PHYSICAL & SOCIO-ECONOMIC ASPECTS OF FARMING IN IRRIGATED SCENARO IN THE CONTEXT OF CLIMATIC VARIABILITY: A CASE OF KHAGERI IRRIGATION SYSTEM IN CHITWAN, LOWER-GANDAKI BASIN, NEPAL

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In Partial Fulfillment of the Requirements for the Award of Degree of
M. Sc. in Environmental Science

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DECLARATION

I hereby declare that the work presented in this dissertation is a genuine work done originally by me and has not been submitted elsewhere for the award of any degree. All sources of information have been specifically acknowledged by reference to the author(s) or institution(s).

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LETTER OF APPROVAL

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CERTIFICATE OF ACCEPTANCE

This dissertation entitled **"Physical & Socio-Economic Aspects of Farming in Irrigated Scenario in the Context of Climatic Variability: A Case of Khageri Irrigation System in Chitwan, Lower Gandaki Basin, Nepal"** submitted by "Ms. Sunam Pradhan" has been examined and accepted as a partial fulfillment of the requirements of M.Sc. in Environmental Science.

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ABSTRACT

Climate change is a slow natural process that has been taking place in earth since its formation. The agriculture production is entirely dependent on precipitation, temperature and other weather conditions. The irrigation systems though constructed to provide supplementary water to the fields are affected due to change in precipitation pattern and volume. Khageri Irrigation System is chosen to study the climatic variability triggered changes in farming in irrigated scenario as it covers a large area of 3900 ha in Chitwan. The district is also considered vulnerable with flood and drought in latest NAPA report attracting concerns in the area. The study stands under the base of descriptive research design which uses fusion of both hard core science data analysis and social survey approaches. Physical data of temperature and precipitation is analyzed using Mann-Kendal test and linear regression in Microsoft excel to observe the extent of climatic variability in the region and FGDs, KIIs, observations, field studies, case studies are persuaded amongst the water users to see the aspects of farming. The findings show that there is increase in annual precipitation along with increasing trend in pre-monsoon and decreasing trend in other seasons. Water insufficiency in the canal existed due to Padampur resettlement from CNP premises to Sagun Tol, an area near Khageri intake; climatic variability and poor maintenance being other contributors. People in the tail region intervene bore well in order to cope with water stress in the farms and in the head region shift transplantation time of paddy from June/July to second week of August. Vegetable farming is flourishing in tail region with 'Spring rice' being abandoned as it demands more water. At the same time people in tail region experience decreasing water table. Glimpse of feminization in agriculture and irrigation management was also observed. The data also point towards increasing maximum and minimum temperature in the region. The emergence of pests and diseases along with increased pesticide and chemical fertilizers prevails in the region. Hence, the study feels the urgent need of intensive research in plant metabolism with changing climatic parameters to come up with sustainable farming. The study doubts the sustainability of the irrigation system, also bore wells under the woven existence of climatic variabilities, feminization in irrigation and declining water table, so strongly recommends the study of recharge and extraction rates in parallel and feasibility study of better alternatives to irrigation.

Keywords: climatic variability, irrigation, water insufficiency, farming

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ACRONYMS AND ABBREVIATIONS

AMIS	Agency Managed Irrigation System
CBS	Central Bureau of Statistics
CDES	Central Department of Environmental Science
CNP	Chitwan National Park
CO_2	Carbon Dioxide
DFID	Department for International Development
DHM	Department of Hydrology and Meteorology
FAO	Food and Agriculture Organization
FMIS	Farmer Managed Irrigation System
FGD	Focus Group Discussion
HDI	Human Development Index
ICIMOD	International Centre for Integrated Mountain and Development
IMTP	Irrigation Management and Transfer Project
INSTRAW	United Nations International Research and Training Institute for the Advancement of Women
IPCC	Intergovernmental Panel of Climate Change
ISF	Irrigation Service Fees
JMIS	Joint Managed Irrigation System
KII	Key Informant Intterview
KIS	Khageri Irrigation System
MS	Microsoft

NAPA	National Adaptation Plan of Action
NISP	National Irrigation Sector Project
SLF	Sustainable Livelihood Framework
TU	Tribhuvan University
UNFCCC	United Nations Framework Convention on Climate Change
VDC	Village Development Committee
WUA	Water User’s Association

CHAPTER I: INTRODUCTION

1.1 Background

Climate change is a slow natural process that has been taking place in earth since its formation. Though natural, several anthropogenic activities have triggered its pace to make it distinctly visible. Framework Convention on Climate Change (UNFCCC), in its article 1, defines Climate Change as, “a change of Climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods” (IPCC, 2014). It takes a long observation of weather changes, at least of 31 years to predict the trend and term it as climate change.

Agriculture is one of the severely impacted areas due to effects of climate change, as the production is entirely dependent on precipitation, temperature and other weather conditions. Climate change and agriculture are interrelated process taking place in a global scale. The changes in average temperatures, rainfall, climate extremes (e.g., heat waves), change in atmospheric concentration of greenhouse gases, change in pests and diseases, change in quality and quantity of food etc. affects agriculture in many ways. The effects of climate change is unevenly distributed across the globe. While it’s projected that crop production will be negatively affected in the low latitudes, the effects in northern latitudes may be positive or negative. With cascades of effects in food security and increased risk of resiliency to the poor and vulnerable groups.

On one way climate change affects overall agriculture in many ways and in the other there are evidences of release of greenhouse gases from agricultural production which contributes to enhance the process of climate change. e.g., Agriculture, forestry and land-use change contributed around 20 to 25% to global annual emissions in 2010. A 2008 study published in Science suggested that, due to climate change, "southern Africa could lose more than 30% of its main crop, maize, by 2030. In South Asia losses of many regional staples, such as rice, millet and maize could top 10%".The projected increase of world’s population to 9.1 billion by 2050 has added more questions to ensure food security in the presence of

Climatic variables. The huge volume of 26 million population at present (CBS, 2011) which is likely to be doubled by 2050, is in itself a challenge to manage.

Nepal has century long history of FMIS running successfully which covers 70% of irrigated land at present (Shukla, et.al, 1997, Pradhan 2003). Special community people in different ecological zones used their expert skills and indigenous knowledge for the construction and operation of FMIS. For eg, ‘Agri’ community in Western Hills, ‘Tharu’ community in Terai. The structure in FMIS differs from one ecological region to the other due to terrain and conveyance characteristics. Hills have cross drainage structures and lining in common whereas the Terai has headwork structures as traditional materials like shrubs, forest products are less abundant (Singh, 2010).

Political shift to invest on large scale public irrigation system is still less effective in comparison to FMIS in agriculture (Gautam, 2011). Gender issues like work division and biasness in FMIS cannot yet be discarded. And is a major issue to focus research on (Acharya & Bennet, 1981). Irrigation in many parts of Nepal is considered to be Men’s work. Activities like plowing require physical labor and more social interaction with the outside community which according to orthodox Nepalese community requires male. This shows prevalent male domination in economic activities as well as social and political arenas. However, these issues have started to be addressed these days by the establishment of several village institutions which have empowered women. Works like water acquisition, water allocation, conflict management are confined within male whereas water distribution, system maintenance are performed by both genders. However, resource mobilization in activities like canal construction are more women participatory than male (Ghimire, 2011). Existing migration (mostly men) has left women to play larger part in agriculture management with less interested educated youths in water management (Prakash, 2016).

1.2 Rationale

Chitwan district lies in high vulnerable zone with vulnerability index from 0.061 to 0.786. The summers are becoming hotter and winter colder with decreased numbers and quality of water resources. Monsoon rainfall has increased whilst winter rainfall has become scarcer and periods of drought have become longer (NAPA, 2010). This has directly posed threat in agricultural production with major impacts on the yield of crops like wheat and maize (Nayava & Gurung, 2010; Bastakoti, 2010). The transplanting season of rice and maize has also changed by 15 to 25 days due to drought and irregular rainfall in Kavre and Chitwan (Bastakoti, 2010). There are changing gender roles with changing social structures; male migration being one of the major triggering factors. Approximately one in ten Nepali men is employed abroad according to CBS (2011). In the other hand Nepal also ranks 113th of 146th in the Gender Inequality Index. Chitwan is a district with major investment in agriculture. The only agriculture college Rampur situates within the district. Many other districts like Kathmandu relies on the production of food from this district. The establishment of Khageri Irrigation System too is a proof to verify this motive. The irrigation systems are in one way introduced to supplement water in the fields but as these systems too depend on the natural river systems for water, the change in temperature and precipitation patterns impact them directly. This can even make people more vulnerable when these systems don't function properly. Despite of all these, this district is not apart from the problems of water scarcity for agriculture even within the irrigation system. All these scenario demands a study of physical and socio-economic aspects induced due to changing climatic context in irrigated scenario. The study attempts to check how the changing climatic parameters are affecting the water users of Khageri Irrigation system.

1.3 Research questions

This research is driven by the following major research question;

How has climatic variability affected physical and socio-economic aspects of farming in Khageri Irrigation System?

In order to answer these questions the exploration was done on two major basis; (i) Assessment of physical aspects of water availability and (ii) Assessment of socio-economic aspects of farming in irrigated scenario

1.4 Objectives

1.4.1 General Objective

The general objective of this research is to study the effects of changing climate context in farming in irrigated scenario of Khageri Irrigation System.

1.4.2 Specific Objectives

The specific objectives of this study are;

- To analyze the variability of temperature and precipitation in the region
- To assess water availability among the water users of Khageri Irrigation System in the command area
- To study the physical and socio-economic aspects of farming in irrigated scenario

1.5 Limitations

The research tries to find the relation between climatic variability and water insufficiency in the canals of Khageri Irrigation System, canal number 6. However, it does not overview the condition in other canals. The research does not incorporate the market dynamics and agricultural productivity of the region. Also, it does not explain the shifting occupation changes of the people in detail.

1.6 Significance

There are enough of researches done in climatic variabilities, agriculture and also gendered vulnerabilities but only few researches have been done integrating these all components in one study. The researches on irrigation system are either limited to the governance or performance where the climatic variability despite of having a heavy weightage remains aloof of being researched. So, this study tries to bridge this research gap and provide insight on the natural factors which has a major role to play in the irrigation system integrating the three above mentioned components within an irrigation system.

CHAPTER II: LITERATURE REVIEW

2.1 Climate change and agriculture

Climate change is a slow natural process that has been taking place in earth since its formation. Though natural, several anthropogenic activities have triggered its pace to make it distinctly visible. Framework Convention on Climate Change (UNFCCC), in its article 1, defines Climate Change as, “a change of Climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods” (IPCC, 2014). It takes a long observation of weather changes, at least of 31 years to predict the trend and term it as Climate Change.

Since 1970, the time of industrial revolution, CO_2 has increased by 31%, methane by 151%, and nitrous oxide by 17% which has contributed in global warming,(HDI, 2007/2008). Change in the trend of precipitation, temperature, disease and epidemics outbreak and vegetation shift are taken as some effects due to changed climate. According to fifth Assessment Report of IPCC, climate change related risks from extreme events, such as heat waves, extreme precipitation, and coastal flooding are already moderate and high with 1□C additional warming. Assessment report of IPCC (2014) also projects that, the production of major crops like wheat, rice and maize in tropical and temperate regions are highly impacted for local temperature increase of 2□C or more above late 20^{th} century-levels, despites, some individual locals may benefit (medium confidence).

Higher variation in rain patterns such as drought or flooding can damage households’ assets and agricultural produce leading to increment in poverty; and it may be serious threat to food security in agriculturally intensive countries. Khanal (2003) state that agriculture has been a major concern in the discussions on climate change as food production is essential for sustaining and enhancing human welfare. The observed temperature increase over the last century is affecting the south Asia region (IPCC, 2001). Tobey et al. (1992) state that due to increase in temperature, regions with massive production have negative effect. Wheeler and von Braun (2013) argue that short-term variability in food supply may have adverse effects on sustainability of food systems in the world under climate change scenario. Climate change can have devastating effect on already vulnerable and malnourished regions of the world. Qureshi et al. (2013) found negative impact of climate change on Australian food exports, indicating that global food security would be affected. Baldos and Hertel (2014) examine global food security in 2050 considering role of agriculture productivity and climate change. Ciscar et al. (2012) found that the impacts of climate change would vary largely among the regions, with the developing regions like Africa, Asia and Latin America. It is empirically verified that that agricultural productivity is the main entry point in level of poverty reduction in developing countries (Christiaensen et. al., 2006).

Cline (2007) discovered that the agricultural damages tend to be greater toward the equator and hence most in developing countries. Zhai, Lin., and Enerelt (2009) have discovered the potential long term impacts of global climate change on agricultural production and trade in the People's Republic of China. Bezabih, Chambwera, and Stage (2010) discovered that despite the projected reduction in agricultural productivity, the negative impacts can potentially be quite limited. The consequences of climate change for agriculture and food security are of serious concern, not least because food supplies are already inadequate and poverty is severe in many low-income countries, particularly in Africa. Moreover, developing countries are generally considered to be most vulnerable to climate change, mainly due to their reliance on rain-fed agriculture. Previous studies linking climate change to food security have typically used agricultural crop models (Parry et al., 2004). Climate change, agriculture productivity, food security, and poverty; and these all are directly linked to each other (Hollaender, 2010). Malla (2008) has discovered that with an average of 0.06 ^{0}C a year, a rise in temperature from 1975 to 2006 by 1.8 ^{0}C has been recorded in Nepal, this has increased the yield of of rice and wheat in all regions, but negative effects in maize especially in Terai. Thapa and Joshi (2010) has found that Annual precipitation is likely to increase crop output in hills, but reduce in Terai. Karn (2014) has found that under a double CO2 scenario predicted for 2100, rice yield in Nepal is expected to drop by about 4.2% relative to current production levels. Paudel et al. (2016) in a research done in Koshi River Basin has found that, an increase in mean temperature at a rate of +0.25 ^{0}C every 10 years between 1971 and 2009 has forced local people to change their cropping patterns such as tea and coffee, and other horticulture and agro-forestry activities, Bastakoti (2010) has found that the transplanting season of rice and maize changed, i.e. by 15 to 25 days for 75% of farmers due to drought and irregular rainfall in Kavre and Chitwan. Nayava and Gurung

(2010) has found that the annual mean temperature in Chitwan is increasing at a rate of 0.039^0C during 1968 to 2008 period which has affected yield of wheat.

2.2 FMIS in Nepal and institutional development

Nepal has century long history of FMIS running successfully which covers 70% of irrigated land at present (Shukla, et.al, 1997, Pradhan 2003). Special community people in different ecological zones used their expert skills and indigenous knowledge for the construction and operation of FMIS. For e.g., 'Agri' community in Western Hills, 'Tharu' community in Terai. The structure in FMIS differs from one ecological region to the other due to terrain and conveyance characteristics. Hills have cross drainage structures and lining in common whereas the Terai has headwork structures as traditional materials like shrubs, forest products are less abundant (Singh, 2010).

The management transfer of the irrigation schemes to the local organizations started globally during 1980s. In context of Nepal, the transfer from government to local users also began in 1980s which lead to success of these systems and were usually recommended for improving the performance of irrigation systems having low performance (Meinzen-Dick, 1997; Murray-Rust & Svendsen, 2001; Renault, 2001; Sam-Amoah & Gowing, 2001; Yercan, 2003). In one hand government plans and policies are being more inclined towards extending FMIS, some researchers still argue that government still have to play a central role in irrigation sector. Government intervention in one way or the other is still vital in irrigation management. However, the responsibility of day-day management, operation and maintenance should be transferred to water users (Bruton et al., 2003).

2.3 Gender in FMIS

United Nations International Research and Training Institute for the Advancement of Women (INSTRAW) defines gender as socially constructed roles and relationships, personality traits, attitudes, behaviors, values, relative power and influence that society ascribes to the two sexes on a differential basis. Whereas biological sex is determined by genetic and anatomical characteristics, gender is an acquired identity that is learned, changes over time, and varies widely within and across cultures. Gender is relational and refers not simply to women or men but to the relationship between them.

The socially constructed norms greatly impacts the involvement of men and women in different occupations within and outside the house. The involvement in different activities of FMIS also is greatly impacted. Political shift to invest on large scale public irrigation system is still less effective in comparison to FMIS in agriculture (Gautam, 2012). Acharya and Bennet strongly argue that gender issues like work division and biasness in FMIS is pronounced and is a major issue to focus research on (Acharya & Bennet, 1981). Irrigation in many parts of Nepal is considered to be Men's work. Activities like plowing require physical labor and more social interaction with the outside community which according to orthodox Nepalese community requires male. This shows prevalent male domination in economic activities as well as social and political arenas. However, these issues have started to be addressed these days by the establishment of several village institutions which have empowered women. Works like water acquisition, water allocation, conflict management are confined within male whereas water distribution, system maintenance are performed by both genders. However, resource mobilization in activities like canal construction are more women participatory than male. Existing migration (mostly men) has left women to play larger part in agriculture management with less interested educated youths in water management (Adhikari, 2013).

2.4 FMIS and livelihood

The narrow goal of meeting household food requirement by FMIS has widened to meet other livelihood needs due to rapid population growth and higher demands (Pradhan, 2003).The existing scenarios of Climatic Variability like erratic rainfall, drought, fluctuating temperatures can possess several impacts on the economy of FMIS in different ecological zones. The proper functioning of FMIS with colorful outcomes demands marriage between modernization and traditional FMIS practices. The modernization approach put forward by NISP, funded under the credit assistance of World Bank in three western regions of Nepal from 1998-2004 was able to meet the purpose to a great extent.

