STUDY OF WATER QUALITY, WATER BALANCE AND CLIMATIC CLASSIFICATION FOR IRRIGATION REQUIREMENT FOR SUSTAINABLE STRAWBERRY CULTIVATION IN OKHARPAUWA

A dissertation submitted to the Central Department of Environmental Science
for the partial fulfillment of the requirement of the Degree of
Master's of Science in Environmental Science

Submitted by:
Prava Pandey
Tribhuvan University
February 2009

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LETTER OF RECOMMENDATION

This is to certify that the dissertation entitled "**Study of Water Quality, Water Balance and Climatic Classification for Irrigation Requirement for Sustainable Strawberry Cultivation in Okharpauwa**" submitted by Miss Prava Pandey for the partial fulfillment of requirement on the completion of Master's Degree in Environmental Science was based on the researcher's original research work under my guidance and supervision. This is the best piece of work among those under my guidance. The data presented in this dissertation are original and has not been submitted for any other degrees. I therefore, recommend this dissertation for approval.

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LETTER OF APPROVAL

This dissertation paper entitled "**Study of Water Quality, Water Balance and Climatic Classification for Irrigation Requirement for Sustainable Strawberry Cultivation in Okharpauwa**" submitted by Miss Prava Pandey has been accepted as the partial fulfillment of M. Sc. Degree in Environmental Science.

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Prava Pandey

Date:…………………

ABBREVIATION

ΔS	=	Storage water
AET	=	Actual Evapotranspiration
AFC	=	Assumed Field Capacity
$AgNO_3$	=	Silver Nitrate
C1	=	Low Conductivity Water
C2	=	Medium Conductivity Water
C3	=	High Conductivity Water
Ca	=	Calcium
CBS	=	Central Beuro of Statistics
Cl	=	Chloride
CO_3	=	Carbonate
DHM	=	Department of Hydrology and Meteorology
E	=	East
E	=	Evapotranspiration
EDTA	=	Ethylene Diamine Tetra Acidic Acid
EIA	=	Environmental Impact Assessment
FAO	=	Food and Agriculture Organization
G	=	Subsurface leakage
GPS	=	Global Position System
HCL	=	Hydrochloric Acid
HCO_3	=	Bicarbonate
JAITI	=	Japanese Agricultural In service Training Institute
K	=	Potassium
Km	=	Kilometer
Meq/l	=	Milli Equivalent per Liter
Mg/l	=	Milli gram per Liter
Mg	=	Magnesium
Ml	=	Millilitre
Mm	=	Millimeter
N	=	North
Na%	=	Sodium Percent
Na	=	Sodium

No	=	Number
NO_3-N	=	Nitrate
P	=	Precipitation
PET	=	Potential Evapotranspiration
PO_4	=	Phosphate
R	=	Runoff
RSC	=	Residual Sodium Carbonate
S_1	=	Low Sodium Water
S_2	=	Medium Sodium Water
S_3	=	High Sodium Water
SAR	=	Sodium Absorption Ratio
TDS	=	Total Dissolved Solid
VDC	=	Village Development Committee
WD	=	Water Deficit
WMO	=	World Meteorology Organization
WS	=	Water Surplus

ABSTRACT

This study has been attempted to obtain some important findings which would indeed further enhance the sustainability of strawberry cultivation in Okharpauwa. As such nowadays farmers in the hills are being aware and attracted by cash crops cultivation.

The study area is located in the middle hills about 25 km west of Kathmandu Valley with altitude ranging from 1600m to 1800masl and slope from 25^0 to 60^0 experiencing temperate to subtropical climate. Some natural vegetation still flourish in the surrounding areas and the drainage density of the catchment is favorable for small irrigation schemes for the strawberry farming.

Strawberry cultivation has already been a success in this area and this study has been conducted with the objectives to improve the yield of this important cash crop. First, the major physico-chemical parameter of river water, which has been used as irrigation water to a limited extent by farmers, has been analyzed. Second, water balance study has been conducted to find the water deficit months for strawberry irrigation. Third; climatic classification for the area has been determined suitable for this successfully growing species of strawberry. Lastly, the socio- economic survey was conducted regarding the population, education economic status, marketing of strawberry and the irrigation status. The study has come up with encouraging and interesting result with a few recommendations as summarized below.

Nine parameters relating to quality of irrigation water have been carefully analyzed. These parameters reveal higher values in pre monsoon season than in the post monsoon season, but in both seasons all of the parameters were in the good to excellent category range, thereby indicating no harmful effect on the strawberry farming by such irrigation- water. Water balance study suggested that irrigation is needed for the 6 months with exception from May to October. Irrigation will be essential because strawberry is a shallow rooted plant requiring good drainage with frequent but less amount of water. The climate type of Okharpauwa region is found to be Per- humid with meso thermal. Strawberry farming may be introduced in other parts of the country with this similar climatic classification.

Strawberry farming has indeed uplifted the livelihood conditions of the local farmers, but the poverty and illiteracy have caused problems relating to marketing, farming, irrigation, using the pesticides and chemical fertilizers. The local farms are sloppy and sandy soil and thus will require frequent watering with sprinkler–irrigation, as the source of water is far way from the farms with rugged topography. Installation cost will be the main problem for the local farmers. With the government support, the local farmers can be convinced to switch over in cultivating different cash-crops beneficial from rural, urban to the national levels.

Key words: Irrigation, Water Quality, Water Balance, Climatic Classification, Strawberry.

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CHAPTER – I

1. INTRODUCTION

1.1 Background:

Water is essential for life. Without enough water, normal plant growth is disrupted and plant will gradually wilt and may die. Plants are most susceptible to damage from water deficiency during reproductive stage of growth. Many plants are sensitive to salinity during the germination and seedling stages. Most of the water that enters the plant through the roots gets transpired into the atmosphere. Less than 1% of the water is actually used up in photosynthesis (i.e. assimilated by the plants). The rate at which plant takes up water is controlled by its physical characteristics, the atmospheric and soil environment.

The amount of water consumed by crop can be determined by water balance model. The water budget components in the atmosphere, hydrosphere and lithosphere are precipitation, rainfall intercepted by the vegetations, surface run off, evaporation, transpiration and infiltration through soil layers, deep percolation and water storage in the soil profile. The surface water can be diverted to the forms or can be stored for irrigation.

Irrigation may be defined as the process of artificially supplying water to soil for raising crops. Water as such and also a carrier of large amount of nutrient is required for the growth of the crops. Due to inadequate and uneven distribution of rain-fall during the growth period of crops, it becomes essential to supply additional water in the form of irrigation to the soil for the plant use. (Punima, 1992).

