigation and Water Resources Management Project (IWRMP) through Investment Support Grant (ISG), DOI is implementing non-conventional irrigation systems as well as small irrigation systems to help small farmers in 31 districts undergoing food crisis and 10 districts undergoing marginal food crisis. Ground Water Resources Development Board helps the development of shallow tubewells (STW) which cover about 4 ha/STW. Partly because of the multiplicity of actors involved, there is lack of consistent policy on small scale irrigation development within the challenging context (Pradhan.2012).

Irrigation development requires multi-sectoral knowledge of hydrology, hydraulics, civil engineering, soil, agronomy and social institutional, environment of the command area. Engineering is one of many components that constitute a social-ecological system (SES) of irrigation domain. An irrigation system composed of a resource (source of water), physical infrastructure (storage and canals), actors who manage and appropriate (farmers and irrigation managers) and a governance structure that regulate the action and interaction of the actors (irrigation institutions) is an example of SES (Ostrom, et. al. 2011). As of now, the dominant approach guiding rehabilitation interventions of small scale irrigation systems in Nepal has been only input oriented for physical infrastructure improvement.

**A CASE STUDY OF IRRIGATION IMPROVEMENT INTERVENTION IN WUPAP**

The International Fund for Agriculture Development (IFAD) supports the implementation of rural development programs in many countries. The agriculture water management (AWM) component is often included in these comprehensive programs.Recently, IFAD asked the International Water Management Institute (IWMI) to undertake a study on " Improving Sustainability of Impact of AgriculturalWater Management Interventions in challenging contexts" in five countries of Africa and Asia, including Nepal.For each irrigation system, the fieldwork explored in detail theirsocio-biophysical environment along with the process of intervention undertaken under WUPAP, the role, power and responsibilities of the users committees in the implementation of the intervention and subsequently the management of the system (Basnet 2010; 2011; Sugden, et.al.2012).

The general characteristics of the selected irrigation systems for study are as follows[4]:

- Most are below 25 ha of command area
- All of them are gravity irrigation systems
- The exact number of Water Users in the command area is not reported. The number of beneficiary farmers in each system is not known
- Land ownership is secured by the individuals. Non-member of the system

4 General characteristics of the systems are given in Table.2.

can cultivate in the command area only as the share cropper.

- Three type of irrigation systems by ownership of water right are reported:

    - o Community irrigation systems owned by the members of the village and they have rules of O&M, water distribution and management, defined membership in the system and fulfill the obligations of membership. Such irrigation systems are considered the property of the community as a whole, regardless as to whose land the canal passes through. Therefore if ownership of fields in the command area changes, the new owners still have a right to use the water. It is worth noting that 'public' implies that the canal is owned by the village, although disputes sometimes arise with neighboring villages over the allocation of water, or when canals from neighboring villages pass through the land of another village.

    - o Lineage owned irrigation system. In some villages such as Potadha and Chaudam in the main Seti valley, property rights for canals are claimed by lineages, generally the descendants of the families who originally built the canal. In these villages, there are often several parallel canals which were built by the founders of the settlement. In Chaudam these were built 13-14 years ago. As a result, the number of descendants is often quite large, with one canal being collectively owned by up to 40 households from the same lineage, and another being owned by just five to six households. The one 'public' canal has this status as it was built a very long time ago when there was apparently only one household in the village. It is however, no longer working due to a landslide.

    - o Private irrigation systems are those which have investment for development and the source of water is registered in that individual name. Such systems can be sold or bought in the market. The owner can sell his extra water to others.

- With these different types of irrigation systems by ownership, there are different types of water rights. Primary water right and secondary water right are usually established under these conditions. The primary water right is the water right to use first. Secondary water right is that which will allow to the person to use water after the primary water right holder finishes irrigation or use of water. Such water right would be established on the basis of agreement between the first water right holder and secondary water holder.

- It is not clear what type of water allocation is made. However, water distribution is on the basis of rotation. In some systems , they have caretaker for water distribution. In Bajhang, the person is known as Kulalo. He is appointed by the beneficiary farmers. He is given remuneration in kind of rice for his job of water distribution in the system. Similar system is maintained in Mugu. The person is know as Seralo. Gilbili system in Mugu has only 8 beneficiaries of the system and he will get remuneration in kind for the job. At present, the system became unattractive due to more lucrative remuneration from out-migration, the monetization of the local economy and rising demand for cash incomes.

- These systems do not have any annual meeting of the members of the system for collective decisions, although decisions are made on an informal basis through consensus.

- However, they have system of annual maintenance and repair of the canal and intake.

    - o In private system, owner of the land where the canal passes, the land owner desilt and clean the canal. The source of the canal will be collectively cleaned.

    - o In public and lineage owned canals, annual repair and cleaning are carried out by collective effort.

    - o One member from the beneficiary family has to contribute two times a year. It is reported that contribution is on household basis, not proportion to the land ownership.

    - o During emergency caused by flood or landslide, contribution of labor becomes strict and failure to comply will be subject to penalty.

Table 2 presents the outcomes of the intervention for each case study system.

**Table: 2.Features of Case Study of Irrigation Systems undertaken by IWMI**

| Characteristics | Chaudala | Pothada | Chaudam | Majhigaun | Gilbili, Mugu |
|---|---|---|---|---|---|
| Ownership | Community | Lineage ownership | Lineage | Community | Community |
| Command area | 19 | 16 | 21 | Not known | 7 |
| Water Supply | In-sufficient | In-sufficient | Insufficient | Sufficient | sufficient |
| | | **After WUPAP Support** | | | |
| Year | 2005 | 2007 | 2010 | 2008 | 2008 |
| Intervention type | Rehab. lining | Rehab, Lining | Rehab, Lining | New system, pipe, lining | Rehab, Lining |

| Status at IWMi study, 2010 | Not completed, improved section ok | Functioning ok, small section damaged by slide | Little improvement | Not completed, settlement flooded | Damaged after one year |
|---|---|---|---|---|---|
| Water status after | increased | increased | negligible | Increased | increased |
| Investment amount in Rs'000 | 216 | 590 | 200 | 420 | 380 |
| Per/ha cost in Rs | 11,368 | 36,875 | 9,523 | Not known | 54,285 |
| | | | | | |

*Source: Basnet, 2010, 2011; Sugdenet al. 2013.*

## ISSUES TOWARDS ASSISTANCE TO SMALL SCALE IRRIGATION SYSTEMS

An effective intervention process has to be designed in conjunction with the operation of the SES rather than conducted as an external process of manufacturing changes to the system. In Nepal, the engineering-centered approach has, and continues to dominate the irrigation development. An intervention project is often considered to be no more than a package of 'deliverables' to be provided by government or donor agency. Officials in these organizations often look at an intervention project from a bureaucratic lens, focusing on manufacturing the deliverables in accordance with some criteria and standards specified by their organizations.

There is need to rethink about the smallScale irrigation policy. Institutional reforms of irrigation development agencies should imbibes the new values of socio-economic change of (a) inclusiveness, (b) gender concern, (c) self-governing local water institutions (d) promotion of self-supporting institutions and(e) poverty alleviation. Community engagement during intervention through project preparation to implementation and O&M has to be the prime concern in the implementation of small scale irrigation development programs. Since many agencies have been providing assistance to SSISs, there has not been uniform and consistent policy on intervention.

Hence, it might be appropriate to think of establishment of a Department of Small Scale Irrigation Development under the Ministry of Irrigation and make in charge of overall consistent policy formulation and implementation procedures and creating a cadre of manpower who can understand the dynamics of SSIS.

Investment in small scale irrigation development is a major issue. It might be appropriate to consider in establishing a "Fund Board" where the users of the irrigation systems on the basis of need can request for grant and loan for the rehabilitation and improvement of the small scale irrigation systems.

There are many other issues to be taken into consideration for sustainable development of Small Scale Irrigation systems.

Manpower development in implementing agencies for small scale irrigation development deserve special attention keeping in view the shortage of trained human resources at the implementing agencies at present.

There are many other issues to be taken into consideration for sustainable development Small Scale Irrigation systems.