However, the increased water demand for drinking and commercial purpose along with sky rocketing trend of globalization, easy market access has worsened the irrigation scenario of peri-urban and water-scarce areas like Kathmandu where wastewater is irrigated to grow crops inside the valley. The failure of infrastructures due to natural hazards like landslides, drought and flood has discouraged farmers to persuade agriculture leaving behind a huge question of unsustainable production in the days to come. So, it is very important to understand the present economic status of introduction and operation of FMIS to properly design and operate along with promotion of culturally ingrained indigenous practices to ensure sustainable production.

2.5 FMIS types

There are three modes of irrigation system in Nepal. A) Farmer's Managed Irrigation System (FMIS) B) Agency Managed Irrigation System (AMIS) and C) Joint managed Irrigation System (JMIS). FMISs are governed by several factors like institutional arrangement, indigenous practices, hydrology, socio-economy factors etc. They are informal and designed as well as managed by the local farmers.

AMISs are more focused on physical capital than institution. They are organized from government initiatives and are capital intensive whereas JMIS incorporates both FMIS and AMIS. The capital investment is mainly done by the government bodies along with the handling of operation and maintenance responsibilities and the management and distribution responsibility lies amongst the local water users.

2.6 Property rights

The right to sell one's property is referred to as alienation. Many scholars have argued that unless users had alienation rights, they did not have property rights. Property rights systems in fact are bundles of rights rather than a single right. According to Schlanger and Ostrom , there are five kinds of property rights, they are;

a. Access: This refers to the right to enter a defined physical property.
b. Withdrawal: This is a right to harvest the products of a resource such as timber, water or food for pastoral animals.
c. Management: It includes the right to regulate the use patterns of other harvesters and to transform a resource system by building improvements.
d. Exclusion: This is a right to determine who else will have the right of access to a resource and whether that right can be transferred.
e. Alienation: This is a right to sell or lease any of the above rights.

Schlanger and Ostrom (1992) posed a possibility of distributing these rights in a combined set of positions that individuals hold in regard to operational settings (Adhikari, 2003). An individual can have any of these rights depending on the context of criteria set before. An authorized user has both access and withdrawal rights. A person with access, withdrawal and management rights is called a 'claimant'. A person with all three rights along with right of exclusion is a 'proprietor'. Finally, owners are individuals with all the five rights mentioned above. There are however, many well defined and operational common property systems without alienation right that have existed for a long time (Netting 1981; Mckean 1982, 1992). These rights enhanced the efficient use of resources and also ensured regulating use and investment.

2.7 The robustness of self-organized common property institutions

Shepsle defined an institution to be robust if it was long-lasting and the operational rules had been devised and modified over time according to a set of higher level rules (which institutional analysis would usually call collective-choice rules) (Ostrom, 2008). The rules can be modified slowly over time. The contemporary definition of 'robustness' in regard to complex systems focuses on adaptability to disturbances'. The maintenance of some desired system characteristics despite fluctuations in the behavior of its component parts or its environment'.

The author has talked about eight design principles he himself formulated in successful long-surviving systems in common-property.

a. Well-defined boundaries

This principle discusses about having proper delineation of a resource system as well as the individuals or households with property rights. The level of trustworthiness and cooperation of the participants involved in the rules related to who can enter, harvest, manage and potentially exclude others impacts the overall performance of the system. The rules need to be properly defined for proper co-operation, use and maintenance of the resource among the participants.

Using this principle enables participants to know who is in and who is out of a designed set of relationships and thus with whom to cooperate. When the boundaries are set by external officials, without local consent there may be chances of failure of this strategic managerial tool. E.g.; Maya Biosphere Reserve, Guatemala where 80% of the farmers did not know anything about the reserve or its boundaries in which they were located.

b. Proportional Equivalence between benefits and costs

The design principle states that the rules-in use allocate benefits proportional to inputs that are required. For example; if a group of users is going to harvest from a resource over a long run, they must devise rules related to how much, when and how different products are to be harvested. This also includes the need to assess the cost of operating a system on users. The advantage of this design principle is that the proportionality of benefits and costs increases the likelihood of participants to make them feel that the rules they are using are equitable. Thus, this design principle is directly related to the types of attitudes that are necessary to sustain a system over the long run.

c. Collective-choice arrangements

This design principle emphasizes that most of the individuals who are affected by a resource regime are authorized in crafting the rules. The rules should be made in the favor of all the local participants and not solely on the benefit of local elites.

d. Monitoring

Most self-organized resource regimes select their own monitors. These monitors are accountable to authorized users and keep an eye on resource conditions as well as on harvesting activities. By creating official positions for local monitors, a resource regime does not rely only on the norms of local right-holders to impose personal costs on those who break a rule. The community creates an official position. In some systems, users rotate into this position so everyone has a duty to be a monitor. In others, the monitors are paid from a fund collected from all authorized appropriators. With monitors appointed, those who want to cooperate with the rules so long as others also cooperate are assured that someone is generally checking on the conformance of others to local rules. No one likes being a sucker! Thus, they can continue to cooperate without the fear that others are taking advantage of them.

e. Graduated sanctions

In many self-organized systems, the first sanction imposed by a local monitor is so low as to have no impact on the expected benefit-cost ratio of breaking local rules (given the high payoffs that could be achieved by harvesting illegally, for example).

The initial sanction can be thought of more as information to the person who is "caught" as well as to others in the community. A user could always make an error or could face difficult problems leading them to break a rule. Letting an infraction pass unnoticed could generate a downward cascade of cooperation in a group that relies only on conditional cooperation and has no capacity to sanction. When graduated punishments are used, a person who purposely or by error breaks a rule is notified that others notice the infraction (thereby increasing the individual's confidence that others would also be caught). Further, the individual learns that others basically continue to extend their trust and want only a small token to convey a recognition that the mishap occurred.

f. Conflict-Resolution Mechanisms

The sixth principle is that there are rapid, low-cost, local arenas to resolve conflict among users or between users and officials. Rules have to be understood in order to be effective. Some participants may interpret a rule that they have jointly made in different ways. By devising simple, local mechanisms to get conflicts aired immediately and resolutions that are generally known in the community, the number of conflicts that reduce trust can be reduced.

g. Minimal Recognition of Rights to Organize

Whether local users can develop more effective regimes over time is affected by whether they have at least minimal recognition of the right to organize by a national or local government. Participants in resource regimes that are not recognized by external authorities have operated over long periods, but they have had to rely almost entirely on unanimity as the rule used to change rules (Ghate, 2000). Otherwise, disgruntled participants who voted against a rule change can go to the external authorities to threaten the regime itself! Changing rules using unanimity imposes high transaction costs and prevents a group from searching for better matched rules at relatively lower costs. When external governmental officials presume that only they can make authoritative rules, then sustaining a self-organized regime is very difficult (Johnson & Libecap, 1982).

h. Nested Enterprises

When common-pool resources that are being managed by a group are large, an eighth design principle may be present in robust systems. The nested enterprise principle is that governance activities are organized in multiple layers of nested enterprises. In addition to some small units, larger institutions exist to govern the interdependencies among smaller units. The rules allocating water among major branches of an irrigation system, for example, may differ from the rules used to allocate water among farmers along a single distributary channel (Yoder, 1994). Consequently, among long-enduring self-governed regimes, smaller-scale organizations tend to be nested in ever larger organizations.

Understanding of FMIS, its institutional behavior, performance is very important, firstly, to understand the existing scenario and secondly, to understand the phase its passing through which includes its existing or would be problems. The success reasons of existing FMISs can add knowledge to all FMIS and show directions for proper functioning. However, it is important to understand the stress posed by varying climate in agricultural practices also in the irrigated scenario.

2.8 Conceptual framework

The study is based on concept that the roles and responsibilities of men and women within and outside the house is greatly influenced by socially constructed norms. The distribution of access and control over any resources, the institutional set-up, formal and informal communal practices play significant role to define these roles. The absence, shortage or insufficiency of resource too has significant role in transformation of these roles and responsibilities. Several physical, political, social and/or environmental factors could be responsible to cause resource scarcity. The state of availability of resource drives new technological as well as social interventions.

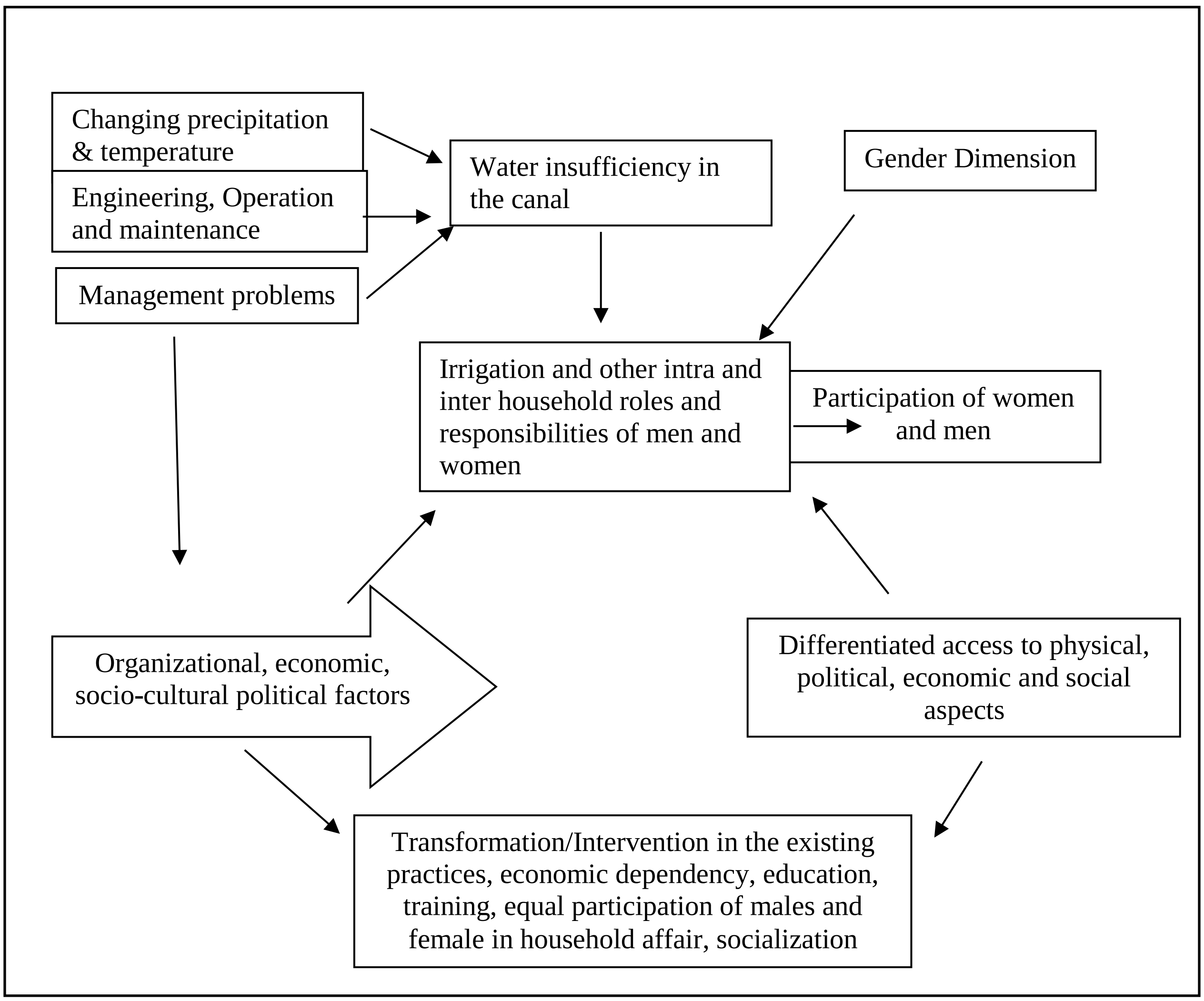


Figure 1: Conceptual framework

CHAPTER III: MATERIALS AND METHODS

3.1 Study area

Khageri Irrigation System was an agency managed gravity irrigation system of Nepal located in Chitwan with a command area of 3900 ha. The management authority of the irrigation system was handed over to the Water User Association Groups of the area in 2024 B.S. Water is supplied via diversion from River Khageri which is one of the tributaries of River Rapti. It was designed by Department of Irrigation in 2017 B.S and the works of construction was completed in 2024 B.S at a cost of 7.6 million (Khanal, 2003). However, riginal planning was done by FAO. The canals are designed such that they are safe from the risks of flooding and inundation. The irrigation canal was constructed mainly with two objectives, to support the livelihood of newly settled people and to supply food to Kathmandu valley but water in the canals has always been insufficient since its formation (Khanal, 2003). The canal has a diversion barrage, main canal (23 Km), 11 branch canals (55 Km), tertiary canal (100 Km) (Khanal, 2003). 7 Km of main canal passes through buffer zone of Chitwan National Park. Water in the irrigation canal comes from River Khageri which is a tributary of River Rapti. Annual rainfall in the catchment averages 1600 mm, 80% of which falls during monsoon. Runoff supplies water in the monsoon season whereas base flow maintains the flow during dry season. The canal was constructed with less agro-metrological information and less data on duties of crops. The engineers too had limited knowledge since it was the first large scale project undertaken by DoI (Khanal, 2003). WUA in Khageri Scheme consists of main committee at system level and branch committee at branch level. The annual operation and maintenance cost of KIS is about 500/ha. 25% of the total maintenance cost is assisted by voluntary labor contribution by the local people. WUA collect revenues as Irrigation Service Fee (ISF) from the users at a rate of NRs. 60/ha per crop (Khanal, 2003). Other sources of revenue are; land from department of Irrigation, fishing contracts in the canal, works like cooperative, fertilizer sellers and seeds.

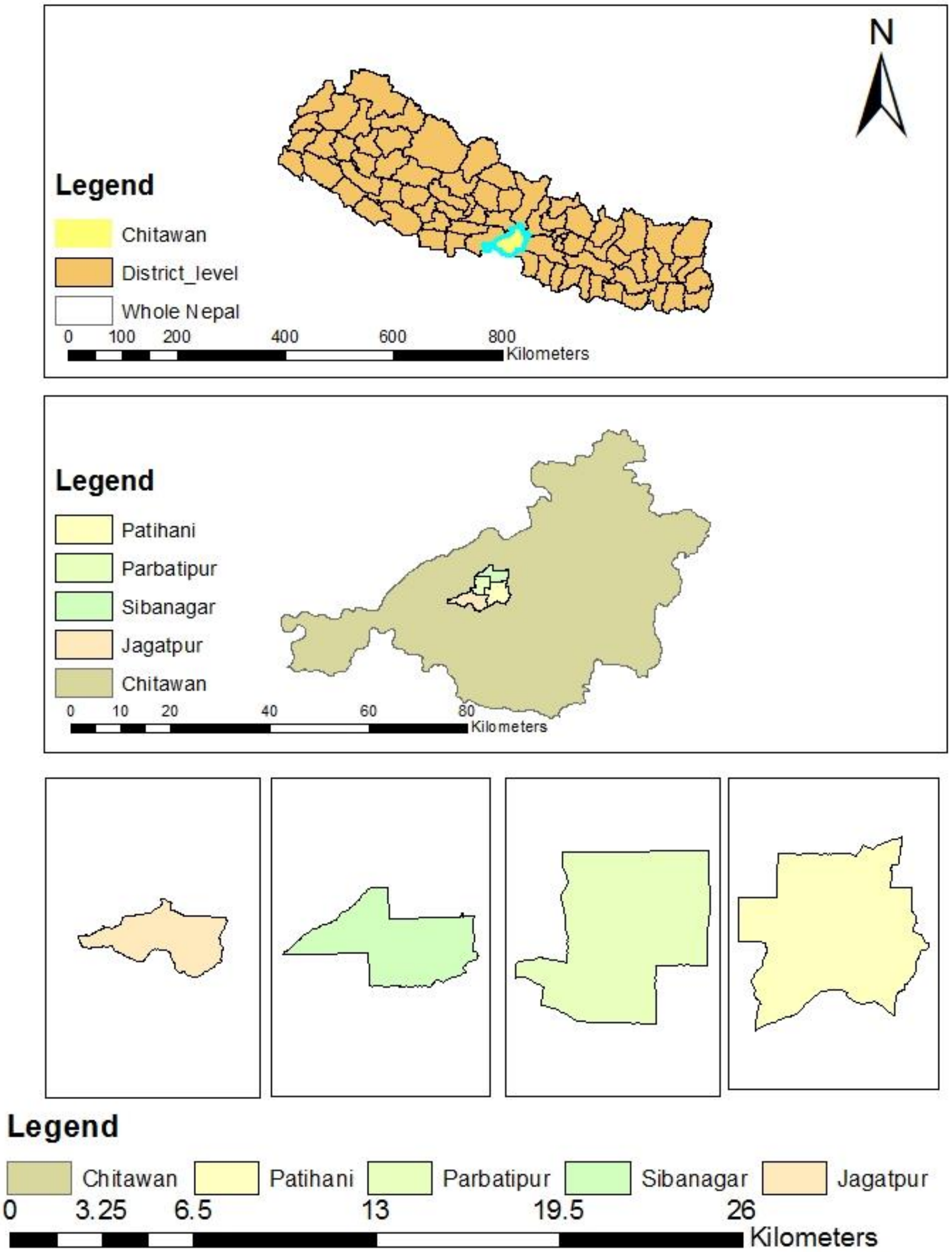


Figure 2: Map of study area

The study is carried out in Canal number 6, Shivanagar of Khageri Irrigation System. It included four VDCs namely, Parbatipur, Shivanagar, Jagatpur and Pathihani which now falls under 5 wards of Bharatpur municipality. The canal head lies in Tikauli near to the premise of Chitwan National Park. Water distribution starts from Shivnagar in canal no. 6 which continues to 1.488 Km in Bhagwanpur where it gets divided into Eastern and Western canals. The study is focused in Eastern canal of canal no. 6 which extends 4.721 km in length to reach Madhupari, Jagatpur. The command area of this eastern canal is 124.59 ha at present. The major supply of water in the canal is from the Khageri River with a discharge of 6200 l/sec. This river is spring fed and originates from Churia range. It has scanty and irregular rainfall. Farming is mostly rain-fed. Cereals, oilseeds and pulses are its major crops with exceptional farming of vegetables, fruits and cash crops. There are 760 water using HHs with 1027 population including the migrated population.