Through water balance study, irrigation needed in crucial month can be determined. Water quality, time of applying water and climatic type are very important factors for the type of cash crop to be cultivated. If these aspects are not known the applied irrigation water could have an adverse effect on the crop yields. Determination of the suitability of land for irrigation requires a thorough evaluation of the soil properties, the topography, climatic type & the quality of water. Understanding of soil/water/plant/climate interactions will help irrigation management for the crop. Nepal is basically an agricultural country and its resources mostly depend on the agricultural output. Cash crops play important role in the economic development of the country. Nepal is under the influence of the sub-continental climatic pattern. It has two distinct seasons: the summer monsoon season and the relatively dry winter season. The summer monsoon season which normally lasts from 15 June to 15 September brings about 70-80 percent of the total annual rainfall. The winter rains account for about 10% of the total annual rainfall (DHM, 1998). Water resources of Nepal dependent on precipitation and accumulated snow in the Himalaya. However, the total rainfall in a particular area may be either insufficient, or ill-timed. In order to get the maximum yield, it is essential to supply the optimum quantity and quality of water and to maintain correct timing of water. This is possible only through detail studies of water quality of irrigation water, timing of irrigation and the type of crop.

Cash crops are generally more sensitive to water stress than agronomic crops such as alfalfa, corn, wheat, sunflower etc. Among cash crops, strawberry fruit is a very sensitive crop to water stress. So the study of water balance, water quality and climatic type for irrigation is conducted here for effective strawberry production in central Nepal.

1.1.1 Quality of Irrigation Water:

The quality of irrigation water is important for long term effect because it will then influence the chemical and physical properties of the soil. The soil quality will also influence the productivity of the crop. Therefore, some of the important physical and chemical properties of irrigation water are necessary to be known to assess its suitability for irrigation. Water used for irrigation can vary greatly in quality depending upon the type and quantity of dissolved salts. Salts are present in irrigation water in relatively small amounts.

They originate from dissolution or weathering of the rocks and soil, including dissolution of lime, gypsum & other soil minerals. These salts are carried by water to wherever it is used. In the case of irrigation, the salts in the water remain behind in the soil as water evaporates or is limitedly used by the crop. In irrigated lands, the hazard of salt water is a constant threat. Poor quality of irrigation water is of concern in arid climatic conditions. Besides affecting crop yield and soil physical conditions, irrigation water quality affects healthy plant growth and longevity. (Ayers and Westcot, 1994).

River plays an important role in agriculture sector and it is indeed an important natural source of irrigation water. Water quality analysis of river is one of the most important issues related to irrigation. Monitoring and assessment of water quality leads to preventive measures against health hazard. The hydro-chemical characteristics of water determine its usefulness for agricultural, municipal, industrial & domestic water supplies. The suitability of river water for agricultural purposes can be determined by evaluating some physicochemical parameters along with some calculated hydro-chemical parameters.

1.1.2 Water Balance:

The closed linkage of events representing the circulation of water in the lithosphere, hydrosphere and atmosphere known as the hydrologic circle forms the basis of the water balance of any region. The term water balance means to account all the water over a region both on annual and seasonal bases, in its various forms and states (Mather et.al, 1978). The surface of the earth receives water from the atmosphere through precipitation and its losses mainly through the process of evapotranspiration and percolation. Some of the percolated water is retained in the soil column to an extent determined by the textual and structural properties and the remaining portion may join the streams by surface and subsurface run off. Water that evaporates from all water bodies and moist land areas as well as that which is transpired by vegetation raises the humidity of the atmosphere and ultimately returns to the earth by precipitation. Thus, as a whole for any region there always exists a balance between the incoming and the out going water.

For continental area, this balance is expressed by the basic hydrologic equation as given below.

$P = E + \Delta S + G + R$..................................... (i)

Where, P is precipitation

E is evapotranspiration

ΔS is the change in water storage on and below the surface of the earth within the region. G is subsurface leakage and R is run off.

If the region under consideration is large and free from unusual geological condition, leakage G can be neglected. Thus, neglecting G, hydrologic equation reduces to,

$P = E + \Delta S + R$...................... (ii)

This equation is known as the water balance equation

Water balance studies reveal that the climatic characteristics of a region cannot be assessed from precipitation alone but only from its quantitative comparison with evaporation and transpiration as seen in the actual evapotranspiration taking place from natural surfaces.

In 1940's, the American climatologist, C.W. Thronthwaite (1948) introduced a water budget book keeping procedure, in which computation involves precipitation, evapotranspiration, soil moisture storage, water deficit, water surplus and run off.

1.1.3 Climatic Classification:

Climate largely defines the global pattern of vegetation distribution, so it sets limits for production of crop and forage, which are the primary bases of today's world food supplies. In general, crops have their optimum climatic conditions for production, although other variable such as soils, relief, pests, market & transportation facility interact to modify the suitability of a particular area for specific type of cultivation.

The daily weather plays a significant role in crop development in early stages and then production in later stage. It is not always possible to perform experiments in soil water for crop but suitable climatic model also helps to determine crop water requirement. There are many agro-climatic models that determine climatic type of region. The model range from simple to highly sophisticated metrological data based model. Some climatic classification such as Thronthwaite climatic classification and Koppen’s climatic classification are widely used.

In 1948, Thonthwaite proposed on a basis for climatic classification the concept of potential evapotranspiration. He regarded potential evapotranspiration as a climatic factor as equal in importance to precipitation. (Critchfield, 1987).

Potential evapotranspiration represents a transfer of both heat and moisture to the atmosphere and is primarily a function of energy received from the sun. It is an index of thermal efficiency as well as water loss and so combines both the moisture and heat factors in climate. Thronthwaite used the indices of humidity or aridity for indicating the seasonal variation on moisture of climate and sub-climate. The thermal efficiency is used for indicating the seasonal variation on thermal regime of climate and sub-climate.

1.1.4 Strawberry Fruit:

The strawberry is one of the most popular soft fruits in the world. The cultivated strawberry (*Fragaria ananssa*) is a newly introduced temperate fruit crop in Nepal. It originated in the eighteenth century from North and South America. (Crystal, 2000)

The fruits are very attractive, luscious, tasty and nutritious with distinct and pleasant aroma and with delicate flavour. They are cone- shaped, red and rich in vitamin C and iron. So it is a highly beneficial fruit for anaemia patients and also for uric acid patients (Bose et.al 1993).Strawberry is simply eaten as fresh fruits. Besides this it is also used for making jam, jelly and soft wine. It is also used in cold cream, ice cream, chewing gum and chocolate flavour.