- Criteria for selection of the candidate system for assistance are to be fixed keeping in view of the challenging context. Since three types of irrigation systems by ownership are identified, can all of them be candidate for assistance. Should only the public irrigation systems be the candidate for assistance from the project? In any case, Water right issue is to be sorted out to avoid the possible conflict in future or incompletion of the project. Such situation is reported in the case study from Bajhang.

- Selection criteria based on equity and social justice is to be fixed. Under such condition, selection of the system on demand driven basis could be misleading towards poverty alleviation objective (WECs1990 and GITEC Consult, 2007, Lohanee.2010)

- Identify all FMIS in the country on a watershed basis or at the initial stage at Village Development Committee basis for making an inventory that establishes a database including information on local water rights.

- After the selection of the candidate system, there should be thorough investigation and interaction with the farmer members of the system. Alternative design issues are to be discussed with the farmer members. Local materials and local knowledge of the farmers are also to be taken into consideration during design of the system.

- List of the beneficiary farmers are to be collected along with the landholding size. The number of the beneficiary is to be established.

- If the system is to be expanded, there is need of more interaction with the present beneficiaries and future beneficiaries. Rules , roles and obligations are to be spelled out.

- It is to be viewed that the Water users organization has to be self-supporting and self-managing. It has to be inclusive with representatives of dalits and women.

- It would be useful to avoid establishing Construction committee for physical intervention. The existing WUA should play the role of providing support during intervention. Construction committee has caused more problems than the solutions to the problem of construction (Ostrom, et.at. 2011).

- In order to promote community engagement, the social mobilizer can play important role. Hence his /her skill has to be strengthened by providing appropriate training suitable for multiple activities he/she has to undertake in the village. Salary to the social mobilize has to be attractive enough so that he/she is motivated to be in the villages for the promotion of motivation activities to the villagers and play the role of advocacy on behalf of the beneficiary farmers. He/she has to be made accountable to the local community as well through his / her activities in the community(Manor, et .al.1990)

- Technical manpower is to be duly trained in the capacity development for consideration of appropriate type of structures, local construction materials and appropriate design of the systems. During the process, the technicians have to promote the skill of community engagement during project selection, design, implementation and O&M of the system. (WECS.1990) The local knowledge of the community will be prominent when the technical people makes attempt to collect the information of the local situation through the village elders before design of the system as well as when the technicians get themselves engaged in appreciative interview in the community. It was reported in one case study that the system was designed without due consideration of physical features like landslides and other social and physical constraints (Sugden, et.al.2012). The type of technical manpower required for the project is not easily available in District Technical Office of District Development Committee. Hence, special training including community engagement, hands on exercise, appreciative interview and approaches towards community empowerment has to be arranged to these field technical staff and officers at the DTO.

- Oftentimes, it becomes difficult to provide benefit to all farmers? by the existing irrigation system funded IFAD for improvement. Under such circumstances, specific program like micro-irrigation for the target group is to be planned.

- Voluntary labor mobilization is wrongly interpreted when we talk about irrigation system construction or rehabilitation. The labor that they provide is the part of their obligation in exchange of water right that they have secured or area of land that is to be irrigated. The labor contribution is obligation of the members of the irrigation system. Therefore, we have to consider about the role, responsibility and obligations of those beneficiary farmers. In the system where community manages the system, the contribution is made on the basis of the size of the landholding or the share of the water right.

- There is need to strengthen complementary sector of irrigation. Irrigation and agriculture activities should go together. Supporting organizations like cooperatives etc are to be established with their active participation. Agriculture support services are to be made easily accessible.

Similar recommendations were made in the Dhulikhel Declaration as the result of the "National Seminar on Small Scale Irrigation: Experiences, Challenges, Opportunities and Pathways" jointly organized by DOLIDAR, SDC, Helvetas and others on December 5-6, 2012. The Declaration includes:

**1.** Small scale Irrigation Systems (SSIS) play critical role in supporting local food security of small and marginal farmers.

**2.** It occupies large percentage of irrigated agriculture in Nepal. If we consider the units of small scale irrigation systems, they consist of over 60 % units of irrigation systems.

**3.** Provisions of Irrigation Policy are to be revisited and Implementation clarity is to be spelled out.

**4.** Central and Local level technical manpower capacity to be updated

**5.** It is to be interfaced with agriculture production system.

**6.** Community engagement during project preparation and implementation is to be strengthened so that the beneficiaries take the ownership of the systems.

**7.** WUAs are to be made functional and due roles and responsibilities are to be taken by them.

**8.** Watershed management for the promotion and protection of Small scale Irrigation System. (SSIS)

**9.** Different technical alternatives for design and construction for SSIS are to be explored.

**10.** Many institutes that are working for SSIS have to work in coordination and work together in order to develop a consistent and complementary program and policy.

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**Appendix.1.**

**Cost of Small Scale Irrigation (surface) Development in Nepal (2013)**

| Project\ cost | Per ha | Per unit of system |
|---|---|---|
| WUPAP[1] | Nrs. 11000 – 54,000 | x |
| LILI Program[2] | Nrs. 1,80,000 | x |
| CIP[3]<br>Rehabilitation<br>New Construction | <br>Nrs.86,000<br>Nrs. 1,30,000 | |
| ISG[4] | Nrs.10,000-15,000 | |
| DADO[5] | | Nrs. Up Nrs. 1,00,000 |
| DDC/VDC[6] | | Nrs 1,00,000- ? |

1 Western Upland Poverty Alleviation Project funded by IFAD. Figure extracted from Fraser Sugden’s Report. p.37

2 Local Infrastructure for Livelihood Improvement (LILI). Information shared by Mr. BhagatBista

3 Community Irrigation Project (CIP) now managed by DOLIDAR, Information shared by Mr. Naveen Mangal Joshi

4 Investment Support Grant of World Bank specially for food crisis districts. Information shared by Mr. BasuDevLohanee, Senior Divisional Engineer, DOI

5 District Agriculture Development Office provides grants for minor repair of the small irrigation systems, similar support is also provided by WB-supported IWRMP also.

6 District Development Committee and Village Development Committee also provide financial support for rehabilitation of small irrigation systems through the Users’ group and supervised by district technical office.

# Analytical Status of Groundwater Irrigation in Nepal

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***Groundwater Irrigation Project, DoI***

***Abstract***

*It is said that about 1766000 ha land of Nepal is irrigable. Out of this, infrastructure of irrigation has been developed on 1311960 ha (74%) land and remained to be developed on 454040 ha (26%) land. In irrigated land, the surface scheme, groundwater scheme, Non-Conventional scheme and Farmers manage scheme are contributing on 715666 ha (54.7%), 342376 ha (26%), 3774 (0.3 %) and on 250144 (19%) respectively. Apart from the Department of Irrigation, another two Government organizations; Agriculture Development Bank (ADB) and Department of Agriculture (DoA) are also equally involving for the development of groundwater Irrigation. In the case of groundwater irrigation, contributing parts of DoI, ADB and DoA are 204862 ha (53 %), 167946 (43%) and 1640 (4%) respectively. On the basis of technology, Deep Tube well is irrigating for 47845 ha (13%) land whereas the Shallow Tube well is irrigating for 341368 ha (87%) land. On the basis of time period, Shallow Tube wells of 108649 ha (32 %) land is age of more than 15 years. Probably, all those Shallow Tube wells which are constructed before 15 years before are not existed now. Similarly, Deep Tube wells of 20284(42 %) ha land have been more than 20 years; even some of them have been more than 40 years too. Consequently, most of them are not in function at present since of damage of pumps and impellors. All together about 128933 (33%) ha land which is showing irrigated through groundwater resources in the record may be defunct. Therefore, the Department of Irrigation should update the existing data. For this, study of re-assessment of groundwater irrigation in Nepal is urgently needed.*

## Introduction

The Terai Plain of Nepal is highly potential for groundwater resources because it is a part of the biggest groundwater basin in the world known as Indo-Gangetic Basin. The unconsolidated porous material of the basin has high capacity to store or release the groundwater resources. Presently, about 1.4 million people are living in the Terai and all of them are utilizing the groundwater resources for drinking, domestic, irrigation, industries, and for cattle purposes. So it can be concluded that approximately half of the entire population of Nepal has been depending on the groundwater resources directly. Among of various uses, high amount of the groundwater resources is utilizing in the sector of irrigation. Now, about 3420,000 ha land of Terai is irrigated from this resource which is about 26 % of the total irrigated land of the country (Figure 1). During the winter (dry) season, most of the surface drainages are dry up and the groundwater is only a main resource for overcome the burning situation. Therefore, the trend of groundwater utilization for irrigation is rapidly increasing in the country.