3.1.1 Demographic structure

Population

According to census (2011), Chitwan has a total of 579,984 population among which 51.88% are females and 48.12 % are males. The population of Chitwan is increasing with an annual growth rate of 2.06%. The population in 2011 has increased by 55.24% since 1981, this indicates demand of more resources in the area.

Figure 3: Population trend of Chitwan district (1981-2011), Source: CBS, 2011

3.1.2 Demographic structure of study area

The study area consists of households from four VDCs namely Jagatpur, Parbatipur, Patihani and Shivanagar. According to census (2011), these four VDCs comprises of 36,875 population with 45.76% of males and remaining females. The Figure below shows the population of Jagatpur, Parbatipur, Patihani and Shivanagar VDCs,

Table 1: Demographic Figure of study area

Source: CBS, 2011

Population	2011 Census			
	Jagatpur VDC	Parbatipur VDC	Pathihani VDC	Shivanagar VDC
Total households	2635	1614	2845	1868
Total population	11195	6506	11500	7674
Male	5217	2937	5282	3421
Female	5978	3569	6218	4253
Average household size	4.25	4.03	4.04	4.11
Total literacy rate of 5 years and above	75.10	76.83	76.39	79.34
Male literacy rate	82.04	84.39	84.41	87.66
Female literacy rate	69.20	70.71	69.68	72.82

3.1.3 Canal layout

Khageri Irrigation canal has 10 main canals with 13 branch canals and many tertiary canals. The canal head lies in Tikauli. The canal with the largest command area of 124.59 ha is canal no.6 which starts from Shivnagar. The main canal of canal no.6 is 1.488 km long. Here, it bifurcates at Bhagwanpur into Eastern and Western canal. The eastern canal is 4.721 km long which extends till Madhupari, Jagatpur. The western canal extends till Shankarchowk, Parbatipur.

3.1.4 Water users

There are a total of 1243 water users in canal no. 6, Shivnagar of Khageri Irrigation canal out of which 238 are females and the remaining are males. The canal has increasing scenario of youth migration. 359 youths of 20 years and above have migrated to other places in search of better opportunities from within the water users from this canal area. The canal faces yearly around 3-4 conflicts amongst the water users with issues regarding water distribution. (The data here are collected from KII in the field.)

3.2 Methods

The study is a fusion of hard core science and social survey to come up with the validation of findings. The trend of precipitation and temperature analysis in the region is done with reference to the data from Rampur weather station extracted from DHM. For the variability analysis of precipitation a time frame of 1968-2015 is taken whereas for the variability analysis of temperature a time frame of 1980-2015 is taken.

The research also explores change in irrigation technology with socio-economic changes brought about with changes in water availability. This part is woven with methodologies of social science approach, i.e., FGD, KII, case study, observation and field visit.

Man-Kendell test (Mann 1945, Kendall 1975 and Gilbert 1987) is a non-parametric test used to identify a trend be it seasonal or annual. The purpose of using Mann-Kendall test is to statistically assess if there is monotonic upward or downward trend of precipitation and temperature. Regression analysis requires normally distributed data whereas Mann-Kendall test can be carried out freely despite of distribution. Several tests like Pettit's test, Grubb's test, Shapiro-Wilk test within Mann-Kendall test to calculate homogeneity, outliers and normality respectively. The analysis is done using XLSTAT in MS Excel and regression.

A refined ICIMOD version of SLF developed by DFID was used to assess gendered roles and responsibilities which could lead to vulnerability.

3.2.1 Desk study

Temperature and precipitation data of Rampur weather station were brought from Department of Hydrology and Meteorology (DHM) for the time period of 35 years (1980-2015) and 47 years (1968-2015) respectively. Mann-Kendell test under XLSTAT software was used to calculate the seasonal and annual trend. Homogeneity was calculated using Pettit's test, outliers were calculated using Grubb's test and Shapiro-Wilk test was done to calculate normality. Trend analysis was done at 5% level of significance and 95% level of confidence using Mann-Kendell test.

3.2.2 Field study

Field visit was done in two phases, (i) Preliminary field visit and (ii) Final field visit. A total of 7 days in preliminary field visit followed by 10 days of final field visit was spent. During the field visit I tried to be familiar with the issues of water distribution in the area, observe the details of the subject matter and analyze some specific cases with regards to farming activities.

3.2.3 Data entry

Data entry was done in excel. The data were chronologically arranged and categorized on the basis of meteorological seasons to find the seasonal fluctuations in temperature and precipitation. The data which showed at least 10 years of consistency without missing data were only considered for analysis.

3.2.4 Data analysis

XLSTAT software was used for calculation of homogeneity, Grubb's test for outliers, normality and Mann-Kendell test for trend analysis. The analysis was done at 5% level of significance and 95% confidence level. As there were very few missing precipitation data (only 5 throughout) they were ignored. The missing maximum and minimum temperature data were handled taking average of previous year's monthly data.

3.2.5 Research design

The research is based on descriptive research design.

a) Descriptive research design

In this research the study is basically divided into two major dimensions; (i) assessment of physical aspect of irrigation and (ii) assessment of socio-economic aspect of farming in irrigated scenario. In the first, the situation of water availability in the canals with respect to several canal aspects (Head, middle and tail) during, before and after monsoon is explored. The analysis of climatic variability of the region using precipitation and temperature data is done in XLSTAT using Microsoft excel office. Mann-Kendall test and regression analysis is done for trend analysis depending on the relevancy of the distribution of data. Along with this the major interventions and technological changes made within the regions along with the drivers and conditions leading to those were examined. In the second, the farm and non-farm occupational changes along with changes in roles and responsibilities among genders at intra-household level were explored. For this revised version of DFID's SLF by ICIMOD was used with FGDs, KII, observations, case studies and survey approaches.

Chapter IV: Results

4.1 Climatic variability

Precipitation (Annual average)

The annual average precipitation of Chitwan district from 1968 to 2015 is 166.78 mm. The rainfall varies from 6.63 mm during November to 534.67 mm in July. The distribution of precipitation in various seasons is as follows,

a) Pre-monsoon (March-May)

Pre monsoon season received 11.65 percent of the total annual precipitation. The western disturbance and locally developed thundershowers results in pre-monsoon precipitation. During the pre-monsoon months March, April and May, the precipitation amount generally increases compared to winter. The precipitation varied from 12.2 mm to 495.2 mm in this season.

b) Monsoon (June-August)

Monsoon normally starts from the second week of June (10 June) and retreats in the fourth week of September (23 September). Monsoon is the wettest season and is the main source of precipitation in Nepal. Monsoon season contributes on an average 66.49 percent of the total annual precipitation in the region. The precipitation ranges from 706.4mm to 1952.1mm in this season.

c) Post-monsoon (Sep-Nov)

During this season, the country receives an average of 19.55 percent of the total annual precipitation which is the second largest share of precipitation after monsoon. The character of the precipitation is similar to the pre monsoon rain. November receives the lowest precipitation of the year. The spatial distribution of precipitation is similar to the pre monsoon and monsoon seasons with low precipitation ranging from 143.2mm to 1051.5mm.

d) Winter (Dec-Feb)

Winter (December - February) is the driest season contributing 2.29 percent of the total annual precipitation. The rainfall during this season varied between 2.3 mm to 86 mm.

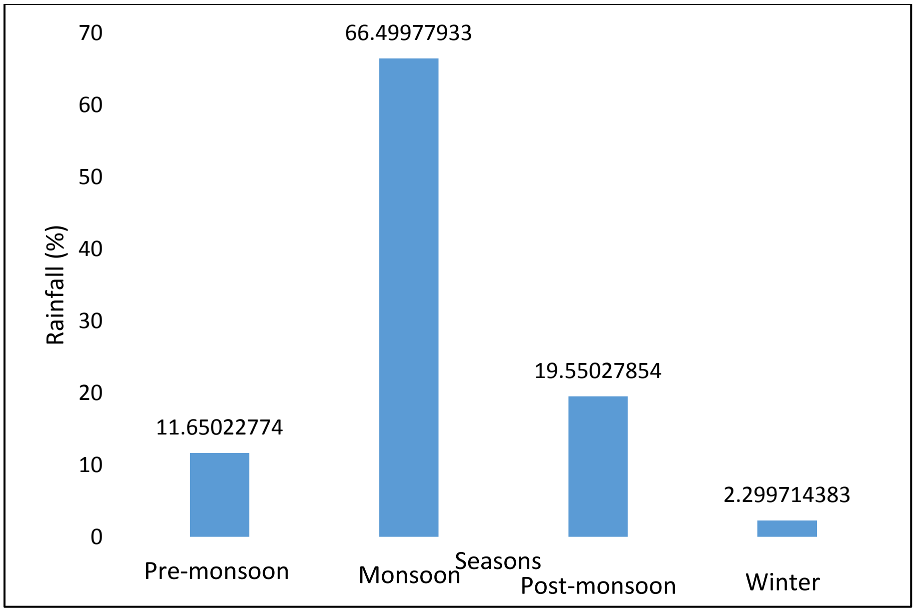


Figure 4: Percentage distribution of seasonal precipitation

Temperature pattern

The temperature is lowest during winter (Dec-Feb) and highest during summer (June-August). The average temperature slightly starts to increase as winter surpasses. The arrival of monsoon however checks the increasing temperature. The temperature starts to fall from October.

a) Maximum temperature pattern

The mean annual maximum temperature varies between 22^0C during the winters to 33^0C during the summer. The average range of maximum temperatures during the summer and winter seasons lies in between 26^0C to 36^0C and 22^0C to 33^0C respectively.

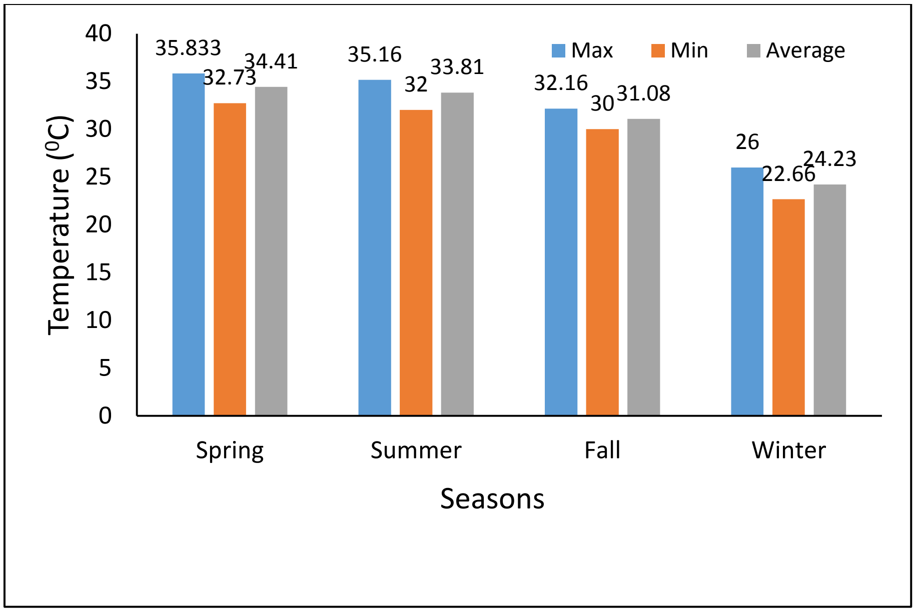


Figure 5: Mean maximum and minimum of T_{max} temperature (1980-2015) in different seasons

b) Minimum Temperature pattern

The mean annual minimum temperature varies between 8.76^{0}C during the winters to 24.96^{0}C during the months of summer. The average range of minimum temperatures during the summer and winter seasons are 22.6^{0}C to 25.66^{0}C and 4.96^{0}C to 10.8^{0}C respectively.

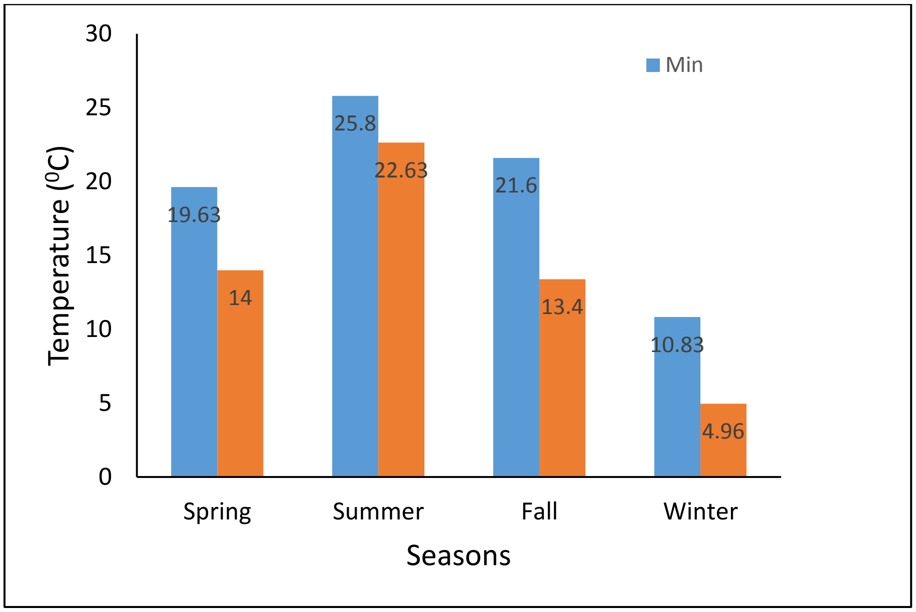


Figure 6: Mean maximum and minimum of T_{min} temperature (1980-2015) in different seasons

Extreme distribution

Precipitation intensities in this region shows high fluctuations. In the year 1998 in the month of August the station has recorded 1046.8mm whereas in the year 1970 in the month of December the station has recorded 0.5 mm of rainfall. Extreme air temperature variation follows the seasonal pattern with extreme minimum temperature 4.96^{0}C in the month of winter to extreme maximum temperature of 35.83^{0}C in the year 1995 whereas the same year had 33.73^{0}C temperature during the summer. In general summers have higher maximum temperatures.

Temperature

Annual trend

Chitwan has increasing trend of annual maximum as well as minimum temperature. The maximum temperature increases by 0.0106 ^{0}C per year from 1980 to 2015 with highest maximum temperature in 1994 (31.775 ^{0}C) and lowest maximum temperature in 1985 (29.075 ^{0}C).

The minimum temperature increases by 0.0209 0C per year from 1980 to 2015 with highest minimum temperature in the year 1998 (19.1167 ^{0}C) and lowest minimum temperature in 2012 (13.95 ^{0}C).

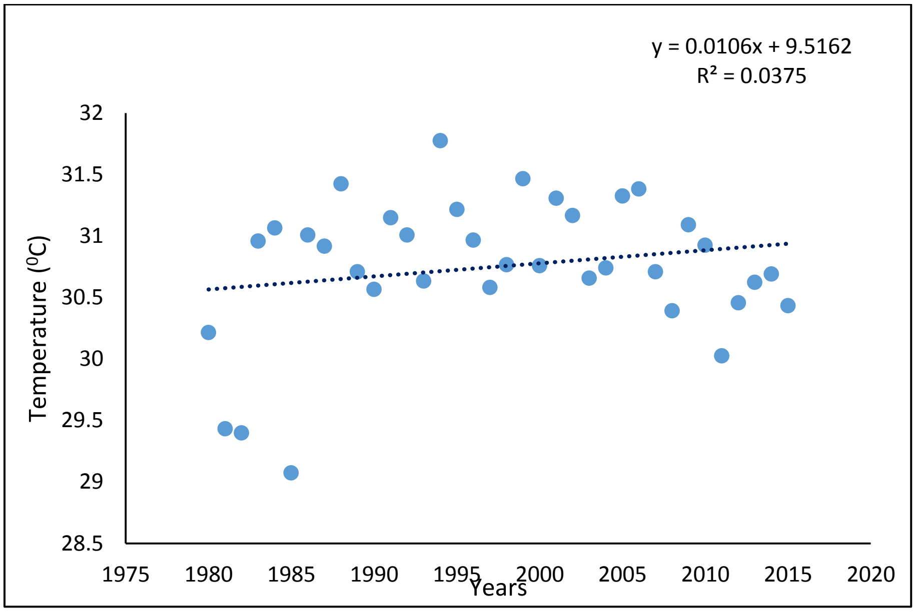


Figure 7: Annual average of maximum temperature

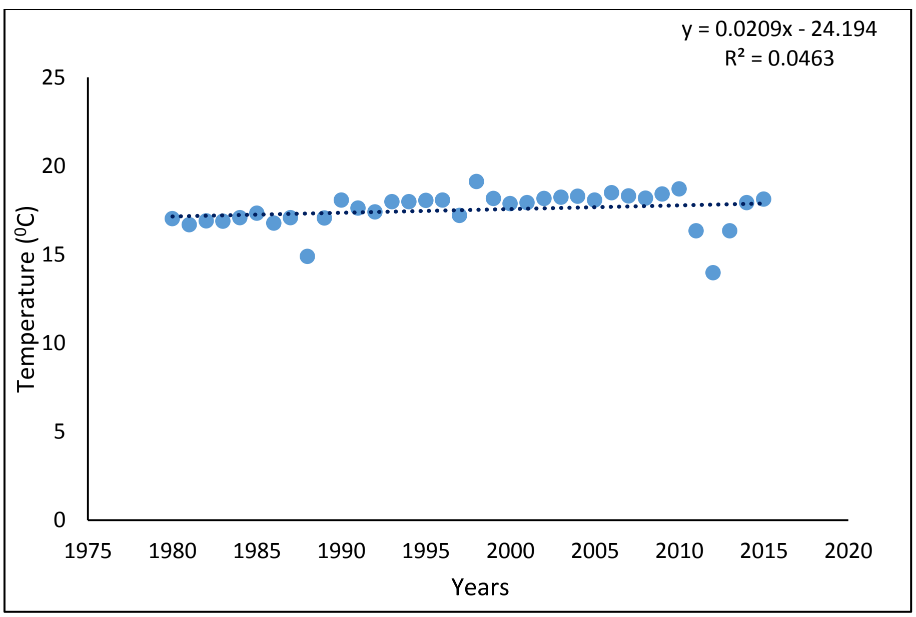


Figure 8: Annual average of minimum temperature

Seasonal trend of maximum temperature (T_{max})

The trend of maximum temperature of winter is negative. The temperature is decreasing by 0.02 ^{0}C per year in this season whereas other seasons show positive trend. The maximum temperature is increasing by 0.003 ^{0}C annually during spring and by 0.0196 ^{0}C per year during summer. In case of Autumn/Fall season the maximum temperature is increasing annually by 0.005 ^{0}C. These show high fluctuations in seasonal maximum temperature.