In Nepal, the cultivation of strawberries started from 2048 B.S., when JAITI Nepal was established at Kakani. Strawberries were brought over from Japan. Since then, farmers in the neighbouring area have started to cultivate strawberry. Nowadays, strawberry farming is fostering over Kakani, Nuwakot, Daman, Makwanpur, Nagarkot, Bhaktapur, Dhading, Lumale and Kaski area (Dhimal, 2002). The cultivation of this fruit has been adopted to improve the economic status of local people in these areas. However in Nepal, the cultivation of this fruit is limited to certain research farms run by private sector and government. Thus, looking at its presents demand, cultivation needs to expand to meet the potential domestic need and the increasing export trend.

However, it is to be noted that the cultivation started without a detailed study of environmental suitability for strawberry growth. To improve the strawberry farming and its future promotion, the study on irrigation water, soil type, economic value and climatic type for suitable for strawberry is required and has been attempted here.

1.1.4.1 Strawberry Cultivation in Okharpauwa:

Strawberry farming is successfully cultivated in Khani gaun of ward no.2, Kaulethana and Kaule gaun of ward no.3, Kule gaun of ward no.5, and Chitre and Hilebhete gaun of wards no. 6 of Okharpauwa VDC.

Strawberries will grow bigger and juicier if the plants are given appropriate amount of water. The soil should be kept moist. The farms are to be well drained with raised rows (Photo Plate-1). Water is to be applied regularly, so soils do not become dry. Strawberry is a shallow rooted plant and the roots are found within 15-25 cm of soil surface. The plant thus requires more frequent but less amount of water in each time of irrigation. Strawberries grown on sandy soil require more frequent irrigation than when grown on heavier soils. Thus Sprinkler irrigation system is most suitable (Photo Plate-2).

Photo Plate 1: Strawberry Farm with Raised Row in Okharpauwa

Plant with new shoots should be 12-15 inches apart. New shoots should be allowed to develop and grow from runners about six inches or so from the mother plant to fill in the rows. Once the plant is well established, the farmland can produce fruits for three to four years. In the fourth year, a new area should be prepared to transplant the new shoots for the off runners. The farmers in Okharpauwa have applied this type of farming technique.

Mulch is an important precautionary measure for strawberry, providing shelter from frost, hail and predecessor like bird and animals. Three important benefits from mulches are first, it helps to keep weeds down. Strawberries will tolerate some crowding, but a weed free patch will produce the biggest and the most berries. Second, Mulch will help to retain soil moisture so that the plants can produce big, juicy berries.

Third, berries need to be kept off the ground with help of mulch else they rot easily.

Photo Plate 2: Sprinkler Irrigation Systems Applied in Strawberry Farm in Okharpauwa

The most common type of mulch used by farmers is straw, arranged thickly around the plants in between rows. However other types of mulches can work too. Farmers used plastic to keep weeds down and temperatures up.

A variety of insects and diseases will affect strawberries. On the insect front, aphids, slugs and spider mites are the common pests. In terms of diseases, strawberries fall victim to fungus leading to rotting and wilting.

Insecticides and fungicides are being applied before fruits set in. Farmers are using organic insect repellents like insecticidal soaps. Disease problems are minimized by keeping the patch well weeded and less overcrowded to promote better air circulation.

1.2 Justification/Rationale of the Study

Nepal is an agricultural country because climatic and environmental conditions favor most of the agricultural activities. The environmental conditions of Nepal permit the growth of many kinds of horticultural crops, which can contribute in improving the livelihood of the people as well as to the economic development of the nation.

Since Nepal's economy is mostly based on agriculture, introduction of new scientific technology and their implementation is essential for the production of crop yield. Almost 80% of the total populations are involved in agricultural, but only 16% of the agricultural land in the country process the facility of irrigation. In dry season due to limited source of water farmers are not able to cultivate. In this modern era irrigation from limited source is possible, which needs scientific study on irrigation water quality, water balance, climatic type of the area. From these studies some important finding will indeed help farmers in crop cultivation. Only a few researchers have conducted study in strawberry farming. There is lack of data for irrigation requirement for strawberry farming that will improve the yield and quality of fruit in the country. Thus this research is focused on elements of irrigation needed for effective strawberry cultivation with identification of climatic type necessary for strawberry farm in Nepal.

Strawberry farming is recently emerging as a high value cash crop in Nepal. Strawberry fruit is highly sensitive and delicate cash crop dependent on the environmental conditions of the farming area. For the strawberry cultivation farmers should be careful about soil, irrigation system, water quality, climatic type, time of irrigation of the area. Without knowing these, farmers cannot get better yield. In particular, strawberry plant is sensitive to water stress. So, the timing of applying water, water quality, water quantity, water surplus, water deficit and climatic type needed for the strawberry should be known to get better harvest.

To get the better yield and improve the quality of the fruit, detailed study of climatic condition, irrigation requirements and other environmental factors are to be explored. Thus this study is focused on all of these aspects. Applying the water in proper time and technique of irrigation will indeed help to increase the yield of strawberry fruit. The water quality analysis will indicate the suitability of water for irrigation. The water balance analysis will reveal the water surplus and deficit months so that recommendations can be made for providing water for the crop. The determination of climatic type and study of water balance for the Okharpauwa areas have been attempted. Such climatic classification is useful for recommending such crop farming in different parts of Nepal with similar climatic type. The Okharpuwa has been selected for the study because it has already been established strawberry farming and easily accessible from Kathmandu.

1.3 Objectives:

General Objective:

The general objective of this study was to study water quality, water balance and climatic classification for irrigation requirement for sustainable strawberry cultivation in Okharpauwa.

Specific Objectives:

The specific objectives of present investigation were as follows:

- to analyze the seasonal variation of quality of irrigation water from the streams used in strawberry farming.
- to study the water balance of Kakani station near Okharpauwa.
- to find Throinthwaite climatic classification of Kakani station near Okharpauwa.
- to look into socio- economic conditions of strawberry farmers of Okharpauwa.

1.4 Limitations of the Study:

1. Okharpauwa VDC of Nuwakot District has been taken as the pilot study area for the strawberry cultivation and the findings may not be applicable to the other distant regions of Nepal.
2. Due to the scattered farms detail study could not be executed in all of them as wished.
3. Only limited work was carried out on account of limited time period for study.

1.5 Study Area:

1.5.1 Location:

Okharpauwa VDC lies in Nuwakot district. This VDC (Fig 1) lies in the southern part of the district. It is located between 27° 46' 20" N to 27° 49' 07" N Latitudes and 83° 13' 34" E to 85° 16' 23" East longitudes with an elevation range of 1200 to 2200 m from the mean sea level. It is bounded by Jitpurphedi VDC in the east, Chauthe VDC in west, Kakani VDC in north & Chhatre deurali VDC in south. It is about 25 kilometers away from Kathmandu valley. The site has the largest cultivated area of strawberry farming at about 1600-1800 m above sea level with south facing slope ranging between 25^0 and 60^0.