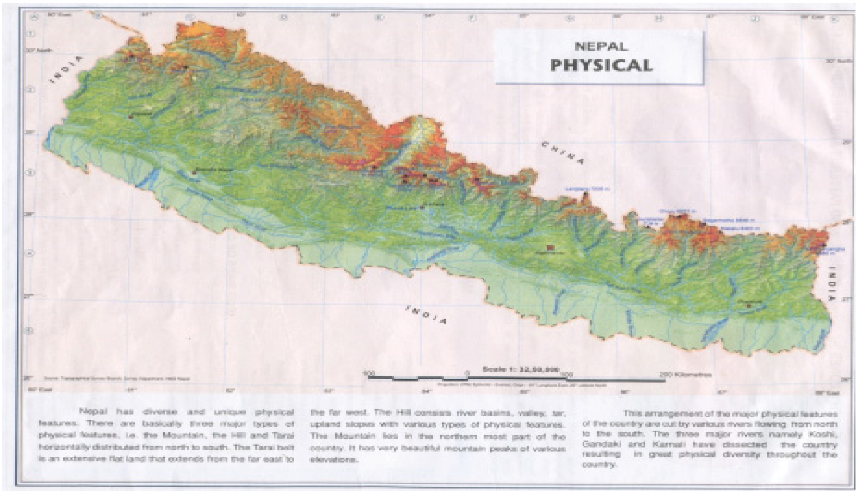



**Figure 1: Agricultural Land in Nepal**

**Present Status**

According to the data of Nepal government about 2641000 ha land of the country is agricultural land. Out of this about 1766000 ha is irrigable. According to the data or the Department of Irrigation (DoI), 2068 the irrigation infrastructure has been developed in 1311960 ha land. In which, contribution of surface scheme, groundwater scheme, Non-Conventional scheme and Farmers Manage Irrigation Scheme are in 715666 ha (54.7%), 342376 ha (26%), 3774 ha (0.3%) and in 250144 ha (19%) respectively (Figure 2).

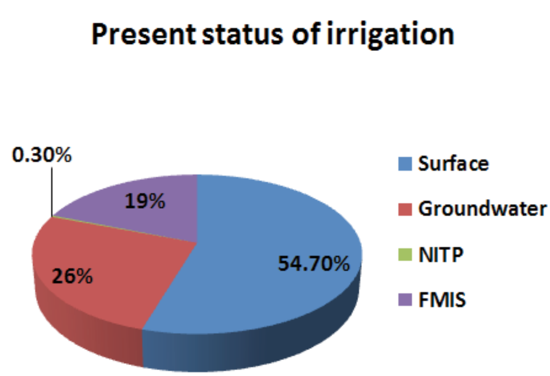



**Figure 2: Present status of Irrigation**

According to the Reassessment of Groundwater Irrigation in Nepal, GDC (1990), about 190000 ha land of Terai is potential for Deep Tube well(DTW)and about 720000 ha land is potential for Shallow Tube well (STW). Similarly, as per the Shallow Aquifer Investigation Project, UNDP (1994) the 924000 ha land is potential for Shallow Tube well and 574000 ha land is potential for Deep Tube well (Figure 3).

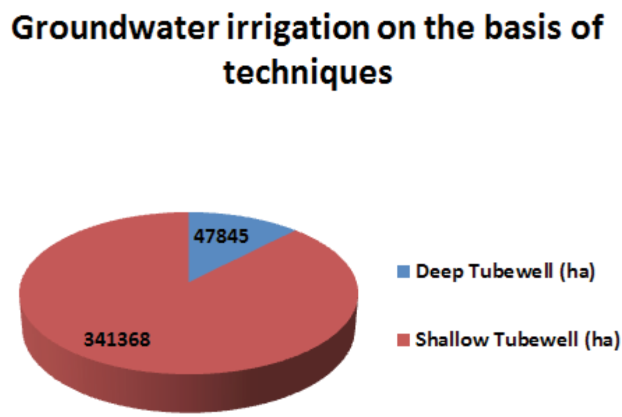



**Figure 3: Groundwater potential area**

On the basis of technology about 47845 ha land is irrigating through the DTW and about 341368 ha land is irrigating through the STW (Figure 4).

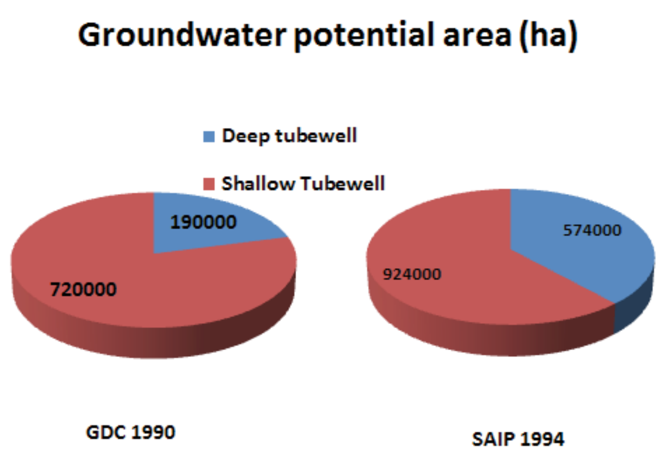



**Figure 4: Groundwater irrigation on the basis of techniques**

If it is compare between the potential land and irrigated land, the irrigated land through the DTW is only 13 % and STW is only 25 % (Figure 4).

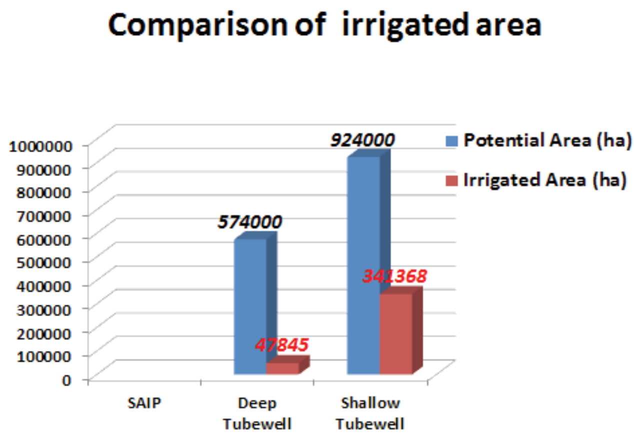



**Figure 5: Comparison of Irrigated area**

The involved organizations for groundwater development in the country are Department of Irrigation (DoI), the Department of Agriculture (DoA) and the Agricultural Development Bank (ADB). The contributing part of the DoI is about 204862 ha (53%). In which DTW part is about 41785 ha and the STW part is about 163077 ha. In the same way the contributing part of the DoA and the ADB are 16405 ha (4%) and 167546 ha (43%). In the DoA, the DTW part is about 6060 ha and the STW part is about 16405 ha. In ADB there is only STW contribution i.e. 167946 ha (Table 10).

**Table 10: Involved Organization**

| S.No | Organization | DTW (ha) | STW (ha) | Total (ha) | % |
|---|---|---|---|---|---|
| **1** | DoI | 41785 | 163077 | 204862 | 53 |
| **2** | ADB | 0 | 167946 | 167946 | 43 |
| **3** | DOA | 6060 | 10345 | 16405 | 4 |
| | Total | 47845 | 341368 | 389213 | 100 |

Development of the groundwater irrigation in 389213 ha land of Nepal is neither done by a single project nor at the one time. Its development was in more than the dozens of different projects in different periods. The name and the periods of the DTW and the STW projects held in different periods are given as below (Figure 6, Figure 7).