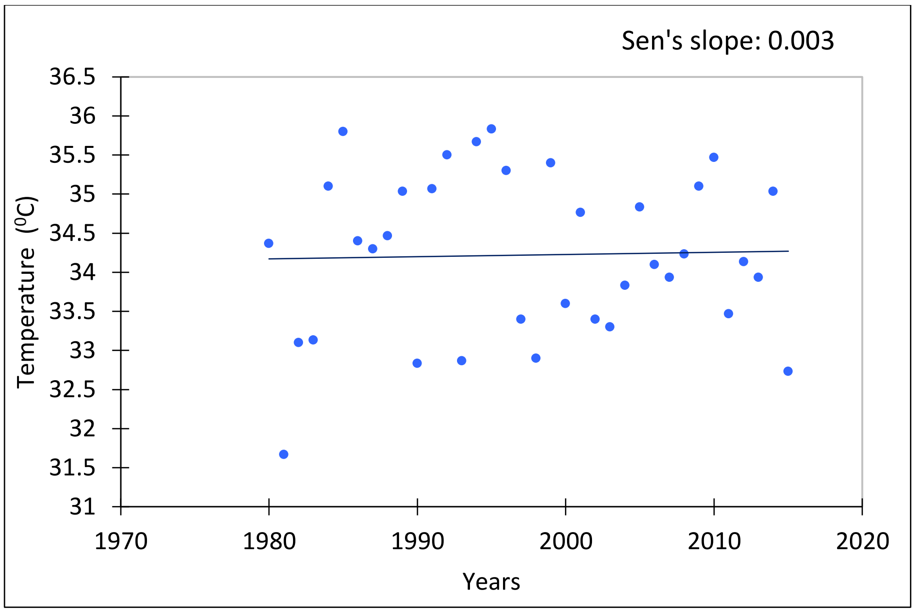


Figure 9: Spring T_{max} trend

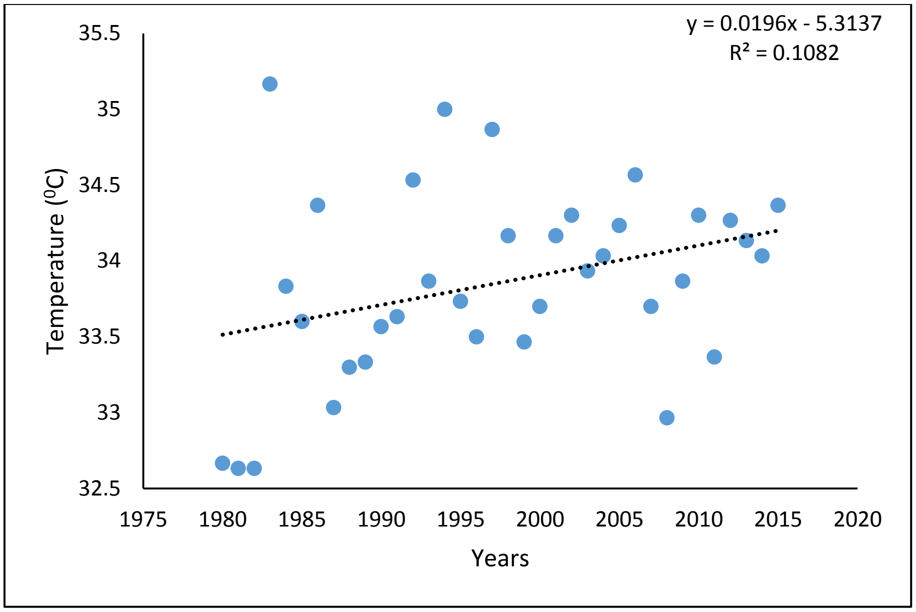


Figure 10: Summer T_{max} trend

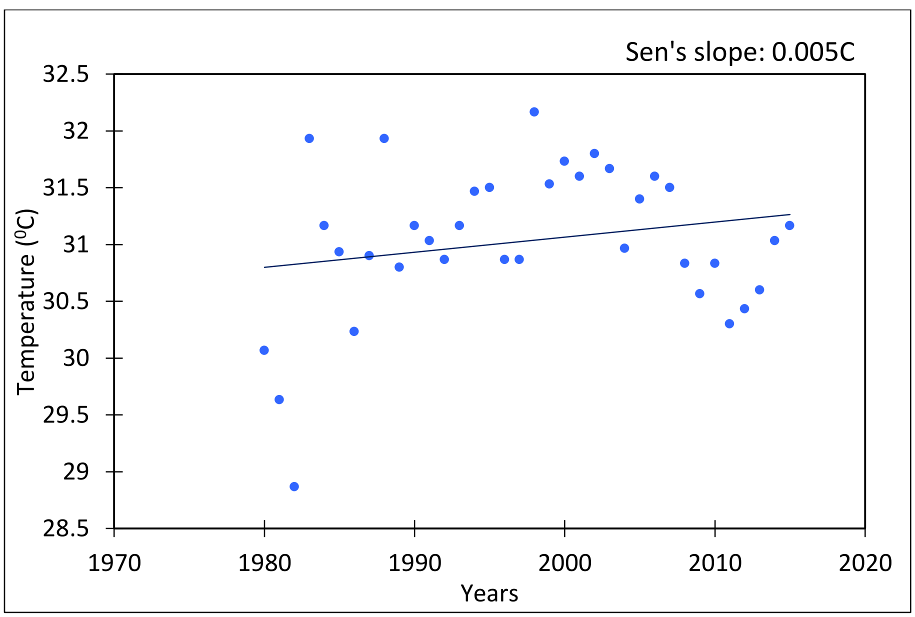


Figure 11: Fall T_{max} trend

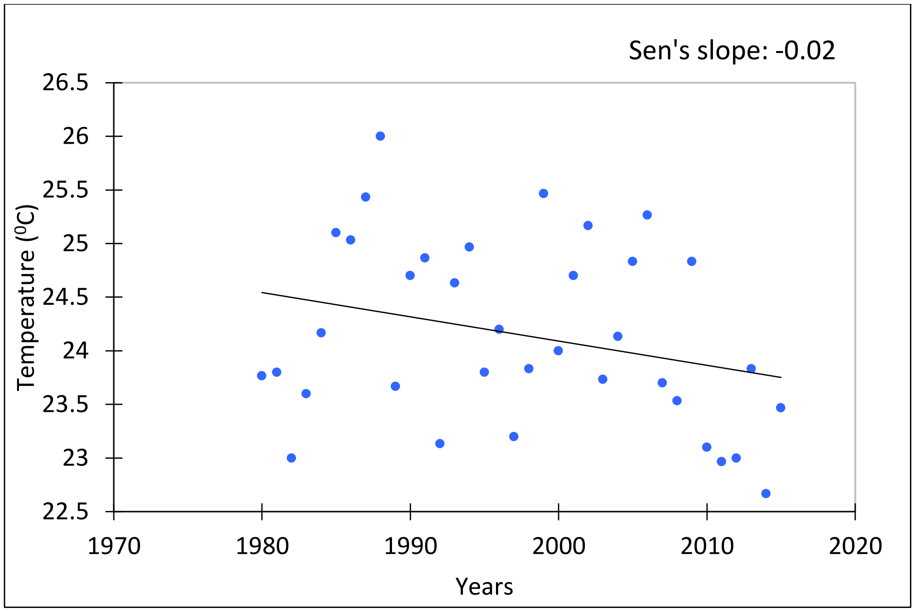


Figure 12: Winter T_{max} trend

Seasonal trend of minimum temperature

All seasons show positive trend in minimum seasonal temperature. The increment is maximum in winter than in other seasons, i.e. 0.0147 ^{0}C per year followed by summer, 0.0128 ^{0}C per year, spring 0.0024 ^{0}C and then fall season, i.e., 0.0239 ^{0}C per year.

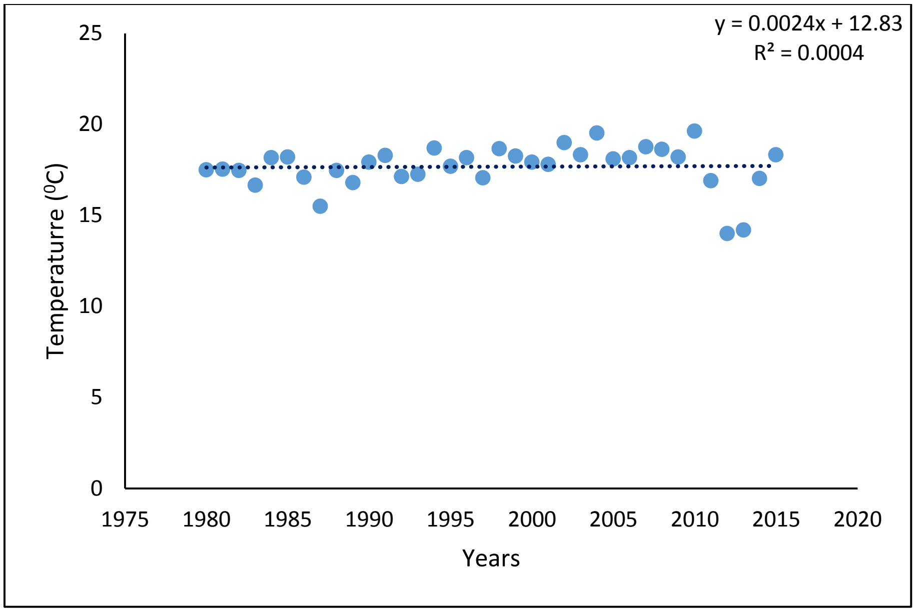


Figure 13: Spring T_{min} trend

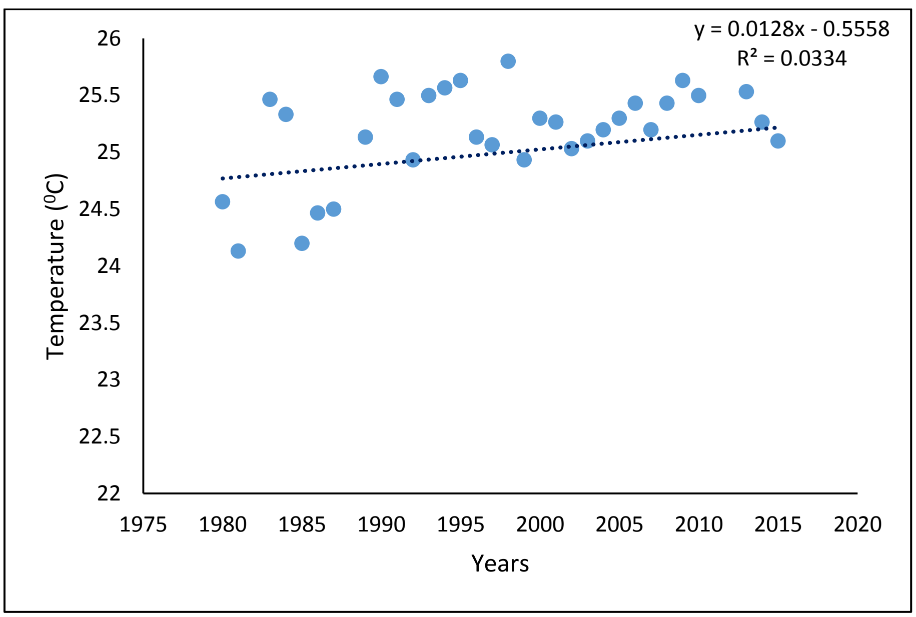


Figure 14: Summer T_{min} trend

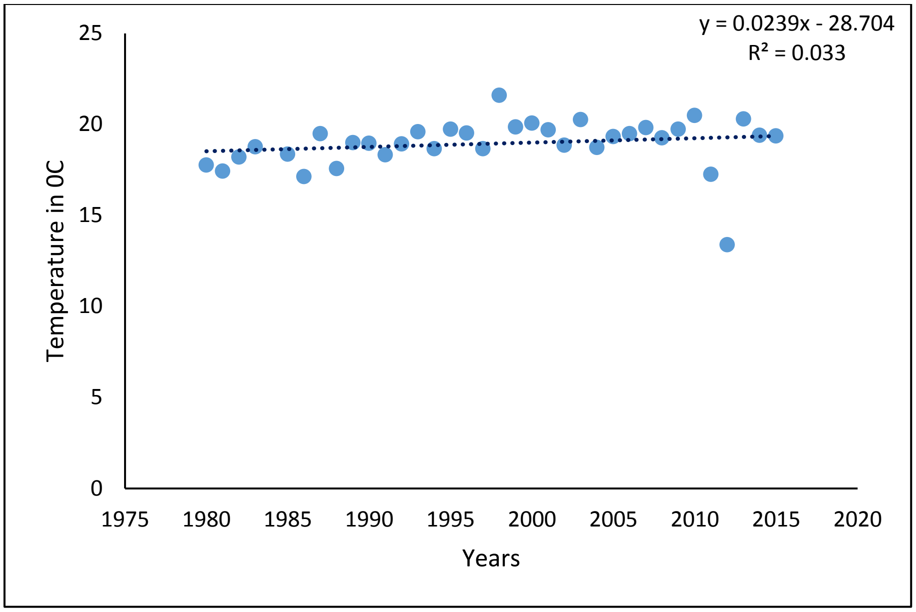


Figure 15: Fall T_{min} trend

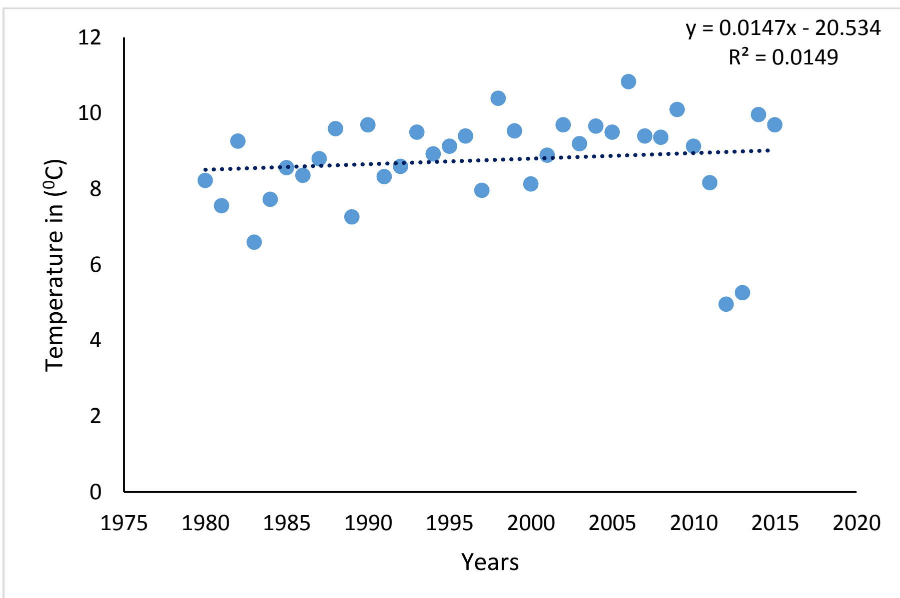


Figure 16: Winter T_{min} trend

Precipitation Trend

Annual trend

The annual precipitation trend in the region is positive. The precipitation increases by 0.85 mm per year.