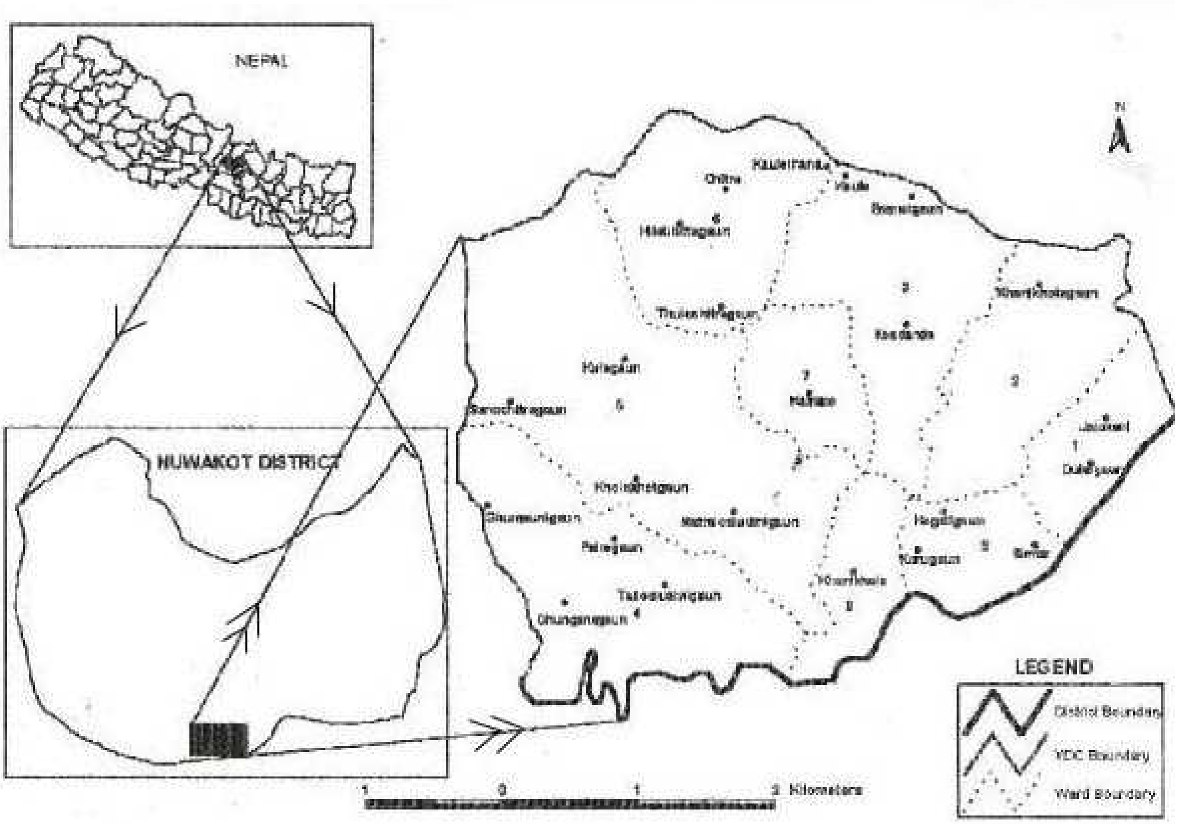

Figure 1: Location Map of Okharpauwa Village Development Committee

1.5.2 Climate:

Okharpauwa falls in the sub tropical climatic and temperate region and is dominated by warm summer monsoon climate. The monsoon begins from early June and continues until early September bringing nearly 80% of the rain-fall which plays a key role in the water & moisture supply for strawberry plant. Isolated thunder storms occur in May and October. The mean monthly average rainfall (Fig. 2) in Kakani station is about 447 mm and mean monthly average temperature (Fig. 3) is about 28.35^0C (DHM 1987-2006). Except for scattered precipitation during the month of December and February, the weather is almost dry in these months. This scattered rain occurs due to the influence of western disturbances.

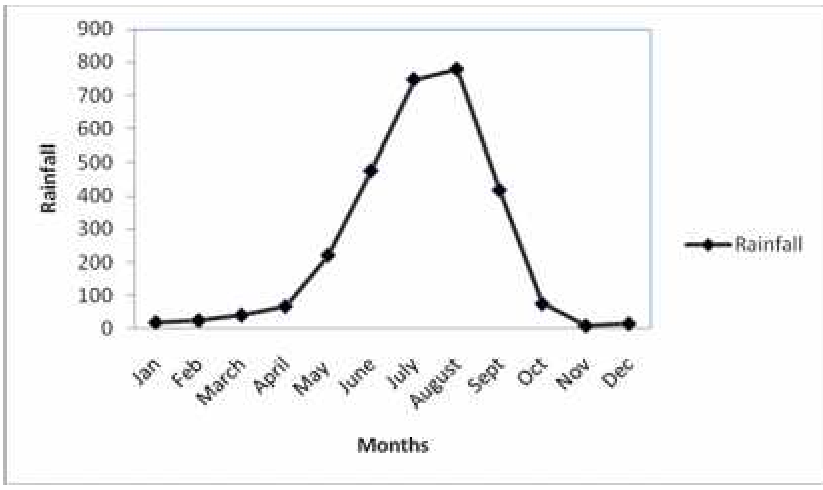

Figure 2: Mean Monthly Rainfall in Kakani Station

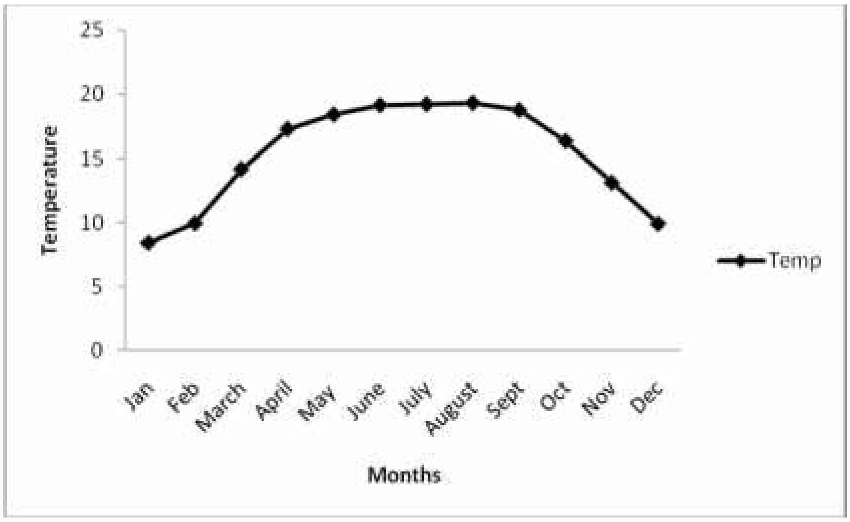

Figure 3: Mean Monthly Temperature in Kakani Station

1.5.3 Water Resources:

Okharpauwa VDC is rich in water resources. Two big rivers such as Kolpu khola and Bachhbichhe khola with their tributaries are the main source of water in the VDC. Among small streams, Kule khola, Chitre khola, Kaule khola and Khani khola and their tributaries are the main water resources contributing to irrigation for strawberry farming. Water used in irrigation accounts for about 80% of the total water applied for strawberry. All the water resources in the study area are not contaminated or diverted.