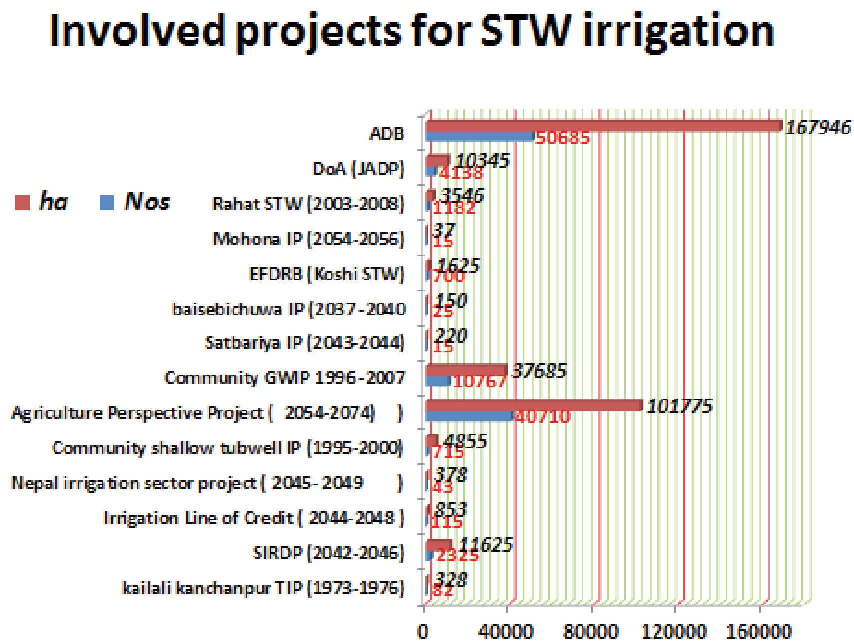
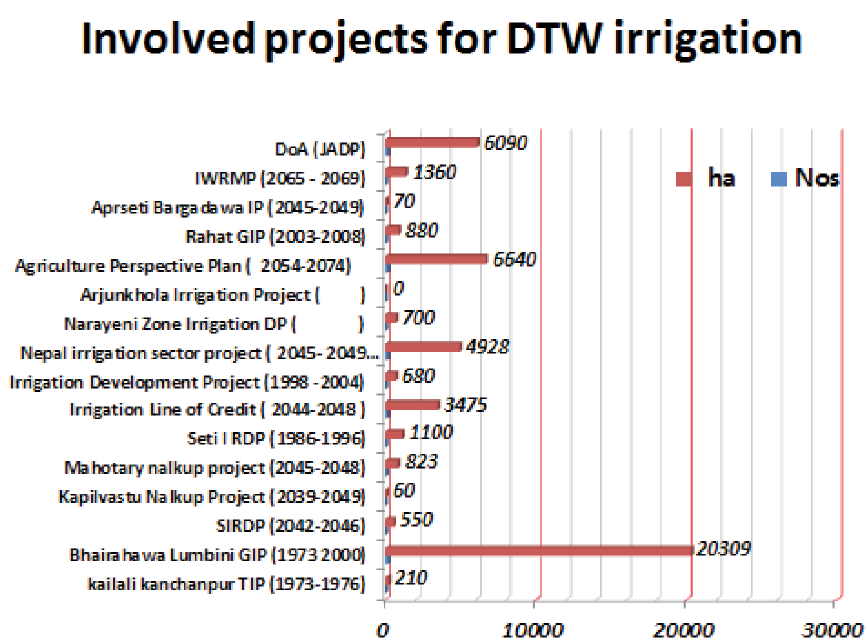



**Figure 6: Involved projects for DTW irrigation**

**Figure 7: Involved projects for STW irrigation**




The groundwater Irrigation from the STW is developed in 30 different districts of the Nepal.

In which Terai comprises 20 districts, Inner Terai comprises 2 district and the districts under Middle Mountain comprises the 8 districts (Figure 8). Similarly the groundwater irrigation from DTW is developed in only 22 districts of the Terai and Inner Terai (Figure 8, Figure 9).

**Figure 8: District wise distribution of DTW**

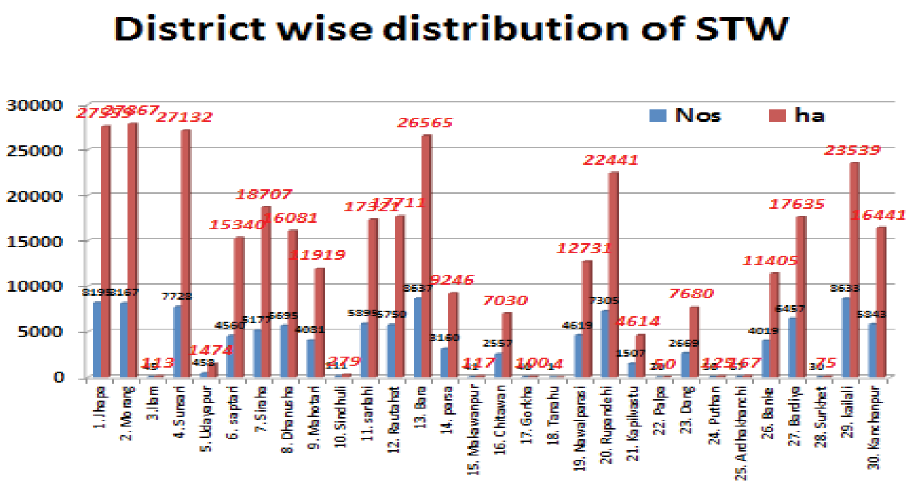
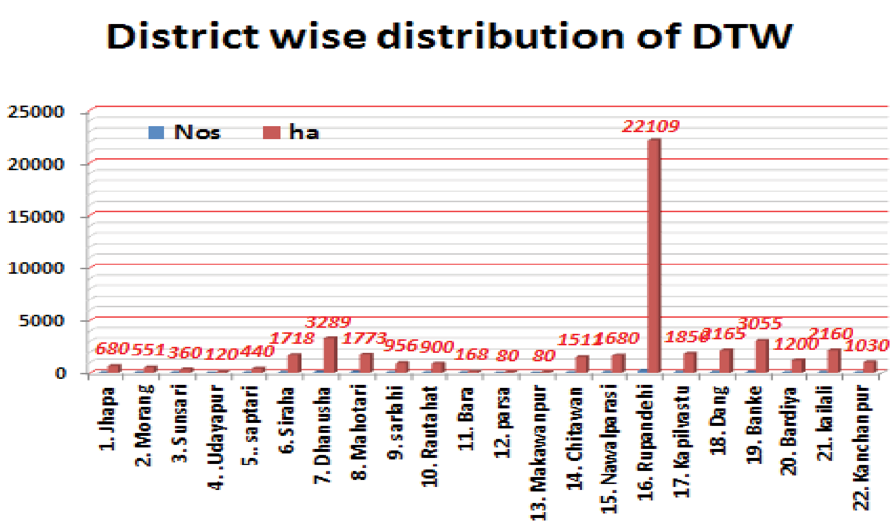



**Figure 9: District wise distribution of STW**




It is already mentioned that in the case of DTW about 47875 ha land is able to irrigate yet now out of 574000 ha potential land. It is about 8.34 %. Similarly in the case of STW about

341468 ha land is able to irrigate yet now out of 924600 ha. The potential area and the irrigated area of both DTW and the STW are shown in Table 11, Table 12.

**Table 11: Potential and developed area of DTW**

| District | Potential Area (ha) | Developed Area (ha) | Remained to be Developed (ha) | Developed Area (%) |
|---|---|---|---|---|
| **1. Jhapa** | 47900 | 680 | 47220 | 1.42 |
| **2. Morang** | 48600 | 551 | 48049 | 1.13 |
| **3. Sunsari** | 50200 | 360 | 49840 | 0.72 |
| **4. Udayapur** | | 120 | | |
| **5. saptari** | 16600 | 440 | 16160 | 2.65 |
| **6. Siraha** | 8300 | 1718 | 6582 | 20.7 |
| **7.Dhanusha** | 34100 | 3289 | 30811 | 9.65 |
| **8. Mahotari** | 48200 | 1773 | 46427 | 3.68 |
| **9. sarlahi** | 54400 | 956 | 53444 | 1.76 |
| **10. Rautahat** | 3800 | 900 | 2900 | 23.68 |
| **11. Bara** | 28300 | 168 | 28132 | 0.59 |
| **12. parsa** | 40600 | 80 | 40520 | 0.20 |
| **13. Makawanpur** | | 80 | | |
| **14. Chitawan** | 39000 | 1511 | 37489 | 3.87 |
| **15. Nawalparasi** | 3900 | 1680 | 2220 | 43.08 |
| **16. Rupandehi** | 26200 | 22109 | 4091 | 84.39 |
| **17. Kapilvastu** | 5200 | 1850 | 3350 | 35.58 |
| **18. Dang** | 12800 | 2165 | 10635 | 16.91 |
| **19. Banke** | 2300 | 3055 | -755 | 132.83 |
| **20. Bardiya** | 30800 | 1200 | 29600 | 3.90 |
| **21. kailali** | 55800 | 2160 | 53640 | 3.87 |
| **22. Kanchanpur** | 17000 | 1030 | 15970 | 6.06 |
| **Total** | 574000 | 47875 | 526325 | 8.34 |