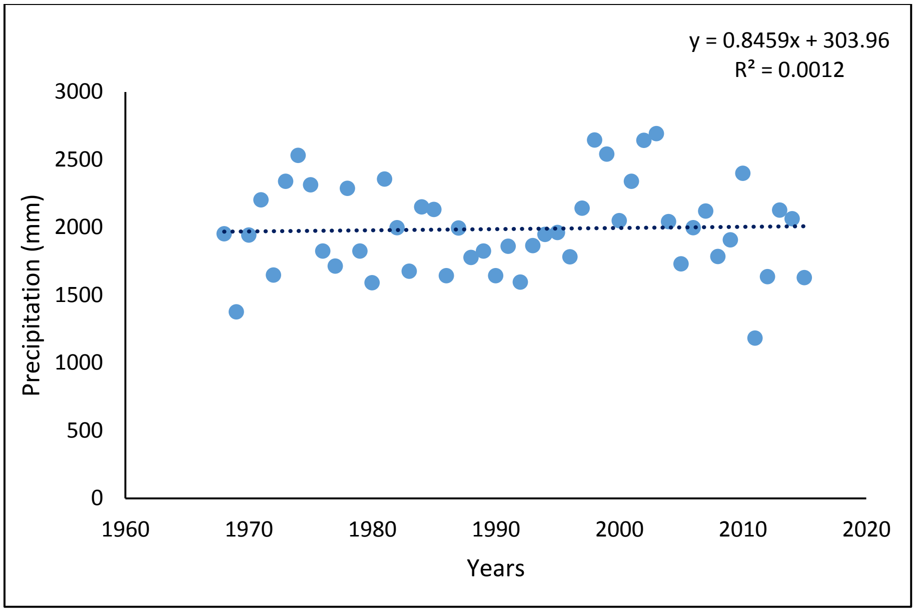


Figure 17: Annual trend of precipitation

Seasonal trend

The seasonal trend of precipitation is uneven. Pre-monsoon season shows positive trend whereas monsoon, post-monsoon and winter seasons show decreasing trend. The precipitation increases by 3.033 mm every year during pre-monsoon season whereas during monsoon it is found to be decreasing by 0.051 mm annually. During post-monsoon the precipitation decreases by 2.599 mm per year and by 0.143 mm per year during winter season.

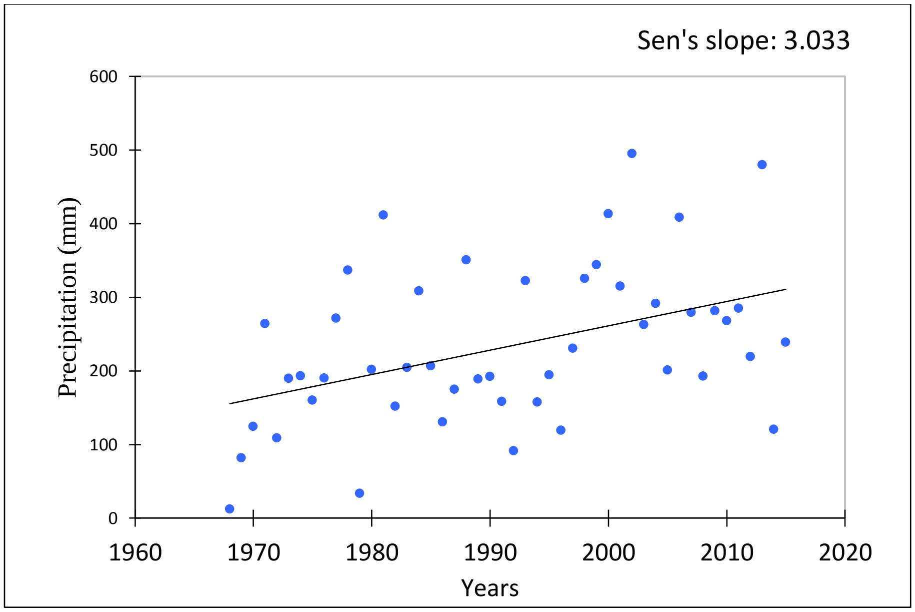


Figure 18: Pre-monsoon precipitation trend

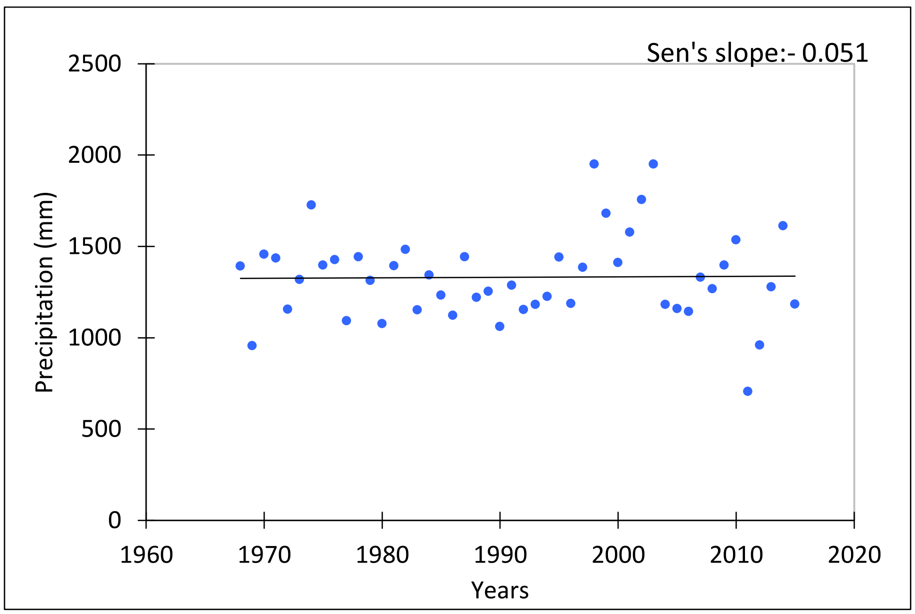


Figure 19: Monsoon precipitation trend

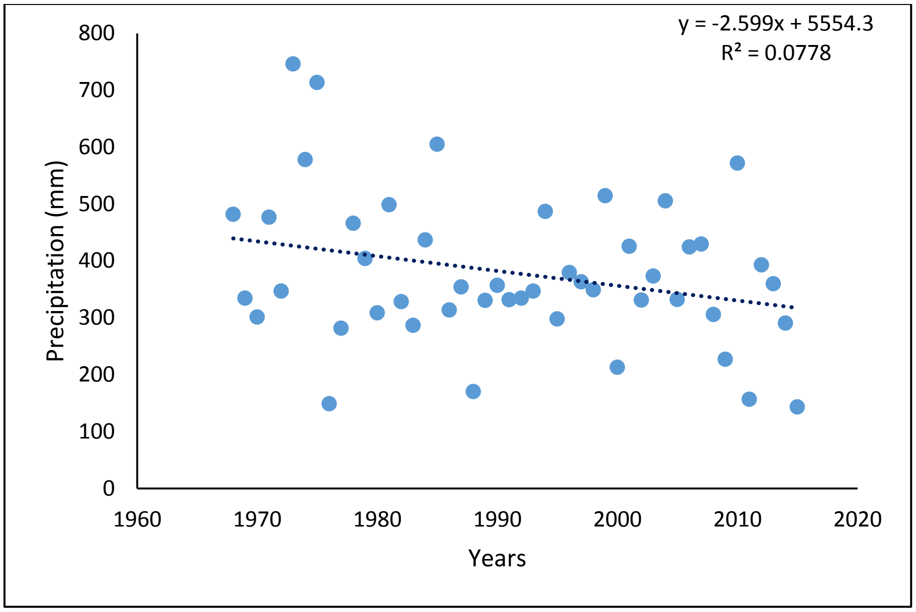


Figure 20: Post-monsoon trend of precipitation

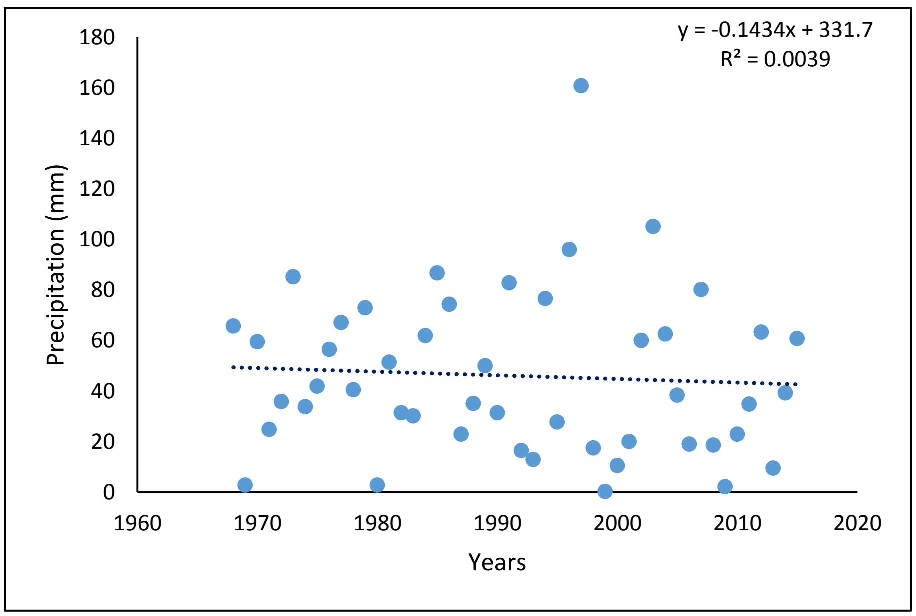


Figure 21: Winter trend of precipitation

4.2 Demography of water users

Shivanagar, canal number 6 consists 1243 water users which is 3.37% population from among the four VDCs. According to the data provided by KIS, 2060, the males comprises of 80.85% of total population and 19.15% females. Among these, 28.88% of people from the water users have migrated to other places. The command area was estimated to be

156.705 ha in this canal during the formation which seems to be reduced to 141.93 ha. However, among the 141.93 ha of land only 124.59 ha are successful enough to receive irrigation water.

Table 2: Demography of water users in canal no. 6

Population (Sagun sichai, 2060)	Water users	Remarks
Total households	760	
Total population	1243	
Males	1005	
Females	238	
Migrated population	359	
Command area (in ha)	156.705 ha	141.93ha (Houses excluded), 124.59 ha receive irrigation water, 17.34 ha of land pay paanipot despite of receiving irrigation water

Source: Secretary, Shivanagar canal no 6

Water distribution practices

Canals have specific rules and methods of water distribution. Water distribution starts from 15th of Ashar till 22nd of the same month. Water is allowed to flow freely in the canals and after this gates are closed starting from Tikauli, which is the head of Khageri Irrigation canal. There is a rain gauge in Devnagar. When the meters read more than 150cm water is distributed in a weekly basis where the canal gates are controlled alternatively. At times when the meter reads less than this, section system is used where the whole canal is divided into three; Gitanagar, Shivnagar and Mangalpur. Heads are irrigated first and then alternatively. Water distribution in the main canal is done from the decision taken by the WUA of the main committee. The branch canal WUA members are informed/notified from the main committee and then the farmers are informed from which date water is about to be distributed and till when. Water at first (Pahilo paalo) is allowed to flow free. This means all the gates are left open. Water at second flow turn (Doshro paalo) is controlled via gates. Water in the canals with no gates are controlled using local materials like stones and muds.

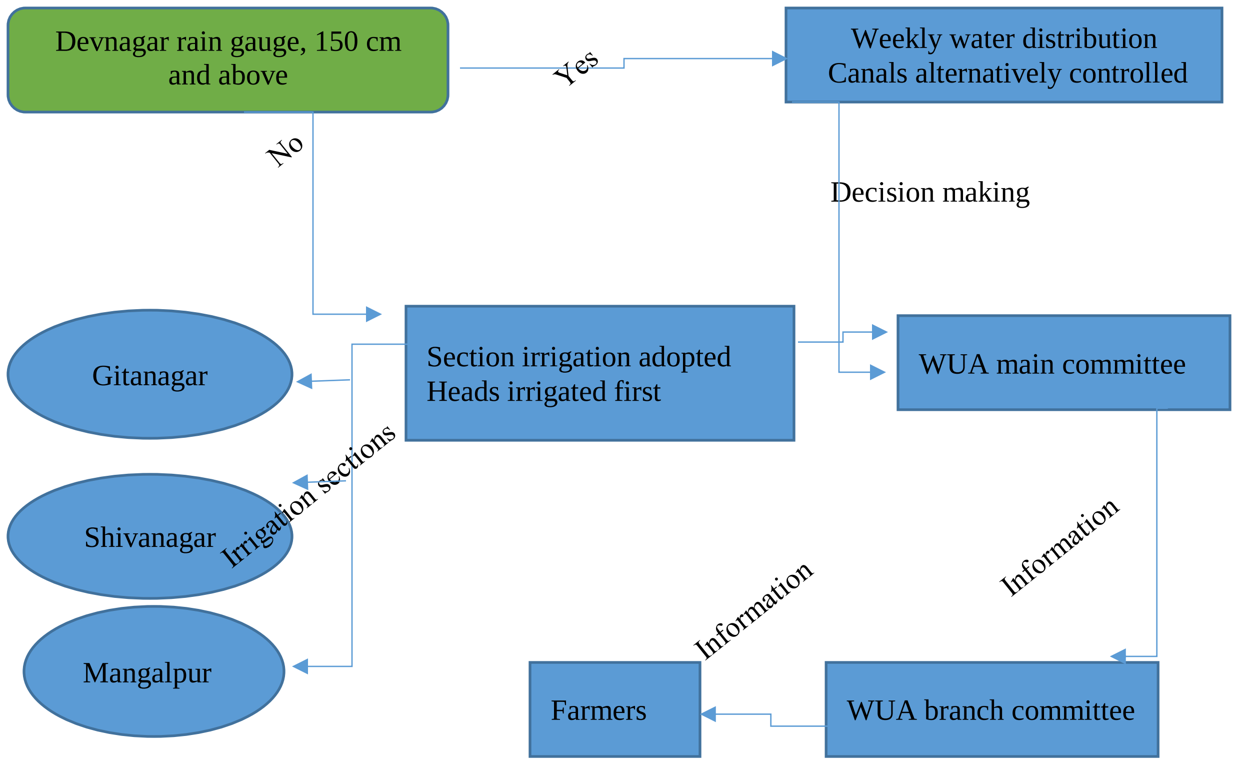


Figure 22: Flow showing water distribution

Issues in water distribution

Insufficient water in the canal is itself a major issue in water distribution. The issues arise more from the residents of tail region of the canal. Farmers claim their loss of rice production if they are allowed to irrigate the fields at the time of plantation and not in other days of requirement as the growth and production declines. Each year WUA faces 3-5 conflicts related to water distribution. There are around 32.11 ha of land at present in the command area of canal number 6 which do not receive irrigation. People show dissatisfaction as they need to pay the charge despite of even not getting water in the fields. WUA decides not to include those areas under the command area at times of less water. There are also issues of not getting continuous water into the fields. Other reasons for conflicts are on canal pathways which arise when people refuse to provide their private land to the canals, volume and timing of water distribution, water leakage and theft. The WUA lacks effective plans for when and how the water should be distributed to minimize the conflicts.

Water availability in the canals

The major source of water in Khageri Irrigation Canal is the River Khageri which is a spring fed river. The issues of water insufficiency and variability in the flow exists in Khageri from the time of its operation. The command area of the canals are decreasing as water in the canals are insufficient. In one hand the command area is decreasing due to housing and other land use changes but water supply to the decreased area is still not sufficient. There are multiple factors responsible in decreasing the volume of water in the canals. Some of the prominent reasons found were,

I. Decrease of water at the source: One of the main reasons behind insufficiency of water in the canals is decreasing water in the source. Out of the total respondents 86.31% agree that the water in the source is declining. People (63.42% of respondents) believe Padampur resettlement to be one of the major factors to increase water consumption in the source. Out of the total respondents who believe the water in the source is decreasing, 13.41% believe changing climatic parameters to be one of the causes behind less water in the canal.

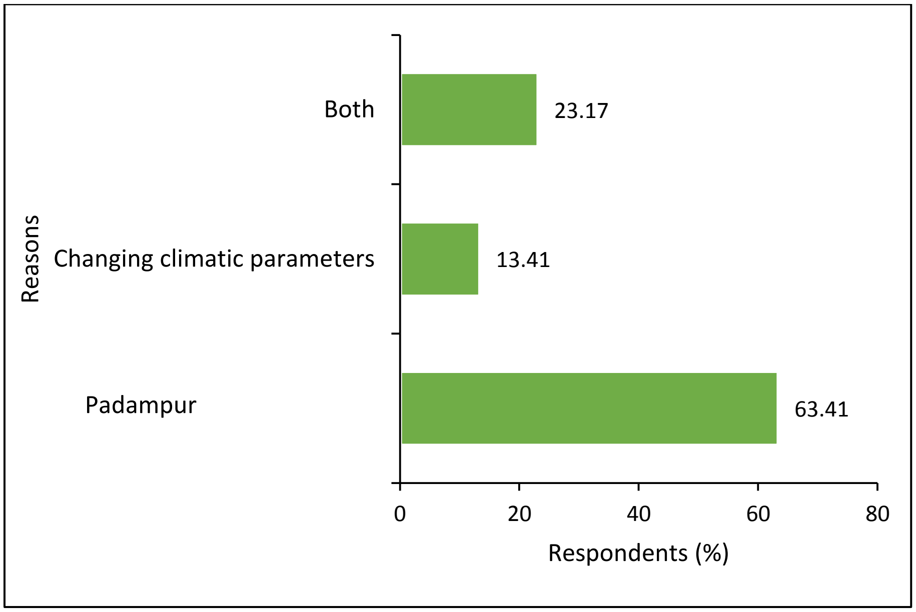


Figure 23: Reasons behind decreasing water at source

II. Leakage and poor maintenance of canals

According to 13.68% of the respondents water in the canal is decreasing due to this reason. The Figures below reflect the respondent's view behind water insufficiency in the canals,

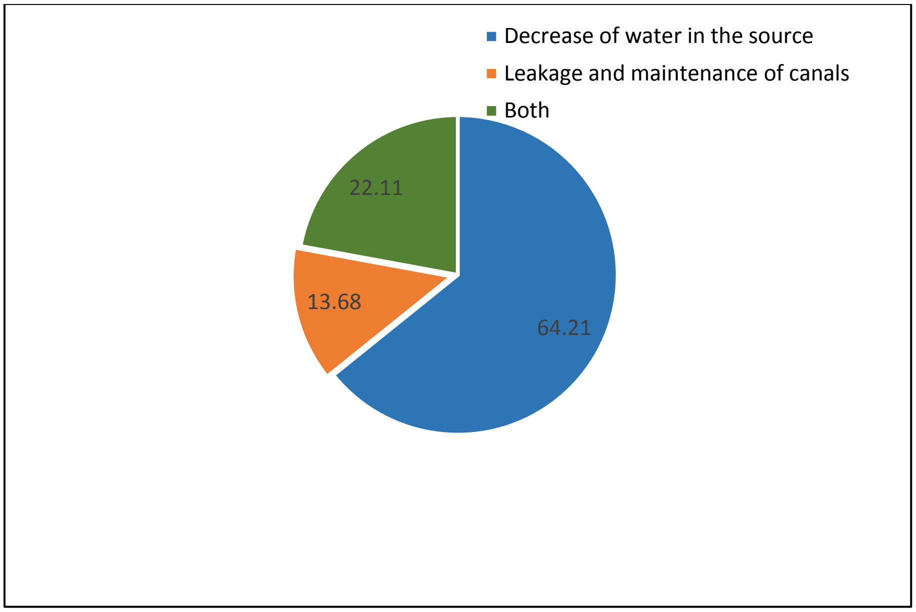


Figure 24: Reasons behind water insufficiency in the canals

Interventions in agriculture

With the changing demographic numbers in the place, there are also interventions in traditional way of farming. Many of the water users of KIS have introduced pumps and bore wells into their fields as they don't receive enough water from the canals when necessary. Many have switched from traditional rice cultivation to vegetable farming. The tendency of doing vegetable farming was more in the tail region with the introduction of bore wells. It was found that one of the indigenous rice variety 'Spring rice' which is to be planted during the month of March-April is hardly planted as it requires more water say 82% of the respondents. The water users of tail region complain of not receiving enough water when required. Around 87% of people of tail region complain of water insufficiency during irrigation. These interventions are mainly done by financially able group of people. People who cannot afford bore wells use water from those having them at certain prices.