1.5.4 Natural Vegetation:

This VDC is rich in natural vegetation. The forest of Luchhe hill and patches of small forest nearby with similar vegetation are the main natural resource found in the VDC.

Temperature deciduous vegetation is found in the middle and upper parts of the Luchee hill. *Pinus wallichi* (Salla), *Juniperus indica* (Dhupi), *Alnus nepalenses* (Utis), *Myrica esculenta* (Kafal), *Fiscus bengalensis* (Bar) and Fiscus *religiosa* (Pipal) are the main species of the middle and the upper parts of the hill forest. The site is located in the low-land of the basin, where altitude is above 1100m with subtropical evergreen vegetation. *Shorea robusta* (Sal), *Syzygium cymini* (Jamun), *Fiscus bengalensis* (Bar), *Fiscus religiosa* (Pipal), *Bauhinia purpurea* (Tanki), *Bauhinia variegata* (Koirala) and *Albizia lebbek* (Sirish) are the main species of the vegetation of the study area.

1.5.5 Soil:

The study area consists mostly of loamy textured soil. The water holding capacity of the soil is poor and the lands are south slopping. Such types of soils have low plant nutrients but are productive with irrigation and addition of organic manure as well as fertilizer.

1.5.6 Geology:

Boulder, gravel, pebble sand etc are the important geological resources. Huge amount of these resources are found in the banks of Kolpu khola, Bachhbichhe khola and their tributaries. All of these minerals are found in the streams that irrigate strawberry farming.

1.5.7 Socio-Economic Pattern:

Okharpauwa VDC covers nine important wards.Among them, strawberry farming is successfully grown in number 2, 3, 5 and 6 wards of the VDC. This VDC consist of 1274 households and the population is about 7277 which consist of 3700 males and 3577 females (CBS, 2001). The caste groups of this VDC are Tamangs, Brahmins, Newars and ethic groups (Nepal, 2004). Agriculture is their main source of economy. Mainly paddy, millet, wheat, cabbage, cauliflower and radish are the major crops cultivated in the area. Nowadays, people are interested in strawberry farming and they are successfully cultivating the cash crop.

CHAPTER – II

2. LITERATURE REVIEW:

2.1 Irrigation:

Lowery and Johnson (1942) determined consumptive use for many different crops for irrigated lands and for humid watershed. They correlated consumptive use with maximum temperature during growing period for crop.

Abidi and Tilestone (1990) published a bulletin on the irrigation requirement for some major crops. They estimated the irrigation requirement using the Blanely and Criddle formula applicable for cash crops like maize, potato tomato tobacco and sugarcane.

Adhikari (1991) published a training manual for applied irrigation in Nepal. He reported that for effective agriculture production, irrigation is essential. Before applying the irrigation on field, it is important to know water quality, water balance, feasibility of irrigation system and method of irrigation. It is essential that before applying irrigation, climatic type that affects the water balance for an area should be determined to apply irrigation with suitable technique.

FAO (1998) published a report which includes the procedure to estimate evapotranspiraton by Penman method and evaporation by evaporation pan method and radiation method. These procedures were applied in Cairo and it was concluded that irrigation would be the solution to increase and sustain food production in the face of rapid population growth. Effective crop production under irrigation would also require adequate management of soil and water.

Eitzinger (2001) gave the computational methods for calculating potential evapotranspiration (PET). These are very simple methods (more empirically based), requiring only information on monthly average temperature to complex methods (more physically based) requiring daily data on maximum and minimum temperature, solar radiation, humidity, wind speed as well as the characteristics of the vegetation and soil. He added that water balance of soil system was essential for the determination of water applied on the particular crop and soil.

2.2 Irrigation Water Quality:

Not much experiments and researches have been conducted on irrigation water quality in Nepal.

Garg (2002) noted some parameters that indicate the analysis of irrigation water quality is essential for the high crop production. He mentioned that electronic conductivity and sodium absorption ratio are the major parameters to classify the water for irrigation and concluded that C1, C2, C3 represent the progressively increasing hazards from salt concentration in the irrigation water. Similarly, S1, S2 and S3 represent the progressively increasing hazards due to exchangeable sodium in irrigation water. If these are hazardous such irrigation water should be stopped or treatment of water should be done before applying it on the field.

Sundaray et. al (2008) investigated the Environmental Studies on River Water Quality with Reference to Suitability for Agricultural Purpose of Mahanadi River India. They analyzed the water parameters such as pH, electrical conductivity hardness, Ca &Mg hardness, Sodium, Potassium, Alkalinity, SAR, RSC, Na % etc. to assess the quality of water for agricultural purposes and he verified the result & concluded that the study area were in the "Excellent to good" category and were suitable to irrigate all soils for semi tolerant crop and tolerant crop.

2.3 Water Balance:

Aryal (1995) selected 48 climatic stations of Nepal and used Thornthwaite's water balance procedure. He concluded that water potential of Nepal is about 154.7 billion cubic meters which is agreeable to actual value.

Dhakal (1996) has attempted water balance in Nepal by imposing evapotranspiration estimated from Throinthwaite method and drew his conclusion that parameters of water balance can be applied for the planning in agriculture and irrigation.

Pokheral (2000) applied the Throinthwaite method for determining the parameters of water balance and climatic classification. He found that parameters of water balance of Kakani station was 2741mm precipitation, 734mm potential evapotranspiration, 727mm actual evapotranspiration, 7mm water deficiency and 2014mm surplus water. The precipitation and potential evapotranspiration are highest in monsoon season and lowest in winter & pre monsoon seasons. So water deficiency occurs in pre monsoon & winter seasons and water surplus is in monsoon season.

2.4 Climatic Classification:

Critchfield(1987) gave Throinthwaite climatic classification based on potential evapotranspration with water balance procedure and later Throinthwaite climatic classification also was extended based on aridity index, thermal index, moisture index and summer thermal concentration for climatic classification of the region.