**Table 12: Potential and developed area of STW**

| District | Potential Area (ha) | Developed Area (ha) | Remained to be Developed (ha) | Developed Area (%) |
|---|---|---|---|---|
| **1. Jhapa** | 56200 | 27559 | 28641 | 49.04 |
| **2. Morang** | 83600 | 27867 | 55733 | 33.33 |
| **3. Ilam** | | 113 | | |
| **4. Sunsari** | 53400 | 27132 | 26268 | 50.81 |
| **5. Udayapur** | | 1474 | | |
| **6. saptari** | 24700 | 15340 | 9360 | 62.11 |
| **7. Siraha** | 50400 | 18707 | 31693 | 37.12 |
| **8.Dhanusha** | 51600 | 16081 | 35519 | 31.16 |
| **9. Mahotari** | 48400 | 11919 | 36481 | 24.63 |
| **10. Sindhuli** | | 279 | | |
| **11. sarlahi** | 52700 | 17321 | 35379 | 32.87 |
| **12. Rautahat** | 46600 | 17711 | 28889 | 38.01 |
| **13. Bara** | 54800 | 26565 | 28235 | 48.48 |
| **14. parsa** | 41500 | 9246 | 32254 | 22.28 |
| **15. Makawanpur** | | 117 | | |
| **16. Chitawan** | 50000 | 7030 | 42970 | 14.06 |
| **17. Gorkha** | | 100 | | |
| **18. Tanahu** | | 4 | | |
| **19. Nawalparasi** | 19900 | 12731 | 7169 | 63.97 |
| **20. Rupandehi** | 54500 | 22441 | 32059 | 41.18 |
| **21. Kapilvastu** | 58800 | 4614 | 54186 | 7.85 |
| **22. Palpa** | | 50 | | |
| **23. Dang** | 34300 | 7680 | 26620 | 22.39 |
| **24. Pyuthan** | | 125 | | |
| **25. Arghakhanchi** | | 167 | | |
| **26. Banke** | 17600 | 11405 | 6195 | 64.8 |
| **27. Bardiya** | 46900 | 17635 | 29265 | 37.60 |
| **28. Surkhet** | | 75 | | |
| **29. kailali** | 53800 | 23539 | 30261 | 43.75 |
| **30. Kanchanpur** | 24900 | 16441 | 8459 | 66.03 |
| **Total** | 924600 | 341468 | 585636 | 36.93 |

The development of the groundwater resources for irrigation purpose was beginning from 40 years ago (1973). Since then the activities are still in continuous process. If we make the clear demarcation of 15 years periods for all those DTWs and STWs than we found that about 395 DTWs are more than 15 years old. The irrigated land from these DTWs is about 20284 ha (Table 13). In the case of STWs, about 31825 STWs are more than 15 years old. The irrigated land from these STWs is about 108649 ha (Table 14).

Figure 10: Water pumping from DTW

Water pumping from STW

**Table 13: More than 15 years old DTW**

| S.No | Projects/Institutions | Total | | Older than 15 Years | |
|---|---|---|---|---|---|
| | | Nos | (ha) | Nos | (ha) |
| I | Kailali Kanchanpur TIP (1973-1976) | 10 | 210 | 10 | 210 |
| 2 | Bhairahawa Lumbini GIP (1973-2000) | 165 | 20309 | 84 | 10155 |
| 3 | SIRDP (2042-2046) | 15 | 550 | 15 | 550 |
| 4 | Kapilvastu Nelkup Project (2039-2049) | 3 | 60 | 3 | 60 |
| 5 | Mahotari Nelkup Project (2045-2048) | 52 | 823 | 26 | 412 |
| 6 | Seti IRDP (1986-1996) | 29 | 1100 | 15 | 550 |
| 7 | Irrigation Line of Credit (2044-2048) | 113 | 3475 | 57 | 1738 |
| 8 | Irrigation Development Project (1998-2004) | 17 | 680 | 0 | 0 |
| 9 | Nepal Irrigation Sector Project (2045-2049) | 144 | 4928 | 70 | 2415 |
| 10 | Narayani Zone Irrigation DP | 29 | 700 | 15 | 414 |
| 11 | Arjunkhola Irrigation Project | 3 | 0 | 0 | 0 |
| 12 | Agriculture Perspective Plan (2054-2074) | 166 | 6640 | 17 | 680 |
| 13 | Rahat GIP (2003-2008) | 22 | 880 | 0 | 0 |
| 14 | Bhairahawa IP (2045-2049) | 3 | 70 | 3 | 70 |
| 15 | IWRMP(2065-2069) | 34 | 1360 | 0 | 0 |
| 16 | DoA (JADP) | 160 | 6090 | 80 | 3030 |
| | Total | 969 | 47875 | 395 | 20284 |

**Table 14: More than 15 years old STW**

| S.No | Projects/Institutions | Total | | Older than 15 Years | |
|---|---|---|---|---|---|
| | | Nos | (ha) | Nos | (ha) |
| I | Kailali Kanchanpur TIP (1973-1976) | 82 | 328 | 82 | 328 |
| 2 | SIRDP (2042-2046) | 2325 | 11625 | 2325 | 11625 |
| 3 | Irrigation Line of Credit (2044-2048) | 115 | 853 | 115 | 853 |
| 4 | Nepal Irrigation Sector Project (2045-2049) | 43 | 378 | 43 | 378 |
| 5 | Community shallow tubwell IP (1995-2000) | 715 | 4855 | 300 | 2040 |
| 6 | Agriculture Perspective Plan (2054-2074) | 40710 | 101775 | 3562 | 9045 |
| 7 | Community GISP (1996-2007) | 10767 | 37685 | 0 | 0 |
| 8 | Setbariya IP (2043-2044) | 15 | 220 | 15 | 220 |
| 9 | Baisebichuwa IP (2037-2040) | 25 | 150 | 25 | 150 |
| 10 | EFDRB (Koshi STW) | 700 | 1625 | 0 | 0 |
| 11 | Mahona IP (2054-2056) | 15 | 37 | 15 | 37 |
| 12 | Rahat STW (2003-2008) | 1182 | 3546 | 0 | 0 |
| 13 | DOA (JADP) | 4138 | 10345 | 0 | 0 |
| 14 | ADB | 50685 | 167946 | 25343 | 83973 |
| | Total | 111517 | 341368 | 31825 | 108649 |

In the percentage about 32% STW and about 42 % DTWs are more than 15 years old

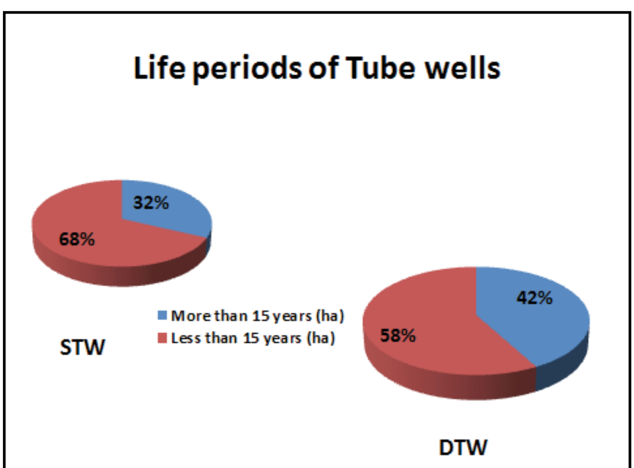



**Figure 11: Life period of Tubewells**

According to the reports which are based on the DTW and STWs the life periods of the STWs are about 12 to 15 years. The STW will be damage due to the causes of damage of pipes or screen and due to the cause of sand filling or some mechanical causes. However in the case of DTW, DTW itself will not be damage within the 15 years. Its life periods are about 30 years but the life periods of pumps and motors are about 12 to 15 years. Several chemical, mechanical and electrical problems will be seen in the pump and motor by which the pump and motor couldn't function as proper way. Thus within the 15 years periods, the pumps and motors should be change.