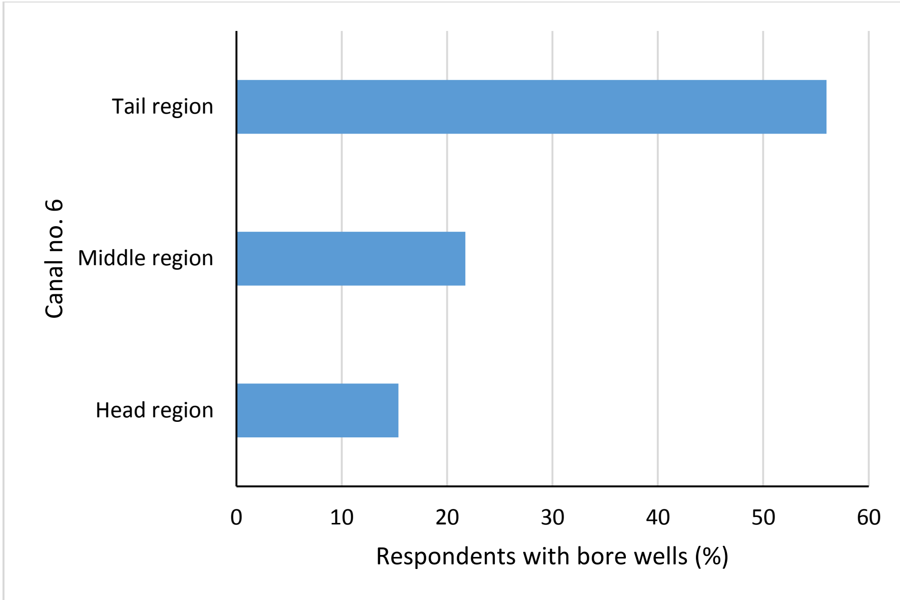


Figure 25: Introduction of bore wells in canal no. 6

Water availability and linked occupations

It was found that the farmers who introduced bore wells mostly belonged to tail region of KIS and insufficient water from the canal was the main reason for the bore well introduction. However, use of ground water has helped farmers of tail region cope with current water stress. People of the head region have not introduced bore well in comparison to that of tail region. People here have changed their cropping pattern. Farmers (90% of the respondents) in head and middle region have shifted their paddy transplantation from June/July to second week of august 20-30 days later than before due to declining precipitation.

Regression analysis in between vegetable farming and bore well introduction shows that these two elements shows strong positive relation. The Figure below explains this in greater detail.

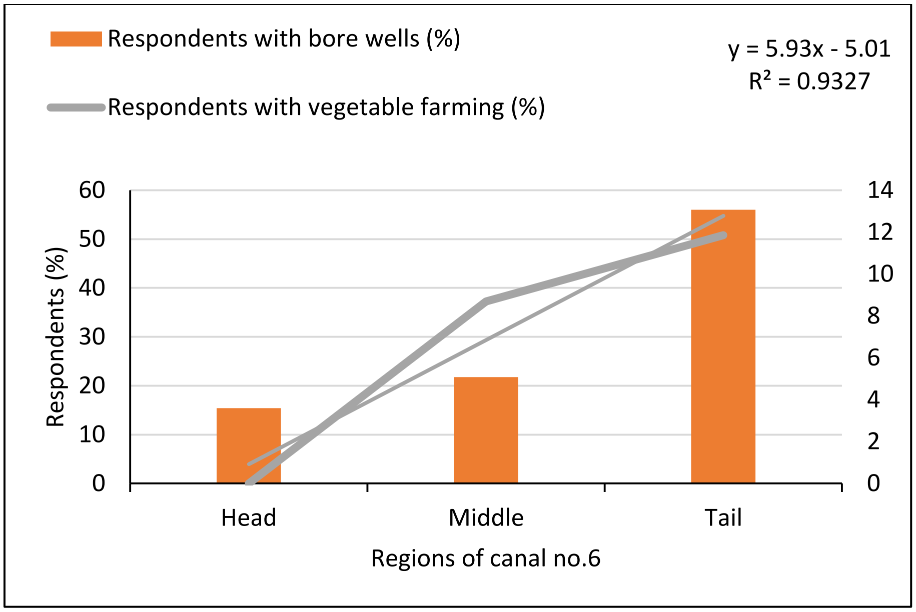


Figure 26: Relation between vegetable farming and bore well introduction

Challenges and issues in farming

The region is highly influenced by the use of chemical fertilizer and pesticides. Among the respondents 99% people were found to be using chemical fertilizers and pesticides. Among these users none of them received trainings of proper handling of chemicals. Chemicals were done in order to increase the production and save the crops from unwanted pests. This has in one way increased the cost of production say the respondents which has in return induced market problems.

Meanwhile, 87 % of the respondent experience changing weather conditions like less fog during winter, bright sun after rain and increased pests. People complain that bright sun after rainy days bring more pests and damage the crops. Decreasing fogs also harms the crops as they deficit moisture into the soil.

Institutions in agriculture

It was equally interesting to find that institutions play a vital role in promoting agriculture. Among the three regions, middle region of the canal Paharipur had good community institutional back force to promote agriculture. The farmers of this place united to build a saving and credit co-operative which provided easy loans to the community farmers. Dislike to the other co-operatives, this in parallel had organization to store farmer's indigenous seed of the produce. Along with this, all the produce of the community were bought by the organization (Krishi Biu Bijan) at market prices and sold to other places. This eased the farmers of not getting proper market. In addition, farmers had a community dairy where all of the milk products of the farmers were deposited and selling was made. The farmers of this region were less worried in comparison to the farmers of the other two regions regarding their produce and agricultural products.

4.3 Gender dimension in irrigation management

History of irrigation system

Khageri Irrigation System was an agency managed gravity irrigation system of Nepal located in Chitwan with a command area of 3900 ha. The management authority of the irrigation system was handed over to the Water User Association Groups of the area in 2024 B.S. Today it is joint managed irrigation system. Water is supplied via diversion from River Khageri which is one of the tributaries of River Rapti. It was designed by Department of Irrigation in 2017 B.S and the works of construction was completed in 2024 B.S at a cost of 7.6 million (Khanal, 2003). However, original planning was done by FAO. The canals are designed such that they are safe from the risks of flooding and inundation. The irrigation canal was constructed mainly with two objectives, to support the livelihood of newly settled people and to supply food to Kathmandu valley but water in the canals has always been insufficient since its formation (Khanal, 2003). The canal has a diversion barrage, main canal (23 Km), 11 branch canals (55 Km), tertiary canal (100 Km) (Khanal, 2003). 7 Km of main canal passes through buffer zone of Chitwan National Park. Water in the irrigation canal comes from River Khageri which is a tributary of River Rapti. Annual rainfall in the catchment averages 1600 mm, 80% of which falls during monsoon. Runoff supplies water in the monsoon season whereas base flow maintains the flow during dry season. The canal was constructed with less agro-metrological information and less data on duties of crops. The engineers too had limited knowledge since it was the first large scale project undertaken by DoI (Khanal, 2003). WUA in Khageri Scheme consists of main committee at system level and branch committee at branch level. The annual operation and maintenance cost of

KIS is about 500/ha. 25% of the total maintenance cost is assisted by voluntary labor contribution by the local people. WUA collect revenues as Irrigation Service Fee (ISF) from the users at a rate of NRs. 60/ha per crop (Khanal, 2003). Other sources of revenue are; land from department of Irrigation, fishing contracts in the canal, works like cooperative, fertilizer sellers and seeds.

Irrigation management

KIS was developed in 1969 to bring 3900 ha of land under irrigation. This system was brought to joint management in 1995 under IMTP by Department of Irrigation (DoI) where the operation and management of the intake and the main canal is the responsibility of DoI while the task of water distribution and management of irrigation infrastructure down the level of main canal is the responsibility of the Water User's Association (WUA).

The WUA has one main committee and 9 branch committees. The main committee has altogether 19 members, 12 of which are from the branch committees. The presidents of branch committees automatically are selected as members of main committee. Three members of the uppermost hierarchy (President, Sub-president and Secretary) are selected through the election process in annual general meeting. Three females, one each from section canals are selected for the main committee. The president of 'Mul Mahila Jagaran' is also the member of the main committee forming a total of 19 members.

The branch committee consists of 7 members. Three belonging to the upper hierarchal posts of president, sub-president and secretary. The remaining 4 members are the members elected from the outlet canal committee (Kulo Samiti). Membership in 'Kulo Samiti' is based on the spatial coverage of the canal outlet. As per the provision, one member in 'Kulo Samiti' is selected from 3.211 ha of land, for more than 3.211 ha but below 6.422 ha of irrigation area 2 members are selected and in area more than 6.422 ha of land 3 members are selected in 'Kulo Samite'. The chart below explains the process in more detail;

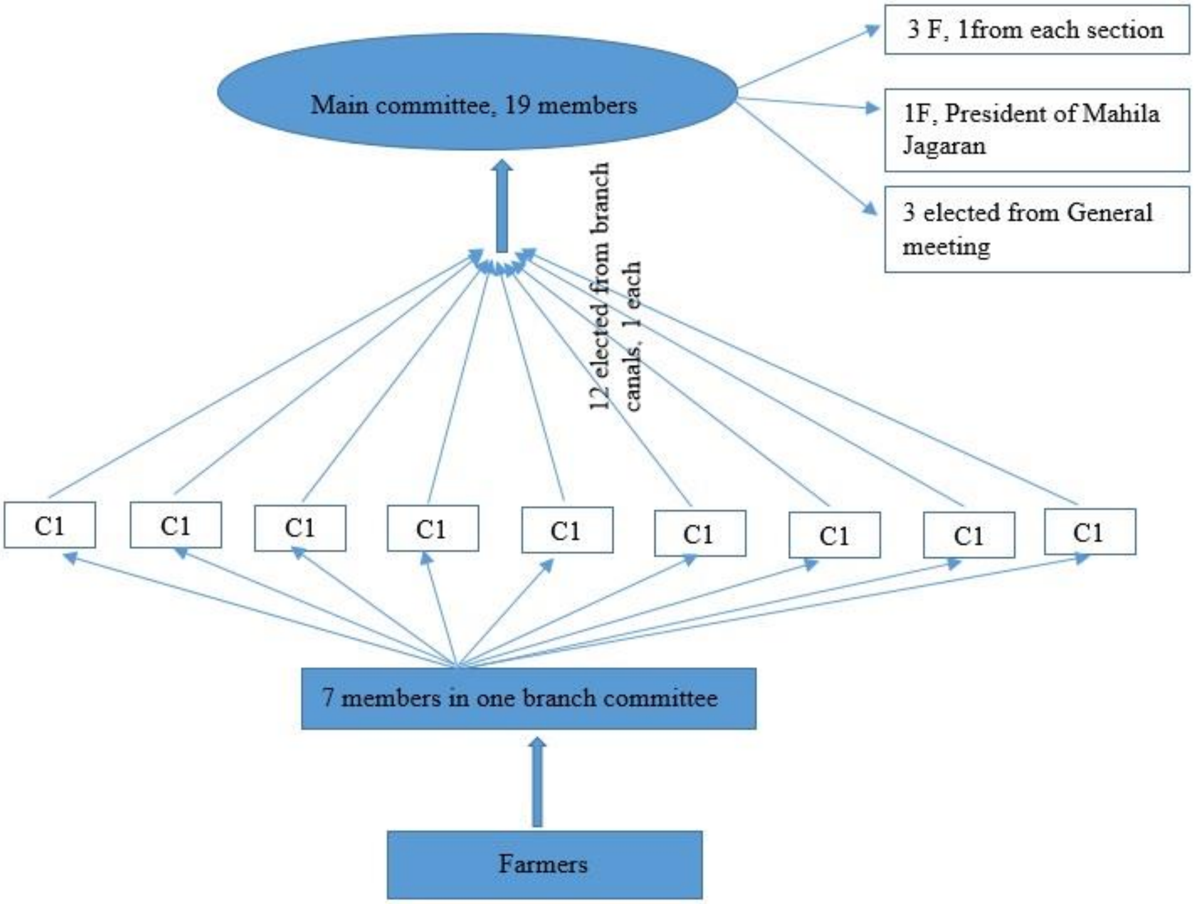


Figure 27: WUA management and participation

Participants in WUA

The total number of women in WUA main committee is four and there are three women in WUA canal no. 6, Shivanagar. The participation of women in these committee has never excelled the designated numbers till date says the secretary of WUA canal no 6. From the field surveys it was also found that the women nomination into these are just to fulfill the government nominated seats and not to voice their opinion.

Table 3: WUA participation in canal no. 6

Designation	Name	Gender
President	Keshab Regmi	Male
Vice-president	Ramesh Shrestha	Male
Secretary	Lekhnath Baral	Male
Member	Homnath Poudel	Male
Member	Pitambar Bhandari	Male
Member	Bhesh Raj Joshi	Male
Member	Goma Thapaliya	Female

In a total of 7 FGDs, 3 FGDs with 39 male participants were carried out in male's group and 4 FGDs with 56 female participants were carried out in female's group. The reason behind low participation of female were explored. Gendered distinction of work was clearly sensed from the discussion where there were two major findings for less female participation;

(i) Females hardly got time to understand the norms and processes enrolled to participation within a WUA and never felt a need to participate. This came out from both male as well as female FGD. The males as well as the females in all FGD agree that females have multiple roles and responsibilities within a family to spare time for them to participate whereas males are often free and can utilize their spare time via participation.

(ii) The discussion also pointed irrigation management to be a male's work. This interestingly came out of male FGDs where males believe that there can be several physical labored works like ploughing, travelling distant places to check water into the canals even during night time the responsibility of which females are doubted. Males too believe that females are illogical while taking decisions and this may end up with more conflicts. This school of thought did not match to females. Females (91%) believe they lack the technological know-how, processes involved within an irrigation management and are never empowered in making them able for these responsibilities due to which they hesitate to participate.

Work division in agriculture

Table 4: List of different tasks performed by male and female

Activities	Always by men	Usually by men	Done by either	Usually by women	Always by women
Agricultural Tasks					
Ploughing	95				
Making ridges	95				
Smashing clods			19		76
Irrigating lands		48	47		
Sowing grains			10		85
Weeding					95
Transplanting paddy					95
Threshing grain					95
Harvesting rice			95		
Hauling manure			15	15	65
Growing vegetables			24		71
Raising chickens			19		76
Going to mills	15		80		
Going to markets			19		76
Daily H.H Tasks					
Hauling water			15		80
Cooking food			15		80
Cleaning cookware			15		80
Washing clothes			15		80
Feeding animals			24		71
Milking animals	33		19	43	
Caring for children			19		76
Off-Farm Activities					
Shop keeping			52	43	

The study also reveals that this place has distinct division of work in terms of agriculture. There are works specific to genders. The works like ploughing, making ridges involves more physical labors so males are assigned for these works. The works like weeding, transplanting paddy, threshing grain are more strenuous and time consuming that lies in the head of women. It is considered one of the most monotonous works so especially children along with the aged people are engaged in this work. There are many works like smashing clods, sowing grains, hauling manure, growing vegetables and raising chickens where mostly females participate. Whereas some works like harvesting rice and going to the mills were done by both male as well as females. However, some household's males alone participated in visiting mills. The place has countable number of male migrants due to which there is insufficient labor. People hire workers from other region which they call as 'Deshi'. Women hire these men to plough the fields as they believe it to be men's work. It was also found that females held more share of household, reproductive and care works**.** 80 respondents believe works like hauling water, cooking, cleaning and cleaning the cooking wares to be women's work. Similarly, 71 respondents believe caring the children to be sole women's responsibility.