Maharjan (1992) classified the climate of Nepal by Koppen's climate classification method and found that Kakani station has Cwb climate type which indicated that warm temperate climate having dry winter season with average temperature of the warmest month less than 22^0 C. This climatic type had warm moist summer and mild winter which was favorable for agriculture activities.

Pokherel (2000) found that moisture regime and thermal regime of Kakani station is Per humid meso thermal with no or little water deficiency with summer thermal concentration of fourth type symbolically represent as AB'_2ra_4.

Baniya (2005) found that climate of Gulmi could be classified as humid climate according to WMO classification and humid meso thermal climate according to Throinthwaite method which was good for coffee plantation.

2.5 Strawberry Cultivation and Other Cash Crops:

Not much experiments and studies have been conducted on water quality, water balance, climate classification in Nepal to determine the irrigation water requirements to achieve high yield for different cash crops. From literature review, most of the agro or water based researches in Nepal have used simple formulae and methods to determine the irrigation water requirements for different crop.

JAITI (1987) was the pioneer in introducing strawberry cultivation as a high value cash crop in Nepal. This organization launched the strawberry farming at Kakani. They conducted studies on the soil, climate and irrigation facility in experimental plots and found out that the climate and soil of this area were very suitable for strawberry farming. However they indicated that there was problem in irrigation facility. They recommended that sprinkler irrigation was the most effective for strawberry cultivation.

Bose et. al (1993) has given detail of all the essential conditions such as climate, day length, temperature, soil, planting, fertilization, pesticide, mulching and irrigation required for strawberry. He mainly mentioned that strawberry was a shallow rooted plant and the roots are found within 15-25 cm of top soil. The plants thus required more frequent but less amount of water in each time of irrigation. Strawberries grown on sandy soil require more frequent irrigation than when grown on heavier soils.

Kaini (1995) reported on the irrigation management for strawberry farming and concluded that for the best production of strawberry, attention was needed in irrigation. For the irrigation management attention in soil, climate and water quality were required.

Farhan et. al (1997) concluded that even under "normal" conditions, irrigation was necessary for strawberries because they had shallow root systems and exhibited sensitivity to water stress. Only 5 days after a soaking rain, strawberries would require irrigation. Strawberry yields with supplemental irrigation were often 40 to 60% greater than when no additional irrigation was provided. He added that in strawberries, a critical stage of growth was the establishment period of the transplants. For about two weeks, newly set transplants were even susceptible to mild water stress. This vulnerability was mainly because plants had not developed good fibrous root system with fine root hairs for water absorption. Researchers achieved the maximum yield when soil moisture was kept above 65% of field capacity in the top 60 cm of the soil.

Shrestha, (1998) concluded that pest management on strawberry by application of plants extract were highly effective especially during April- May and September – October. During her study, she found that the most important pest in strawberry was *Haltica coerula* and the extract of pesticides *Zanthoxylum acanthopodium* and *Artemia vulgaris* showed the most significant difference between the pest before and after spray at both concentrations.

Shrestha (1999) reported on coffee plantation in Nepal. He concluded that coffee plantation was a high value cash crop in hilly regions. In dry summer season irrigation was essential twice a month for the coffee plant. For recently planted plants, fertilizer and irrigation were essential. From his report it is concluded that application of irrigation water depended on quality of soil, climate and the variety of coffee.

Baral (2001) reported about the strawberry farming in Kakani. He wrote in general on the soil, climate, plantation, fertilizers, irrigation, slope, sunshine etc essential for strawberry fruit. He mainly mentioned that farmers should be aware of irrigation system for the better yield of fruit. He continued that for better production of strawberry fruit, micro irrigation or sprinkler irrigation was most essential in Nepal. However no experimental results were mentioned about the irrigation water for the fruit.

Khanal (2001) reported on Avocado plant in Nepal. He found that avocado was essentially a horticultural crop. The fruit was highly nutritious. The fruit tasted like a cheese or butter while eating, so in Nepali it was also called butter fruit. He mainly focused on irrigation applied to avocado plant and concluded that sprinkler irrigation is better than surface irrigation for avocado farming because the fruit needed frequently and little water. He added that before irrigation the farmers should know about the climate, soil, varieties of crop and water quality to get high yield. In his experiment he found that in loamy soil between 20 and 30 ^{0}c water should be applied after 21 days of plantation which increases the quality and quantity of fruit.

Thapa (2001) analyzed the effect of irrigation on oil-seed crops like mustard, sunflower etc. He found that in Nepal, crops solely dependent on precipitation with irrigation facility in appropriate time the size of mustard seed enlarge.

Dhimal (2002) focused on irrigation applied on strawberry and found that for the strawberry plant, the farm should be wet but with good drainage. Water should be applied in the flowering and fruiting periods. The sprinkler system should be applied for irrigation and he also recommended that detail study about the climatic type, soil type, and water crop relation-ship should be carefully looked into.

Nepal (2004) studied the livelihood, problem and prospector of strawberry farming in Okharpauwa VDC. He surveyed 222 households that cultivated the strawberry fruit. From survey he also found that irrigation was essential for growing strawberry. Irrigation facility was the main problem for strawberry plant in this area. He added that due to this reason the farmers did not profit in spite of their high investment. He stressed that government had not been able to manage for the irrigation facility. There have been no irrigation projects and researches conducted in this area.

Shrestha, (2004) studied in laboratory for the effective irrigation for crop in Tribhuvan University. The study concluded that the irrigation was essential to plant growth. Without enough water normal plant growth was disturbed, plants gradually wilted to death. Many plants and crops were sensitive to saline soil during their germination and seedling growth stages. The rate at which plants took up water was controlled by physical, chemical, atmospheric and soil environmental conditions.

Gotame (2006) analyzed the effect of organic sources of fertilization on quality of strawberry fruit in the mid hills of Nepal. He noted the plant in experimental plates of $3.3m^2$ for the crop period. He found that application of chicken manure and oil cake may become one of the options for organic fertilizer to produce strawberry in Nepal. In his experiment, he noted that irrigation water and climate of the study area would affect the production of strawberry farming.

Pokherel (2007) analyzed on irrigation for banana farming. He mentioned that banana was a high valued cash crop in the Terai region and that banana plant needed more water than other crops. Therefore in dry summer season farmers should be engaged in irrigation. For applying water in hilly region sprinkler irrigation is the most effective. However for terai region surface irrigation is the most effective than sprinkler irrigation because of the variation in topography. He added that for dry summer season water should be applied in interval between 3 to 4 weeks so that the farmers would get fruit full result.