**Conclusion**

According to the report of the DoI, the developed infrastructure of the groundwater irrigation is about 342376 ha out of total developed infrastructure in 1311960 ha. In the groundwater infrastructure, about 969 DTWs and the 111517 STW are constructed. However, 395 DTWs are seen older than 15 years which covers about 20248 ha (42%) irrigated land. Similarly, the 31825 STWs are seen older than 15 Years and its coverage land is about 108649 ha (32%). All together about 128933 ha (33%) land which showing irrigated through the groundwater irrigation may not be existed in the field.

**Recommendation**

To resolve the cases, DoI should be done

1. Either rehabilitation program for both Shallow and Deep Tube well or

   Revision and update the present data of groundwater irrigation.

2. Field based re-assessment program of the groundwater irrigation of Nepal to find out the real status of the DTWs and STWs.

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# Ground Water Resources in Nepal and Role of GWRDB in its Management

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***Surendra Raj Shrestha2***

***ABSTRACT***

*Groundwater (GW) has played an important role in sustainable development of many parts of the world by providing water for domestic, industrial and agricultural uses. In terai Nepal, Groundwater is the main source for irrigation and municipal drinking water supply. terai plain is regarded as the continuation of Indo-Gangetic plain and constitute very thick layers of alluvial sediments, which has a huge renewable ground water potential.*

*It is reported that annual GW balance of terai plain is in surplus in compare to the abstraction rate. But excessive and unplanned use of this precious resource may create serious threats to its sustainability which is happening in Kathmandu valley. Due to high water demand i.e, 325 Million liters per Day (MLD), the daily abstraction rate of groundwater is increasing rapidly by reason of lack of surface resources in the Kathmandu valley. The abstraction of groundwater is reported to be about 78.4 MLD. The exact situation of groundwater extraction within the valley is however not known because there is no legal requirement or well established institutional mechanism to regulate or control it.*

*Shallow aquifers are also over - exploited, unprotected and uncontrolled. Similarly, Dhunge Dharas have dried up in many areas of Kathmandu valley and built up area is increasing year by year even within the identified recharge area. It is therefore, detail exploration is need of the time and a following suggestive measure has to be applied to solve the threats.*

- *One of the appropriate techniques would be artificial recharge through surface spreading, which is still possible at the upper reaches of Bagmati and Manohara rivers. However, in the built up area, the only way for GW recharge is through the well injection.*
- *Numerous springs from limestone karstified zones are found in the southern frame of the valley with totaled discharges 497 Lit/sec or 43 MLD can be the very good option to fulfill the present water demand in some extent. If it came to be feasible its exploration would require less investment and short time consuming in comparison to other drinking water projects.*

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*Now the question arises, which organization is responsible for these works? There are many institutions working in the groundwater development and management. Among these institutions Ground water Resources Development Board (GWRDB) established in 1976, which has been mandated with oversees policy related to groundwater and implementing body of groundwater resources development may be the obvious choice. With extensive experienced and comprising related qualified experts Ministry of Irrigation/GWRDB can play a vital role, but which in not happening now. In this perspective GWRDB may be the most important actor for*

- *In Groundwater Investigation & development*
- *In groundwater Database Management*
- *In Groundwater Regulation*

*Kathmanu valley Water Supply Management Board (KVWSMB) established in 2006 with the mandate of regulating the groundwater extraction and issuing license do not have related experts can be considered as a good example of ground water mismanagement in Nepal.*

## INTRODUCTION

Nepal is a landlocked mountainous country, geographically: it is bordering with China in the North and India in the South, East and West. Nepal lies between latitudes $26^0 22'$ N to $30^0 27'$ N and longitudes between $80^0 4'$ E to $88^0 12'$ E, covering an area of 147,181 square kilometers, of which East to West length is 885 km and the mean width form North to south is 193 km. One-third of Nepal is covered by plain area ("Terai"), which lies in the southern part of the country having elevation from 100m, to 200m, above mean sea level.

## GENERAL HYDROGEOLOGY OF NEPAL

Groundwater is one of the resourced of Nepal. It is found in most parts of the country. Only the amount and depth vary from place to place. The preliminary hydrogeological mapping suggests that except the unfractured granite, gneiss and meta-sediments of higher metamorphic grade in midland and higher Himalaya, the rest of the geology has potential for groundwater. Among the potential, loose sediments of Terai and inner Terai, karstified and fractued carbonate rocks of midland and Tethys group are considered to be highly productive aquifers. And unconsolidated deposits of Kathmandu and Surkehet valleys, Siwalik rocks, non-karstic but fractured carbonate rocks in lower Himalaya, Crystalline Complex and Tethys group are interpreted as moderately productive aquifers (figure 1).

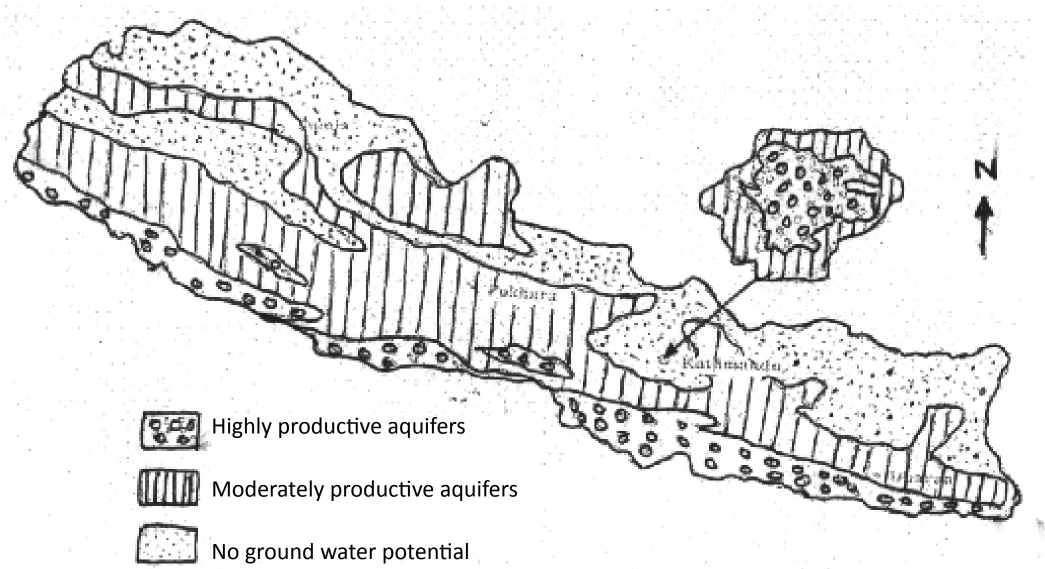



***Figure-1:- Preliminary Ground water Potential Map of Nepal***

Except this preliminary map, there is no nationwide hydrogeological study out so far. However, the uses of groundwater are well known throughout the country in the form of springs, dug-wells and tubewells. In compare to other parts, groundwater investigation and development are concentrated in Kathmandu valley, inner Terai (structural basin) and main Terai only.

In hills and mountain region of Nepal, springs sources are used extensively for drinking and irrigation purposes and detail investigation works has not been done yet. But ground water resources development works for irrigation and drinking purposes is mainly concentrated in "Terai" (plain) area. It is therefore, the text is very relevant to brief here in two parts; (i) Groundwater resources in terai and (ii) Groundwater resource in the Kathmandu Valley.

**GROUNDWATER RESOURCES INVESTIGATION IN NEPAL: AT A GLANCE**

*The Major during investigation are:*

1. Groundwater feasibility survey by Geophysical methods and Exploration of tube wells in Terai district of Nepal.

2. Construction of Deep & Shallow Tube wells for Aquifer test. These wells are also development and Environment Impact.

3. Monitoring of water level, water quality and quantity its interpretation for further development and Environment Impact.