CHAPTER V: DISCUSSION

Climatic variability

Precipitation analysis

The annual average precipitation of Chitwan district from 1968 to 2015 is 166.78 mm. The rainfall varies from 6.63 mm during November to 534.67 mm in July. Pre monsoon season received 11.65 percent of the total annual precipitation. Monsoon season contributes on an average 66.49 percent of the total annual precipitation in the region (Fig: 4). Winter (December - February) is the driest season contributing 2.29 percent of the total annual precipitation. Precipitation intensities in this region shows high fluctuations. In the year 1998 in the month of August the station has recorded 1046.8mm whereas in the year 1970 in the month of December the station has recorded 0.5 mm of rainfall. The annual precipitation trend in the region is positive. The precipitation increases by 0.85 mm per year.

According DHM (2015), the analysis of data from 1971-2012 showed that all development regions except mid-western development region showed positive trend in annual precipitation. However, the country experiences variation in precipitation trend where small pocket areas observed over 30mm/year increase in annual precipitation and decreasing trend of 40mm/year. The report talks about increasing trend of precipitation in Chitwan district. The increment varies from north to south Chitwan with the range of 0-5, 5-15 and 15-30 mm/year moving towards the south. Chamakar (2010), Baidhya et al. (2007) also agree that overall rainfall in the country is increasing since last 21 years.

Seasonal trend of Precipitation

The seasonal trend of precipitation is uneven. Pre-monsoon season shows positive trend whereas monsoon, post-monsoon and winter seasons show decreasing trend. The precipitation increases by 3.033 mm every year during pre-monsoon season whereas during monsoon it is found to be decreasing by 0.051 mm annually. During post-monsoon the precipitation decreases by 2.599 mm per year and by 0.143 mm per year during winter season (Fig: 18, 19, 20 and 21).

DHM 2015, reports both increasing as well as decreasing trend of pre-monsoon precipitation depending on geographical regions. Most part of the Terai experience positive trend in precipitation. Chitwan experiences 0-2.5 mm annual increase in pre-monsoon precipitation in the northern part and 2.5-5 mm/year increase in the southern part. The monsoon precipitation trend shows high variation all over the country. Many places mostly the hills experience significant decreasing trend ranging from 0-30 mm/year during monsoon. However, many regions of Terai and the mountains experience the trend. The northern part of Chitwan experiences decreasing trend of 5-10 mm/year and 0-5 mm/year during the season. However, the southern part experiences increasing trend ranging 5-30mm/year. Post-monsoon precipitation in the country shows both positive as well as negative trends. The trend varies from -5 to 3 mm/year during the season. Chitwan records decreasing post-monsoon precipitation by 2mm/year. These data corresponds to the findings of increasing precipitation trend during the pre-monsoon with decreasing precipitation trend in other seasons in Chitwan.

Temperature variation analysis

The mean annual maximum temperature varies between 23.94^{0}C during the winters to 33.60^{0}C during the summer (Fig: 7). The average range of maximum temperatures during the summer and winter seasons are 24.46^{0}C to34.86^{0}C and 16.5^{0}C to 26^{0}C respectively. The mean annual minimum temperature varies between 8.76^{0}C during the winters to 24.96 ^{0}C during the months of summer. The average range of minimum temperatures during the summer and winter seasons are 22.6^{0}C to 25.66^{0}C and 4.96^{0}C to 10.8^{0}C respectively. Extreme air temperature variation follows the seasonal pattern with extreme minimum temperature 4.96^{0}C in winter months to extreme maximum temperature of 35.83^{0}C in the year 1995 whereas the same year had 33.73^{0}C temperature during the summer. In general summers have higher maximum temperatures (Fig: 6).

DHM (2015), reports that the mean maximum temperature pattern follows the topographical variation of the country; it is recorded more than 30^{0}C over the southern plains of Terai while it is below 0^{0}C in the Himalayan range. The mean maximum temperature of the country ranges from 0-32^{0}C. The pre-monsoon experiences highest mean maximum temperature reaching more than 36^{0}C in the southern tips of central Nepal. The maximum temperature ranges from less than 4 ^{0}C to 36^{0}C. Chitwan experiences mean maximum temperatures in between 20 to 36^{0}C. During the monsoon the mean maximum temperature of the country ranges from 2 to 34^{0}C. Chitwan has mean maximum air temperature ranging from 22 to 34^{0}C during this season (Fig: 6). The mean maximum temperatures of post-monsoon in the country ranges from less than 0 to 32^{0}C. Chitwan experiences 16-32^{0}C range during this season. The mean maximum temperature of winter ranges below -4^{0}C to 25^{0}C. Mean maximum temperature of winter in Chitwan ranges from 8 to 20^{0}C. Alike to the mean maximum temperature, DHM (2015) further explains that the mean minimum temperature varies between 16^{0}C to 20^{0}C in Terai to less than -8^{0}C in the north. During the winters, the mean minimum air temperature ranges from -12 to 12^{0}C. Chitwan experiences a range of 8-12^{0}C temperature during this season. The mean minimum air temperature in the country ranges from -6 to 20^{0}C whereas in Chitwan the temperature lies in between 16-20^{0}C. Mean minimum air temperature in the country ranges from less than -2 to 25^{0}C during the monsoon season. It ranges in between 20-25^{0}C in Chitwan. Post-monsoon season records a range of -8 to 19^{0}C mean minimum air temperature within the nation. The ranges of temperature in Chitwan lies in between 8 to 19^{0}C.

Temperature trend analysis

Chitwan has increasing trend of annual maximum as well as minimum temperature. The maximum temperature increases by 0.0106 ^{0}C per year from 1980 to 2015 with highest maximum temperature in 1994 (31.775 ^{0}C) and lowest maximum temperature in 1985 (29.075 ^{0}C) (Fig: 7 and 8). The minimum temperature increases by 0.0209 ^{0}C per year from 1980 to 2015 with highest minimum temperature in the year 1998 (19.1167 ^{0}C) and lowest minimum temperature in 2012 (13.95 ^{0}C). The trend of maximum temperature of winter is negative (Fig: 12). The temperature is decreasing by 0.02 ^{0}C per year in this season whereas other seasons show positive trend. The maximum temperature is increasing by 0.003 ^{0}C annually during spring and by 0.0196 ^{0}C per year during summer (Fig: 9 and 10). In case of Autumn/Fall season the maximum temperature is increasing annually by 0.005 ^{0}C. These show high fluctuations in seasonal maximum temperature. All seasons show positive trend in minimum seasonal temperature. The increment is maximum in winter than in other seasons, i.e. 0.0147 ^{0}C per year followed by summer, 0.0128 ^{0}C per year, spring 0.0024 ^{0}C and then fall season, i.e., 0.0239 ^{0}C per year (Fig: 13-16).

DHM (2015) also reports that the spatial pattern of mean maximum temperature trend is in increasing trend almost in the entire country leaving some places of southern Terai region. Chitwan experiences less than 0.00 to 0.04^0C increase in mean maximum temperature trend. There is significant decreasing trend of winter maximum temperature in Terai region. The report explains the reason for this decreasing trend in maximum temperature due to cold waves and foggy weather conditions. Pre-monsoon, monsoon and post-monsoon season show positive trend in mean maximum temperature. The temperature in these seasons increase in the range of 0.00-0.02, 0.00-0.06, and 0-0.04^0C annually in respective seasons. The annual mean minimum temperature of Chitwan increases from 0.00 to 0.04^0C every year. The trend of mean minimum temperatures in the reason is positive. The temperature increases by 0.02-0.04, 0.02-0.04, 0.002-more than 0.04, and 0 to more than 0.06^0C per year during the months of winter, pre-monsoon, monsoon and post-monsoon respectively.

Water insufficiency in the canals and the reasons

The place has problems of water insufficiency. The canal WUA records reducing irrigation in the command areas. They even report cases of removing agricultural land from the water users as they cannot provide water. A survey done by Sagun Sichai in 2002/2003 reports that the command area was estimated to be 156.705 ha in this canal during the formation which seems to be reduced to 141.93 ha. However, among the 141.93 ha of land only 124.59 ha are successful enough to receive irrigation water (Table: 2). The observation, interviews and analysis from the field indicates that the problem is more prone to the tail region of canal no.6. Padampur resettlement came out as more pronounced reason than changing climate behind decreasing water at the source. Padampur VDC residing in the left bank of Rapti River within the Chitwan National Park were resettled to Sagun Tol due to human animal conflicts. Sagun Tol lies in the catchment of Khageri River. This increased abstraction of surface and ground water for domestic and agricultural purpose. People also started clearing the forest and built check-dams which interfered the flow regime of Khageri River downstream. Khageri and Panchakanya irrigation schemes had filed a petition in 1997 in the supreme court of Nepal against this resettlement program.

However, 13.41% of the respondents believe changing climatic parameters to be one of the causes behind decreasing water in the canals (Fig: 23). Data analysis of precipitation and temperature show that, the annual trend of precipitation though shows increasing trend has high fluctuation in seasonal precipitation pattern. Data clearly show shift in precipitation from monsoon to pre-monsoon season along with decreasing precipitation in other months. Fu, Congbin, et al. (2014) explains that changing climate impacts hydrological variables like rainfall, evaporation, run off and soil water content which influences the supply and demand balance of water. Elliot, J., Deryung, D., Muller, C., Frieler, K. Konzmann, M., Gerten, D.,…& Eisner, S. (2014) also write that limitations of freshwater in some irrigated regions like United States; China, and West, South and Central Asia could lead to 20-60 Mha of cropland from irrigated to rainfed management by the end of the century with a further loss of 600-2, 900 Pcal of food production. Similarly, a study done in Spain by Diaz, J. R., Weatherhead, E. K., Knox, J. W., & Camacho, E. (2007) also speaks of typical increase of 15-20% in seasonal irrigation need by the 2050s from modelling of irrigation water requirement, depending on location and cropping pattern, along with changes in seasonal timing of demand.

Engineering design, maintenance and operation plays equal role in water availability in the canals. In order to understand these aspects it is equally important that we understand its ownership and management controls and access. Khageri Irrigation is now a joint managed irrigation system. Before this it was under DoI which now looks after operation and maintenance. The management and distribution responsibility is handed over to the WUA elected from within the WUs. The physical infrastructure of Khageri Irrigation System consists of 22.4 km long main canal, 9 branch canals, 4 sub-branch canals, 375 direct outlets and spillways, cross regulators and cross-drainage. The physical infrastructure in canal no.6, Shivnagar consists of 1.488 km long main canal which gets divided into eastern and western canals. The eastern canal is 4.721 km long which extends till Madhupari, Jagatpur. The western canal is 3 km long and ectends till Shankarchowk, Parbatipur. The command area of this canal (Shivnagar) is 124.59 ha. From the information provided by Khageri Irrigation System office, the areas with more seepage and leakage of water is concretized. In the process, around 300m starting from the head region of Khageri, i.e. Tikauli is concrete. Around 1 km of the main canal in canal no. 6 and around 1200m in the eastern branch is concrete. The problems of leakage is triggered more by the activities of rats and mice;

according to 13.68% of the respondents water in the canal is decreasing due to this reason (Fig: 24).

Socio-economic aspects of farming

Water distribution starts from 15th of Ashar (29th June) till 22nd of the same month (6th July). People experience changes in the rainfall timing and intensity. Due to these reasons people of head region of canal no.6, Shivapur of KIS farmers have changed their paddy transplantation time from June/July to 2nd week of August (page: 52).. However, the people in the tail region do not get proper water though late. This water stress has led to use of ground water through bore wells introduction in order to combat water stress (Fig: 25 &26). Paudel et al. (2016) in a research done in Koshi River Basin has found that, an increase in mean temperature at a rate of 0.25 ^{0}C every 10 years between 1971 and 2009 has forced local people to change their cropping patterns such as tea and coffee, and other horticulture and agro-forestry activities, Bastakoti (2010) has found that the transplanting season of rice and maize changed i.e by 15 to 25 days for 75% of farmers due to drought and irregular rainfall in Kavre and Chitwan.

Though climatic variability in the study did not appear as significant reason behind declining water in the canals. The study also shows threats in farming despite of its less contribution to water insufficiency in the canals. Many literatures claim that with the increment in temperature crop metabolism changes.

Many authors agree that changing climate has increased the water demand of many crops. Yano et al. (2007) predicted an increase in water demand for irrigation of wheat in the Mediterranean environment due to decreasing precipitation. Fischer et al. (2006) suggested that with the change in climate irrigation water requirement increases which could be nearly as large as the changes projected from socio-economic development. Silva et al (2007) studied the impacts of climate change on irrigation water requirements in the paddy field of Srilanka and predicted an increase of 13% to 23% of irrigation water demand depending on climate change scenarios.

Similar to the literatures, the findings from the field shows that abandon of an indigenous crop variety ‘Spring rice’ in the region is mainly due to lack of water. Data show that farming is affected due to changing weather conditions like less fog during winter, bright sun after rain and increased pests. People complain that bright sun after rainy days bring more pests and damage the crops. Decreasing fogs also harms the crops as they deficit moisture into the soil. Along with this, the farmers in this region intensively use chemical fertilizers and pesticides to increase the production of crops.

Rosenzweig, C., Iglesias, A., Yang, X. B., Epstein, P. R., & Chivian, E. (2001).explain the expansion of crop weeds, insects, and diseases as a result of changing climate. .rability to infection, pest infestations, and choking weeds. Rosenzweig, C., & Hillel, D. (1995). also discuss that current best estimates of changes in climate indicate an increase in global mean annual temperatures of 1°C by 2025 and 3°C by the end of the next century leads to a number of implications for temperature-dependent insect pests in mid-latitude regions resulting in changes in crop-pest synchrony, changes in interspecific interactions and increased risk of invasion by migrant pests along with other impacts.

In one hand cost in agriculture is increasing and in the other there are climate induced challenges, farmers have no proper solution to cope with this problem. Farmers face problems to sell their produce in their local markets as the market is highly dominated by Indian price and production. Here is an illustration;

Case no. 1:

Mr. Sambhu Baral of Paharipur village which lies in middle region of KIS explains that the local market has high Indian influence. He further explains, 'The rice of Chitwan has good quality assurance and people prefer them; especially the 'Sabitri' brand of rice, but these days the shopkeepers buy same rice from India at low price and sell them with local brand name. This has discouraged farmers like us. We cannot sell the produce at loss as the investment in agriculture has increased due to labor as well as chemical fertilizers and pesticide inputs and neither can we compete.'

The socio-economic aspects has much to do with climate induced resilience and adaptation. Howden, S. M., Soussana, J. F., Tubiello, F. N., Chhetri, N., Dunlop, M., & Meinke, H. (2007) argue that more systemic changes in resource allocation such as targeted diversification of production systems and livelihoods need to be considered as adaptation to changing climate. They also explain that increased adaptation action will necessitate integration of climate change-related issues with other risk factors, such as climate variability and market risk, and with other policy domains, such as sustainable development.

The major interventions for adaptation which requires economic investment are carried by the elite groups whereas it is always the poor who are vulnerable. Vulnerability also exists at inter as well as intra household level in parallel. The place has distinct divisions of work at intra as well as inter household level. (Table: 3). Most of the household works are done by the females who often complain of getting physically tired and find no time to get involved in other occupations. The sad part within this reality is these household works are not valued as other economic works as it does not bring direct money into the family.

The tabular data (Table: 3) is a proof to claim that women have multiple roles and responsibilities than men. Out of total types of works listed, only 2 types of work i.e., ploughing and making ridges are done by only males and other works like going to the mills and milking cattle are some other works which they assist in but the greater share of these works are done by either male or female. In the contrary 3 distinct works like weeding, threshing the grains and transplanting rice are done by females only. The data also suggests that most share of the shared work like Smashing clods, sowing grains, hauling manure, growing vegetables, raising chickens, going to market and shop keeping are done by females. Women don't even realize these activities as work.

For illustration;

When asked to one of the women during FGD about the kind of work she does. She replied this way, "I don't work anywhere. I do nothing."

And when she was asked for who persuaded the household works' she replied; "I do almost all of the kitchen works and also look after the children and in-laws. I also work in the farms."

This clearly shows how our cultural responsibilities have ingrained the belief about the definition of work. It puts researchers like me to question; "Is it only what brings in money, work? If not, when shall people realize the essentials of these works and value them?"

The participation of women in activities besides household works like in management in irrigation also is not satisfactory. The nominal numbers of women included are few to claim a success in equal participation. Information from informal interviews with men and women of the place also directs researchers like me to believe that women involvement in such participation is just to accept the constitutional rule of including 33% of women which in the contrary had to be to value the voice and opinion. Let us put forward the illustrations from 'Kulo Samiti', 'Sakha Samiti' and 'Mul Samiti'. Interestingly, it was found that most women who participate in kulo samiti rarely participate in Sakha samiti but the women who have reached to Sakha samiti have never till date reached to Mul samiti. When searched for the reason it was found that, Mul samiti includes presidents of Sakha samiti as members but women in Sakha samiti were never thought responsible to handle presidency and were always booked for membership posts, a reflection of fulfilling just the constitutional rule.

Zwarteveen, M., & Neupane, N. (1996). During a study in Chhatis Mauja irrigation system found that only male participate in the irrigation management despite women being the main users. The report further explains the emergence of problems of free-riding and labor mobilization in the head end which eventually leads to weak performance. This report also focuses on widespread of these problems threatening the sustainability of irrigation scheme when feminization in agriculture continues.