CHAPTER – III

Methodology and Data:

3. METHODOLOGY:

Research is a non-interventional study and is descriptive scientifically. The data collection process includes on-site data collection, laboratory analysis and relevant secondary data acquisition as well. Simple random sampling technique has been applied for sampling. For the collection of baseline information for this research in Okharpauwa, the area was visited from 13 to 15 February 2008 and more information was collected by consulting the related experts, local people, literatures and map of the research area. For the detail research work sampling was done in two consecutive seasons: early summer (pre-monsoon) in March, 2008 and in October, 2008 (Post -monsoon). The values obtained from the experiment were pooled together so as to worked out the mean which represented the irrigation water quality of the study area.

For the study of water balance and climatic type of the study area, 34 years (1962-1996) climatic data of Kakani meteorological station were obtained from DHM Thronthwaite methods for water balance and climatic classification of the study area were adopted keeping in view of the data available.

The social survey so employed was related to simple random sampling technique and the sample size chosen was approximately 10 % of the total households (Fig 4). The questionnaire survey was carried out immediately after the post-harvest of the strawberry in the strawberry farmlands in the month of November 2008.

3.1 Place and Duration of Study:

The study area (Fig 4) is located about 25 kms away from Kathmandu valley (Fig 1).The farms were located in the topographic map and cross-checked by reconnaissance survey on March, 2008. The study was carried out for about ten months which involved observation for two seasons in pre monsoon (March) and post monsoon (October) relating to irrigation water quality and house hold survey after harvest of strawberry in November and December.

3.2 Sampling Sites:

3.2.1 Socio –Economic Sampling Sites for the Study Area:

The study area is situated about 25 kms west away from Kathmandu in the west. The core study area is located in strawberry producer community (Fig. 4) and the area of strawberry farmland of Okharpauwa VDC (Fig. 5).

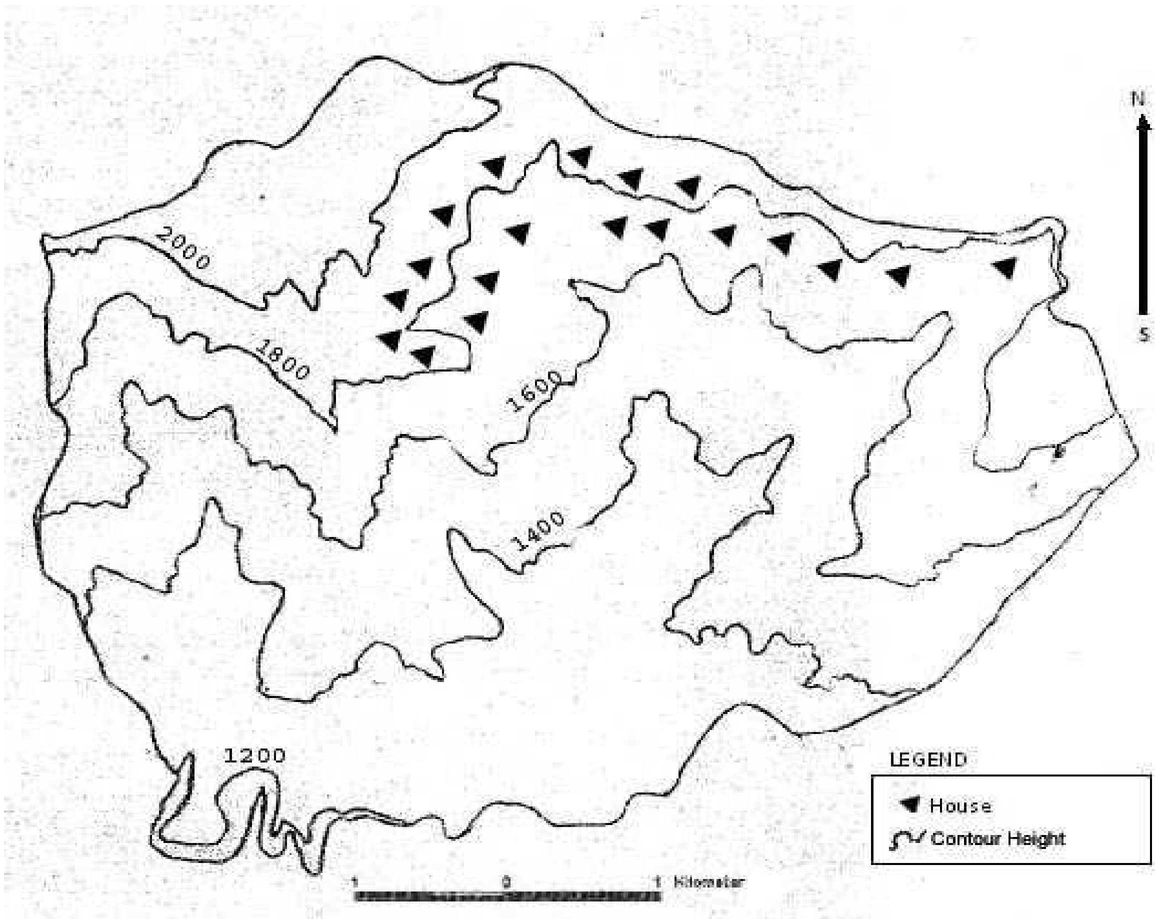

Figure 4: Location map of Strawberry Producing Households in Okharpauwa VDC

3.2.2 Water Sampling Sites:

Four different strawberry farm sites were selected. These sites (Fig. 5) were selected on the basis on highly used irrigation water.

***Site 1**:*

Site 1 is located in Kule gaun and the farms are irrigated from Kule khola. It is surrounded by hills which are covered by forest of Lucche dada in north. Kule stream separates ward no.5 and no.6 of the Okharpauwa VDC. The samples of water in the site were taken within $27^0$48'00"N to

$27^0$48'09"N latitudes and $85^0$13'34"E to $85^0$13'41"E longitudes at elevation between 1600m to 1750m above sea level. This area had minimum human interference.

Site 2:

Site 2 lies in the Thulo chitre and Hilebhitta gaun. Chitre khola provided the irrigation for the farms in this site. The samples of water in the site were taken within $27^0$48'15"N to 27^0 48'54"N latitudes and $85^0$14'02"E to $85^0$14'11"E longitudes at elevation between 1730m to 1800m above sea level.

Site 3:

Site 3 has farms that lie in Kaulethana and Kaule gaun. Kaule khola is used for irrigation purpose. The samples of water in the site were taken from $27^0$48'35"N to 27^0 48'43"N latitudes and $85^0$15'10"E to $85^0$15'17"E longitudes at the height between 1680m to 1770m above sea level.

Site 4:

Site 4 consists of farms in Khanigaun. Khani khola is used for irrigation facility. This stream flows along the side of the high way road of Kathmandu to Nuwakot. Therefore the farms in this site were having maximum human interference as comparison to others sites of the study area. The samples of water in the site were taken from $27^0$48'30"N to $27^0$48'50"N latitudes and $85^0$16'14"E to $85^0$16'35"E longitudes at the height between 1640m to 1730m above sea level.