Concerning with above works, GWRDP is fully involved in the investigation and development of Groundwater resources for irrigation purpose mainly in the Teria and inner Terai. Those technical data are used to delineate groundwater irrigation development projects.

**Hydrogeology of the Terai**

The Terai plain is a continuation of Indo-gangetic plain, lies southern part of mountain range of Nepal. The Terai aquifers occur in the following two hydro-geological significant depositional units:

- Bhabar zone is situated in the foothill of the Siwalik range consisting of alluvial and colluvial coarse sediments (boulder, cobble and pebbles). This is the major recharge area of terai palin. The Bhabar zone sediments consist of permeable, unconfined aquifer, deep water table. High rainfall occurs in this zone about 1700 mm in compare to the southern area.
- The southern zone (terai Plain), which consists of thick sediments of Indo-Gangetic floodplain, comprises clay, silt, sand and gravels, these sediments are merged with Bhabar zone. Fine sediments are predominant towards the Indian border. This zone gets relatively low rainfall in compared to the Bhabar zone; recharge amount is high due to large area of unconsolidated sediments.

There are about 1000 deep and 112000 shallow tubewells operating in the Terai. They are used for domestic, industrial and irrigation purposes as well. The irrigation use is estimated to be 1146 MCM on the basis of 1000 deep tubewells operating at the rate of 40 to 60 litre per second for 1000 hours and 112000 shallow tubewells operting at the rate of 10 litre per second for 200 hours. Comparing the total withdrawal, the groundwater use in the Terai is less than 15% of the renewable annual recharge.

Mainly two types of aquifers in the Terai are being tapped i) Shallow aquifer, (upto 50m), below groundwater level, unconfined to semi-confined aquifers and ii) Deep aquifers, (normally from 50m to 200m below ground level), confined aquifers. The total thickness of the sediment pile under the Terai is still unknown. For water well investigation purpose, the maximum drilling depth is 450m.( drilled by Department of Water Supply and Sewerage in Nepalgunj). It has been noticed that deeper drilling (upto 3500m) has taken place in eastern terai for petroleum exploration purpose drilled by Department of Mines and Geology. The Annual groundwater balance of terai plain is as follows:

| | |
|---|---|
| • Ground Water Recharge | 8800 MCM |
| • Pumping Discharge for Irrigation | 1146 MCM |
| • Pumping Discharge for Drinking Purpose | 462 MCM |
| • GW Extraction for Industrial use | 115 MCM |
| • Balance | +7077 MCM |

The total area irrigated by the groundwater in the terai area is shown in table no 1. So far only about 42% of the area having good potential for the groundwater irrigation has been provided by the irrigation in the terai. The table indicates that there is huge scope for the groundwater irrigation in the terai.

Table no 1: Current status of groundwater irrigation in terai

| Irrigation Scheme | Total Potential Area for Irrigation(Ha) | Irrigated Area(Ha) | % of Developed Area |
|---|---|---|---|
| **Shallow Tubewell** | 726000 | 338767 | 46.66 |
| **Deep Tubewell** | 190000 | 45935 | 24.17 |
| **Total** | 916000 | 384702 | 41.99 |

**Water Quality**

The quality of groundwater in terai is generally suitable for irrigation as well as drinking purpose. Especially for drinking purpose, the groundwater from confined aquifers is better than those form unconfined aquifer.

Arsenic is noticed in some of the wells of the terai. In most of the terai districts, 5% of the samples have shown more than 0.05 mg/lit of Arsenic, but in some parts of the terai districts, 26% of the samples show more than 0.05/lit of Arsenic. The cause of arsenic content in the terai areas is still to be known by detail investigation.

## GROUND WATER RESOURCES IN KATHAMANDU VALLEY

Kathmandu valley, which contains the urbanized centers of Kathmandu, Lalitpur and Bhaktapur cities, is an intermontane circular basin, which covers as area of about 650 sq.km (Figure no-2). The average altitude of the valley floor is about 1350 m above means sea level and surrounding hills are 2800m above sea level.

Kathmandu valley is surrounded by the mountains of lesser Himalayan range, are composed of intensely folded, faulted and fractured bedrock that includes igneous and meta-sedimentary rocks of Precambrian to Devonian age consist of quartzite, phyllites, schists, slates, limestone and marbles with intrusions of acid and basic rocks. Those rocks are also form the basement complex beneath the floor of Kathmandu valley. The valley is filled with a thick succession of late Pleistocene and quaternary unconsolidated sediments of fluvio-lacustrine origin. The sediments cover has a thickness of 550m to 600m in the central part of the valley.

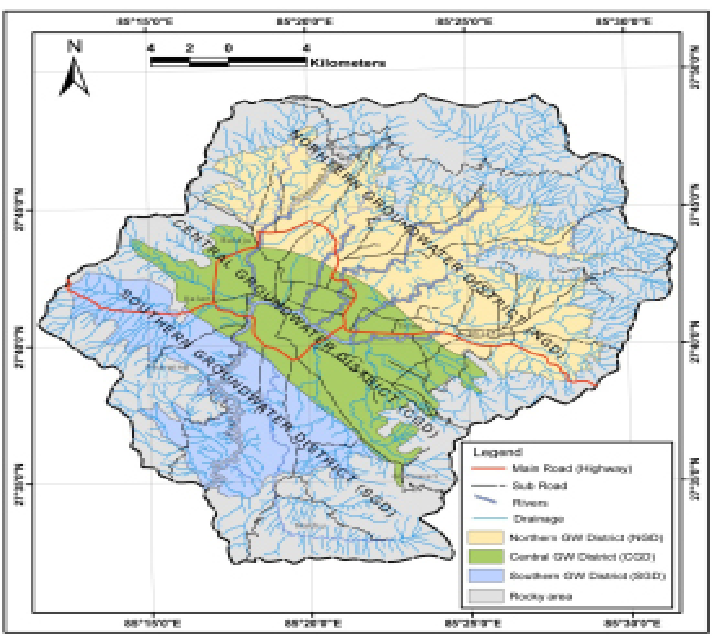
**Hydrogeology of Kathmandu Valley:**

*There are three types of sediments in the valley. They are:*

- **I.** Arenaceous sediments (Sandy)
- **II.** Argillaceous sediments (clayey),
- **III.** Intermediate type of arenaceous and argillaceous deposits.

From the above sediments distribution and river deposited sediments in the Kathamandu valley floor, it has been divided into three ground water districts (Figure no 3).

- The northern district is the main recharge zone with high transmissivity (83-1963 m2/ day) and the water quality water quality is good.
- The central district has shallow aquifers supporting stone spouts, dug well and shallow tubewells. Thick impermeable clay layers follows these shallow acquires. Which is underlain by permeable coarse sediments called deep aquifers of Kathmandu valley. These deep aquifers have rather low transmissivity (32-960 m2/day) and contain methane and hydrogen sulphide gases. Ground water in this deep zone is non-rechargeable and according to radioactive isotope dating, its age as about 200,000 years.
- The southern district has thick impermeable clay with underlying gravel deposits of low transmisivity, and the aquifers are not developed much as other two GW districts.




*Source: JICA*

**Figure no 3: Groundwater Potential of Kathmandu Valley**

## Water Quality

Groundwater from both deep and shallow aquifers is suitable for irrigation without any treatment but for drinking and industrial uses, treatment is necessary. Mostly the shallow aquifer pollution is high in the area beneath the main cities in the valley. The shallow aquifers are polluted by industrial effluents and also form the polluted rivers infiltrating to the shallow aquifers. Shallow tubewells are less contaminated than dug wells and deep tubewells are least affected. Pollution concentrations are higher during rainy period.