Now, within these circumstances another element of male migration triggers imbalance in the already unequal gendered roles and responsibilities. Females in one hand have very less technological know-how and processes involved with irrigation and the existing farmers have no rigid solutions to combat or cope with the effects of changing climate. Respondents in the tail region also point towards declining ground water table after the introduction of bore wells. The situation is comparatively less pronounced in head regions. Pest infestations are in other hand adding challenges in farming. These elements of male migration, ignorance of solutions to changing climatic parameters, water insufficiency, changing dimensions; roles and responsibilities of females and their poor state of understanding and handling irrigation issues altogether indicates serious agricultural challenges. These demands a serious stakeholder's attention to actually come up with sustainable measures to address the water problems and its massive agricultural impacts.

CHAPTER VI: CONCLUSION AND RECOMMENDATION

6.1 Conclusion

i. The analysis of climatic variability shows that the annual precipitation in the region is increasing. Pre-monsoon precipitation is increasing every year whereas precipitation in monsoon, post-monsoon and winter is decreasing. The region faces shift in precipitation pattern.

ii. The area shows increasing mean maximum as well as mean minimum temperature which indicates global warming. Similarly, the seasonal mean maximum temperature shows positive trend except winter and mean minimum temperature shows positive trend in all seasons.

iii. The distribution of water in the canal is highly dependent on water availability at the source. The water in the tail region of canal remains scarce during most of the days of the year leading to reducing command areas. There are countable reasons behind water insufficiency at the source, i.e. at Khageri River. The findings point towards Padampur resettlement to be one of the major reasons behind the drastic change in the water volume. Other reasons found were changing climatic conditions and leakage and poor maintenance.

iv. The impact of shifting pattern of precipitation and temperature is clearly seen in different geographical aspects of the canal. Farmers of the head region have shifted their paddy transplantation time from June/July to 2nd week of August as they believe they get irrigation water even if it be weeks later but farmers in tail region have no glimpse of hope to get water from the canal when needed. So, they have introduced pumps and bore wells to cope with this water stress.

v. With the new technological intervention the farming occupations have been found to be modified. The varieties of rice like 'Spring rice' is believed to require more water and people are discouraged to plant this variety. This also indicates change in plant metabolism with change in temperature. Farmers are found to be using chemical fertilizers and pesticides to increase the production and combat pest and diseases. The presence of good market and availability of ground water via bore wells in the tail region have arose vegetable farming as new farm occupation in tail region of the canal.

vi. Irrigation sustainability is highly triggered by feminization in agriculture. The place has more male participation in irrigation management. Females lack proper technological know-how and consider themselves unable to handle the irrigation responsibilities. This could be more inclined due to multiple roles and responsibilities of the female leaving them less spare time to empower.

6.2 Recommendations

The study comes up with two major recommendations;

i. Shift in paddy transplantation time, switch from traditional cultivars to vegetable farming due to climatic variability reflects ripples of change in agriculture. The abandon of rice varieties like 'Spring rice' marks a question of food insecurity in coming days. The increment in mean maximum and minimum temperature along with existing water stress points towards chances of changing plant metabolism. So, this research feels the need of intensive research in plant metabolism with changing climatic parameters to come up with sustainable farming.
ii. With the extensive use of ground water via bore wells in the tail region of the canal, threats in drinking water table has started to emerge. The existing water stress in agriculture in the area despite of having large irrigation system like KIS doubts sustainability of the canal within the premises of feminization in agriculture. There can be however many reasons behind declining ground water besides its extraction. The study feels an urgent need to study recharge rate with extraction rates in parallel and feasibility study of better alternatives to irrigation system like rainwater harvesting, construction of conservation ponds keeping in mind the existing scenario of climatic variability for sustainable agriculture.

References

Adhikari, B. (2003). *Property rights and natural resources: Socio-economic heterogeneity and distributional implications of common property resource management*. SANDEE, Kathmandu, NP.

Adhikari, P. (2013). Conflict- Induced Displacement, Understanding the Causes of Flight. *American Journal of Political Science*, *57*(1), 82-89.

Arora-Jonsson, S. (2011). Virtue and vulnerability: Discourses on women, gender and climate change. *Global Environmental Change*, *21*(2), 744-751.Buijs, B. (2007). China, Copenhagen and Beyond. The Global Necessity of a Sustainable Energy. *Outlook*, 201.

Baldos, U. L. C., & Hertel, T. W. (2014). Global food security in 2050: The role of agricultural productivity and climate change. *Australian Journal of Agricultural and Resource Economics*, *58*(4), 554-570.

Bezabih, M., Chambwera, M., & Stage, J. (2011). Climate change and total factor productivity in the Tanzanian economy. *Climate Policy*, *11*(6), 1289-1302.

Cook, H. J. (2012). *Understanding Philanthropic Motivations of Northeast State Community College Donors* (Doctoral dissertation, East Tennessee State University).

Cline, W. R. (2007). *Global warming and agriculture: Impact estimates by country*. Peterson Institute.

Dahal, N. M. (2009). SchEMS.

Diaz, J. R., Weatherhead, E. K., Knox, J. W., & Camacho, E. (2007). Climate change impacts on irrigation water requirements in the Guadalquivir river basin in Spain. *Regional Environmental Change*, *7*(3), 149-159.

Dinar, A., Rosegrant, M. W., & Meinzen-Dick, R. S. (1997). *Water allocation mechanisms: principles and examples* (No. 1779). World Bank Publications.

Elliott, J., Deryng, D., Müller, C., Frieler, K., Konzmann, M., Gerten, D., ... & Eisner, S. (2014). Constraints and potentials of future irrigation water availability on agricultural production under climate change. *Proceedings of the National Academy of Sciences*, *111*(9), 3239-3244.

Fu, C., Jiang, Z., Guan, Z., He, J., & Xu, Z. (2008). Impacts of Climate Change on Water Resources and Agriculture in China. In *Regional Climate Studies of China* (pp. 447-464). Springer Berlin Heidelberg.

Gautam, U. (2012). Nepal: Food Security, a Localized Institutional Irrigation Perspective on Public Irrigation Systems. *Hydro Nepal: Journal of Water, Energy and Environment*, *11*(1), 95-99.

Ghimire, S. (2005). Women and irrigation in Nepal: Context, issues and prospects.

Kane, S., Reilly, J., & Tobey, J. (1992). An empirical study of the economic effects of climate change on world agriculture. *Climatic change*, *21*(1), 17-35.

Khanal, P. R. (2003). *Engineering participation: the processes and outcomes of irrigation management transfer in the Terai of Nepal* (Vol. 2). Orient Blackswan.

Kumar, A., & Sharma, P. (2013). *Impact of climate variation on agricultural productivity and food security in rural India* (No. 2013-43). Economics Discussion Papers.

Loayza, N. V., Olaberria, E., Rigolini, J., & Christiaensen, L. (2012). Natural disasters and growth: going beyond the averages. *World Development*, *40*(7), 1317-1336.

McKean, M. A. (1992). Success on the commons: a comparative examination of institutions for common property resource management. *Journal of theoretical politics*, *4*(3), 247-281.

Meinzen-Dick, R. (1997). Farmer participation in irrigation–20 years of experience and lessons for the future. *Irrigation and Drainage Systems*, *11*(2), 103-118.

Meinzen-Dick, R. S., Brown, L. R., Feldstein, H. S., & Quisumbing, A. R. (1997). Gender, property rights, and natural resources. *World development*, *25*(8), 1303-1315.

Murray-Rust, D. H., & Svendsen, M. (2001). Performance of locally managed irrigation in Turkey: Gediz case study. *Irrigation and Drainage Systems*, *15*(4), 373-388.

Nayava, J. L. (2010). Impact of climate change on production and productivity: A case study of maize research and development in Nepal. *Journal of Agriculture and Environment*, *11*, 59-69.

Netting, R. M. (1981). *Balancing on an Alp: ecological change and continuity in a Swiss mountain community*. CUP Archive.

Ostrom, E. (2008). Design principles of robust property-rights institutions: what have we learned?.

Parry, M., Rosenzweig, C., & Livermore, M. (2005). Climate change, global food supply and risk of hunger. *Philosophical Transactions of the Royal Society B: Biological Sciences, 360*(1463), 2125-2138.

Participants, P., Colavito, L., & Nepal, I. D. E. Participants of the Conference.

Porter, J. R., Xie, L., Challinor, A. J., Cochrane, K., Howden, S. M., Iqbal, M. M., ... & Travasso, M. I. (2014). *Chapter 7: Food security and food production systems*. Cambridge University Press.

Pradhan, P. (2003). Farmer-Managed Irrigation Systems (FMIS): a mode of water governance. *WaterNepal WaterNepal*, 327.

Pradhan, P., Parajuli, U. N., & Khanal, R. C. (2017). Framework for effectiveness and resilience of small-and medium-scale irrigation systems in Nepal1.Qureshi, M. E., Hanjra, M. A., & Ward, J. (2013). Impact of water scarcity in Australia on global food security in an era of climate change. *Food Policy*, *38*, 136-145.

Regmi, B. R., Morcrette, A., Paudyal, A., Bastakoti, R., & Pradhan, S. (2010). *Participatory tools and techniques for assessing climate change impacts and exploring adaptation options: a community based tool kit for practitioners* (pp. 1-58). Kathmandu: Livelihoods and Forestry Programme.

Renault, D. (2001). Re-engineering irrigation management and system operations. *Agricultural water management*, *47*(3), 211-226.

Rosenzweig, C., Iglesias, A., Yang, X. B., Epstein, P. R., & Chivian, E. (2001). Climate change and extreme weather events; implications for food production, plant diseases, and pests. *Global change & human health*, *2*(2), 90-104.

Saveyn, B., Paroussos, L., & Ciscar, J. C. (2012). Economic analysis of a low carbon path to 2050: A case for China, India and Japan. *Energy Economics*, *34*, S451-S458.

Sam- Amoah, L. K., & Gowing, J. W. (2001). Assessing the performance of irrigation schemes with minimum data on water deliveries. *Irrigation and drainage*, *50*(1), 31-39.

Smithson, P. A. (2002). IPCC, 2001: climate change 2001: the scientific basis. Contribution of Working Group 1 to the Third Assessment Report of the Intergovernmental Panel on Climate Change, edited by JT Houghton, Y. Ding, DJ Griggs, M. Noguer, PJ van der Linden, X. Dai, K. Maskell and CA Johnson (eds). Cambridge University Press, Cambridge, UK, and New York, USA, 2001. No. of pages: 881. Price£ 34.95, US $49.95, ISBN 0- 521- 01495- 6 (paperback).£ 90.00, US $130.00, ISBN 0- 521- 80767- 0 (hardback). *International Journal of Climatology*, *22*(9), 1144-1144.

Stocker, T. (Ed.). (2014). *Climate change 2013: the physical science basis: Working Group I contribution to the Fifth assessment report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

Shukla, A., Joshi, N. R., Shivakoti, G., Poudel, R., & Shrestha, N. (1997). Dynamics in water rights and arbitration on water right conflicts: Cases of farmer managed irrigation systems from East Chitwan. *Water rights, conflict and policy*.

Thapa, S., & Joshi, G. R. (2010). A Ricardian analysis of the climate change impact on Nepalese agriculture.

Webber, H., Gaiser, T., & Ewert, F. (2014). What role can crop models play in supporting climate change adaptation decisions to enhance food security in Sub-Saharan Africa?. *Agricultural Systems*, *127*, 161-177.

Yamin, F., & Depledge, J. (2004). *The international climate change regime: a guide to rules, institutions and procedures*. Cambridge University Press.

Yercan, M. (2003). Management turning-over and participatory management of irrigation schemes: a case study of the Gediz River Basin in Turkey. *Agricultural Water Management*, *62*(3), 205-214.

Zhai, F., Lin, T., & Byambadorj, E. (2009). A general equilibrium analysis of the impact of climate change on agriculture in the People's Republic of China. *Asian Development Review*, *26*(1), 206.

Zwarteveen, M., & Neupane, N. (1996). *Free-riders or victims: women's nonparticipation in irrigation management in Nepal's Chhattis Mauja Irrigation Scheme* (Vol. 7). IWMI.

Appendices

Annex I:

Checklists for FGD

Respondent's information
Name of respondent:
Caste/ethnicity:
Age:
Sex:
Religion:
Position in WUA:

Part I

Water availability in the canal

1. Do you receive irrigation water from KIS? If yes, how long, in which months? If no, why?
2. What problems do you face during irrigation? What might be the reasons?
3. How is the management of irrigation water?
4. How many members are there in WUA?
5. How many members are from the women‘s member?
6. How many are included in terms of Muslim, Dalit, and ethnic groups?
7. How often the women attend the meeting?
8. How often the men attend the meeting?
9. How were you selected?
10. Can the women raise problem and discuss on the specific topic or issue in the meeting who are holding high position? If not why not?
11. Who decides what is to be done?
12. Can women speak freely in the meeting?
13. What are the other roles of women besides putting signature in the paper? Why not other prominent roles?
14. Who goes to the main canal at night for the distribution of water? If only males why not females?
15. Is there practice of offering training to women for the genuine participation?

16. What do you think about training if there is not the practice of offering them training?
17. Is there the practice of stealing water from the canal?
18. How are the conflicts solved?
19. Who resolves the conflict in your village in terms of irrigation?

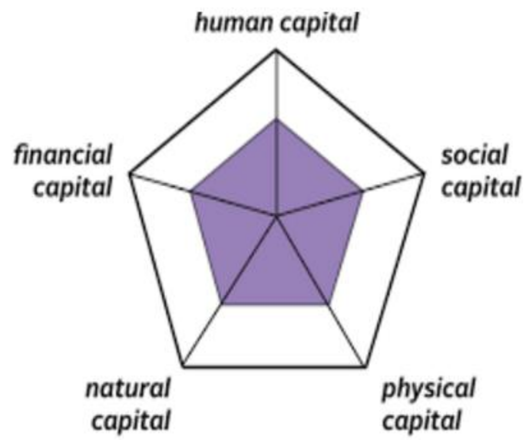
Part II

Changing climate and farming

1. Do you find any changes in the intensity and pattern of precipitation? If yes, since how long?
2. Any experiences of changing weather? What are they?
3. What kind of impacts have you felt?
4. Any changes in farming or any interventions?
5. Why vegetable farming in the tail region and not in the head region?
6. How often do you use chemical fertilizers and pesticides? Why?

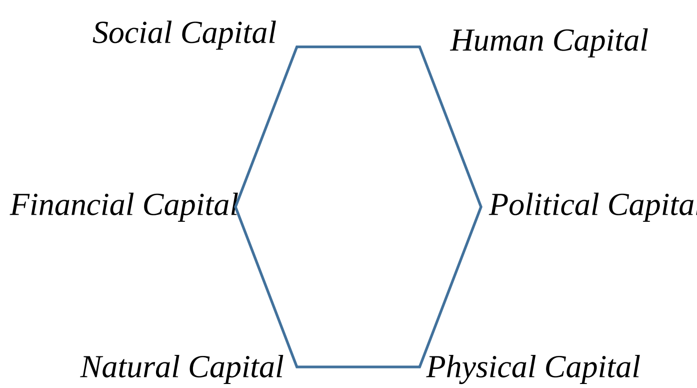
Annex II:

Sustainable livelihood framework, DFID (2000)



Adopted version of ICIMOD

Adopted version of ICIMOD



Annex III:

FGD Dataset

1. ACTIVITY, BENEFIT & INCENTIVE PROFILE

ACTIVITIES	WHO	BENEFITS/INCENTIVES	WHO	REMARKS
PRODUCTIVE				
REPRODUCTIVE (CARE)				
COMMUNITY				

2. RESOURCES ACCESS & CONTROL + BENEFIT & INCENTIVE PROFILE

RESOURCES	ACCESS	BENEFITS/INCENTIVES	CONTROL	BENEFITS/INCENTIVES	REMARKS
NATURAL					
PHYSICAL					
FINANCIAL					

3. INSTITUTIONAL CONSTRAINTS AND BENEFITS

INSTITUTIONS	ACCESS	BENEFITS/INCENTIVES	CONSTRAINTS	REMARKS
FORMAL Governmental Political Religious Developmental Financial				
NON-FORMAL				

Annex III:

CASE STUDIES

Check Lists

Name:

Address

Caste/Ethnicity:

Marital Status:

Level of Education:

Position in the Committee:

1. What is your major occupation?
2. Do you receive water when required in monsoon from the canal? If no, why?
3. Are you satisfied with the ongoing in farming? If not, why?
4. What are your challenges in farming? Why are these so?
5. How is the produce sold? Any problem in market dynamics?
6. What do you do to mitigate the challenges? Any solutions?
7. If you have chosen any adaptive measure, what is the reason to choose that?
8. How often do you use chemical fertilizers and pesticides? How do you use them?
9. Have you received any trainings to use them/related to agriculture?
10. Whose domain is to take the children to the school?
11. Who prepares food, washes clothes and cleans dishes usually? Why?
12. Who assists you especially in the household affair?
13. Who is involved primarily to take care of children and elderly?
14. Do you want say something at the end?

Annex IV:

Checklist for the Activities Analysis

Table-1

Activities	Always by men	Usually by men	Done by either	Usually by women	Always by women
Agricultural Tasks.					
Ploughing					
Making ridges					
Smashing clods					
Irrigating lands					
Sowing grains					
Weeding					
Transplanting paddy					
Threshing grain					
Harvesting rice					
Hauling manure					
Growing vegetables					
Raising chickens					
Going to mills					
Going to markets					
Daily H.H Tasks					
Hauling water					
Cooking food					
Cleaning cookware					
Washing clothes					
Feeding animals					
Milking animals					
Caring for children					
Off-Farm Activities					
Shop keeping and others					

Photo 1: KII, KIS secretary

Photo 2: FGD, Parbatipur


Photo 3: FGD, Shivanagar

Photo 4: Farmer in Parbatipur

Photo 5: FGD Paharipur

Photo 6: FGD, Paharipur