## Water demand

Ground water resources are extensively used in Kathmandu valley, in spite of limited scientific investigations of the resources. The present water demand in the Kathmandu valley is 325 MLD but only 90 to 140 MLD of water is available for supply and 50% of it is obtained from the ground water resources by means of shallow and deep tubewells. The estimated number of deep and shallow tubewells including dug wells, rower pump, and hand pumps are about 1000 and 5000 respectively. Although 75 MLD of ground water is abstracting in Kathmandu valley. Out of which 60MLD of ground water are extracting from production tubewells and springs, and 10-15 MLD from dug wells, rower pumps and hand pumps. According to the study, Nepal Water Supply Corporation (NWSC) alone consumes nearly 30 MLD. JICA, 1990, suggested that ground water in Kathmandu valley can be drawn only about 15 MLD. The well fields of the NWSC in the deep aquifer have shown a drawdown of the surface by 15-20 meters since the construction of the wells in 1984/85 indicating substantial overexploitation. A report of Metcalf and Eddy/ CEMAT consultant and the ADB (Asian Dev. Bank) as a part of Melamchi Water supply Project noted that both static and pumping water level have been depleted in most part of the Kathmandu valley. It is reported that water level in Kathmandu valley is lowering at an average rate of 2.5 meter per year. It has been found that more than two dozens of valley's stone spouts, which is an alternative source to the water-scarce in the valley gone dry and water levels at "Ranipokhari" (might be constructed in medieval times for infiltration pond) are declining. In Nepal, there does not exist any legislative measures to control the high abstraction rate of ground water. Due to absence of ground water act, the private drilling companies can install the vary depth of tubewells as per the consumer's demand without any management. Table 2 & 3 show groundwater abstraction in Kathmandu valley and decreasing trend of water levels in heavy pumping areas.

**Table 2: Groundwater abstraction in the valley**

| User | Total (MLD) |
|---|---|
| NWSC | 29.17 |
| Plastics, Textiles, Bottlers and Enterprises | 4.1 |
| Dying, Washing, Carpet Industries | 0.57 |
| Government Institutions | 5.36 |
| Embassies | 0.43 |
| Hotels | 6.53 |
| **Total** | **59.26** |

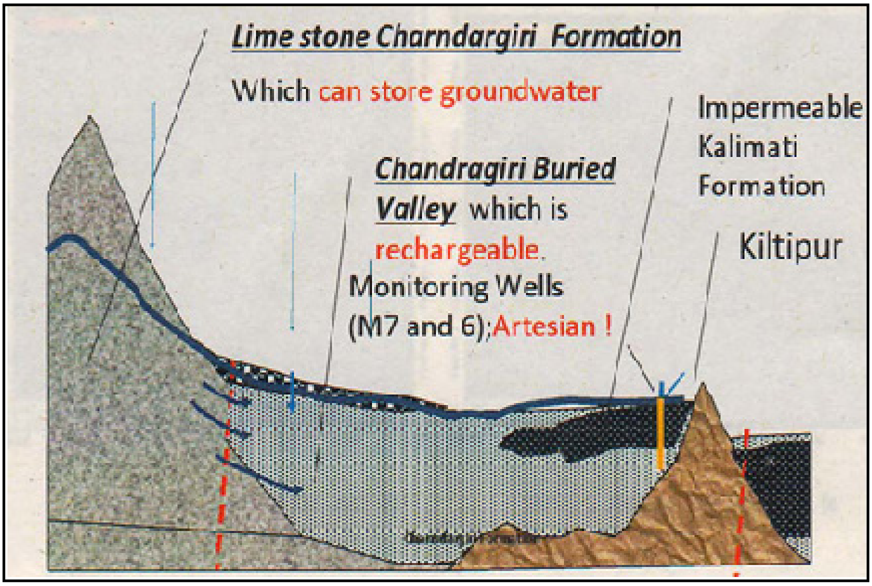
**Table 3: Aquifer Depletion**

| Location | Year | SWL (m) | Year | SWL (m) |
|---|---|---|---|---|
| Northern Well Field | 1984 | 15 | 1999 | 30 |
| Central Well Field | 1976 | Artesian | 1999 | 20 |
| Southern Well Field | 1976 | Artesian | 1999 | 13 |

**Alternative Sources of groundwater in the valley**

The lime stones of the Precambrian to Devonian rocks surround the Kathmandu valley. Intensely folded, faulted and fractured limestones are distributed SE and SW rims of the valley. The estimated area of the limestone is about 50 sq.km. Numerous springs from limestone zones are found in the southern frame of the valley. The discharge increases in post monsoon. The springs originate at the slopes and base of the mountain slopes, mostly from the fractured limestone or bedrocks. Large discharge and variation of the seasonal discharge from these springs show that the connection between the spring to springs. The nature and the total potential of this source have not yet been studied. Total yield remains unchanged throughout the year and these hard rock zones may have enough potential to supply the present demand in the valley. If the source were found satisfactorily, it would be a great relief to solve the problem of water demand in Kathmandu valley to some extent. Distribution of limestone rocks to be studied is shown in figure 4.

*Figure 4: Schematic diagram of Chandragiri limestone*




*Source: Supporting Investments in Water Security in River Basin (ADB, JWA)*

**Challenges in GW Resource Management**

**Kathmandu Valley:**

- Ground water is over- utilizing in Kathmandu valley to fulfill the increasing water demand.

**Terai Region:**

- Ground water is under- utilizing in this region

- Arsenic concentration is reported from many parts of terai. Study to be concentrated in detail, water sample analysis to be done at laboratory rather than field kits.

- Increase of urbanization and industrialization near the Bhabar zone (Recharge zone) of terai may pollute the whole aquifer systems. To solve this legal aspect should be developed.

**Problem encountered**

There is no control mechanism so far to limit ground water abstraction in the country. People are free to construct tubewell wherever they like and also can pump any quantity of water without considering its effect. Virtually in some area like Kathmandu valley, ground water being mined.

There is no information on the quantity of ground water being used by the industries other government and non-government agencies. As a result, there is no exact data on the number of existing tubewells operated in the public and private sector in the country. Kathmandu valley Water Supply Management Board (KVWSMB) established in 2006 with the mandate of regulating the ground water extraction and issuing license do not have related experts can be considered as a good example of ground water mismanagement in Nepal.

There is no control on spacing of tubewell. Some places interference problems are encountered. The unlimited number of tubewells construction, unlimited abstraction and unplanned tubewell construction can create the pollution in aquifer which will hazardous to the human health. Water pollution is a serious problem near urban areas. The problem is expected to increase due to rapid pace of urban growth unless measures are taken to control and treat effluents.

## ROLE OF GROUND WATER RESOURCES DEVELOPMENT BOARD (GWRDB)

Proper use of ground water in Kathmandu valley and systematic managing, role of GWRDB is important, but which is not happening in present context. In this perspectives, GWRDB may be the sole authority for systematize investigation, and management of ground water in the country as per mandatory works given to GWRDB. The following task ahead, is necessary to sanction immediately by government in related to investigation and regulation.

### In GW Investigation

- Groundwater Management in Kathmandu Valley
    - Groundwater Characteristics
    - Contamination level of shallow aquifers
    - Shallow aquifers exploitation
    - Groundwater balance in respect to the climate change
    - Possibility & quantification of artificial recharge
    - Study of hard rock aquifers
- Possibilities of exploitation groundwater resources in Hills & mountains as well as in ”Tar” areas

- Study on recharge of aquifers in Terai plain from Bhaber Zone applying available modern technology.
- Inter-relationship between surface runoff and groundwater along the major rivers.
- Established as a centre for the groundwater database

**In GW Regulation:**

- Should be run as national level regulatory as well as controlling body for groundwater resources
- Policy making
- Development of guidelines for the proper utilization of groundwater
- Design of groundwater development projects
- Project monitoring
- Evaluation and impact study of groundwater related projects
- Training centre for the groundwater related technicians

**CONCLUSIONS**

- ➢ GW use in Terai is very less than total recharge amount
- ➢ Bhabar zone is the main recharge zone of Terai, it needs to be protected
- ➢ Investigation works in the Kathmandu valley still have to be done for the study of aquifer system and nature of recharge of groundwater
    - ➢ Artificial groundwater recharge applying suitable technology to balance the overdraft condition
    - ➢ The withdrawal of the GW in Kathmandu valley is more than recharge rate,
    - ➢ For unlimited abstraction and pollution control , the regulating institution should be established
    - ➢ An alternative source for supplement of water supply in Kathmandu valley, an appropriate technology is to be applied in the limestone terrain.

- Ground water is a valuable resource of the country; that's why, it is needed to have a responsible government agency to protect it, which will manage the depletion of the ground water, licensing for the new tube well construction and metering for the existing tube wells etc.

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# Annex – 4
# Photos of Workshop


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National Irrigation

Government of Nepal
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