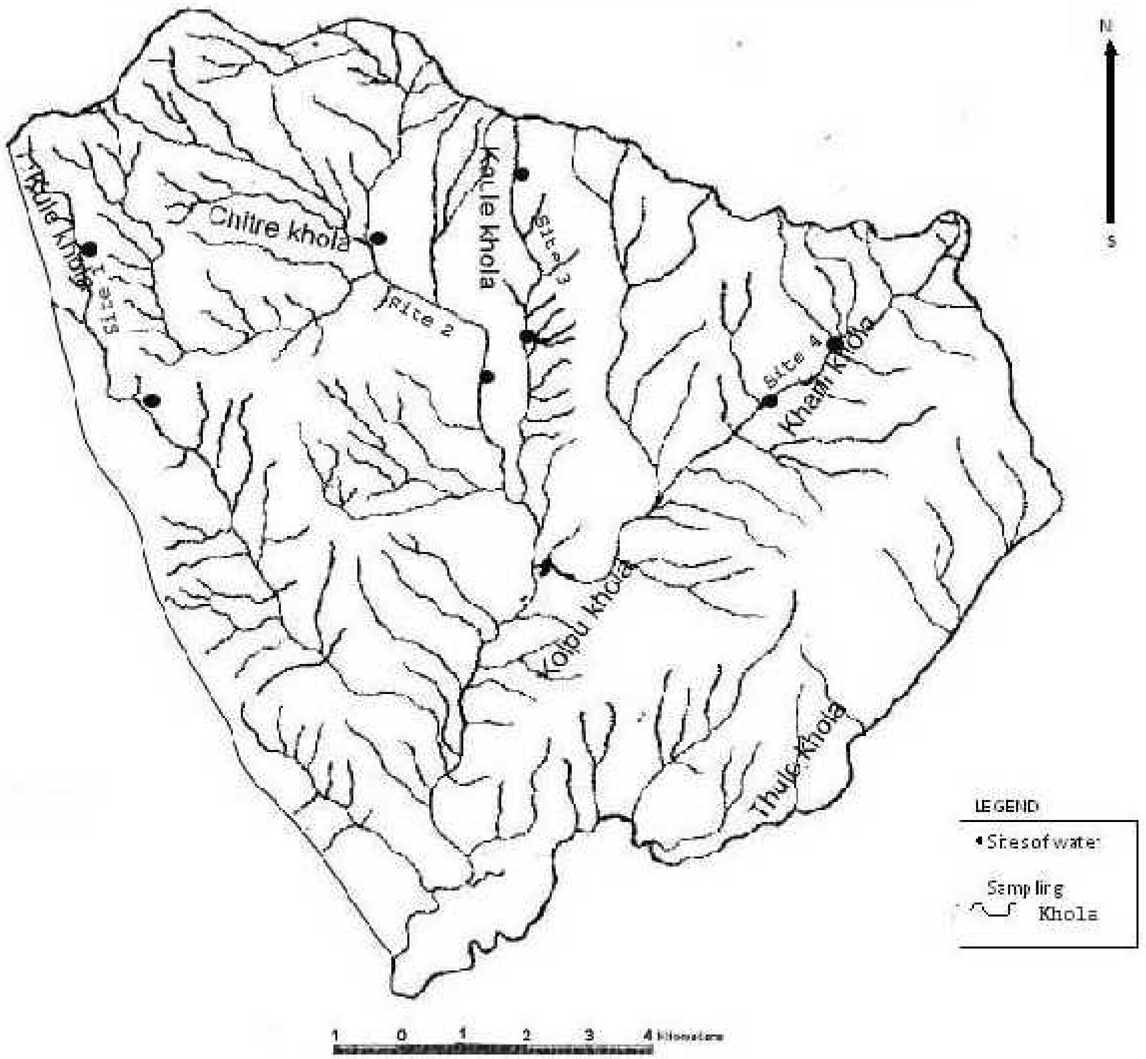

Figure 5: Water Sampling Sites of the Streams of Okharpauwa VDC

3.3 Sources of Data:

Data required for this study were acquired from different sources. The primary data were collected directly by interaction with the concerned people, field observation, standard laboratory experimental data and the secondary data were collected from the literatures, authenticated documents etc. The secondary data were supposed to facilitate the scientific study by availing the necessary information, not exactly covered in field.

3.3.1 Primary Sources:

3.3.1.1 Key informants' interview:

Informal interviews were made with the identified key informants namely senior citizens, local renowned people, farmers, heads of local organizations etc.

3.3.1.2 Questionnaire Survey:

Structured questionnaires were prepared so as to reinforce the scientific outcomes of the study and also to cross-check scientific results that are supposed to highlight on socio-economic aspects and farmers' opinion on the research.

3.3.1.3 GPS and Compass records:

The data recorded by GPS served to provide basic information in the field regarding location co-ordinates; altitude etc and Brunton compass measured the slope gradients.

3.4 For Irrigation Water Quality:

3.4.1 Water Sampling:

Water samples were collected from two sites along the course of each stream namely Kule Khola, chitre khola, Kaule Khola and Khani khola of the Okharpauwa VDC /Nuwakot district. Pipes from these steams are used to irrigate the strawberry farms (Figure 5). Field visits were made during two season's viz., Pre-monsoon in the month of March, and post- monsoon on the month of October in 2008. In each season; sampling was carried out from the water surface of two sites of each stream. Plastic bottles of different sizes (500/1000ml) were used to collect the water samples. These sampling bottles were first rinsed with respective water samples and then filled air tight. The onboard measurements of PH and conductivity were carried out immediately after the collection of samples in the field. Other parameters such as Total Dissolve Solids (TDS), Chloride (Cl), nitrate (NO_3-N), Hardness, Alkalinity, Sodium (Na), Potassium (K), Calcium (Ca) and Magnesium (Mg) were analyzed following standard guidelines and procedures (APHA et. al 1998, Vogel 1961) in laboratory. Each analysis was done in triplicate and the mean value was taken. The analytical data quality was ensured through careful standardization, procedural blank measurement and duplicate samples.

3.4.2 Procedures for the Analysis of Irrigation Water Parameters:

For irrigation water quality analysis, salt content such as chloride, Calcium magnesium hardness are estimated by meq/l which is obtained by dividing value in mg/l by the equivalent weight of the required salt. (Misra et. al.,1987).

3.4.2.1 pH

The pH of water was recorded by a portable pH meter. The probe of which was dipped in beaker with half filled sample water. The displayed reading was noted down.

3.4.2.2 Conductivity

Conductivity of water was recorded with a conductivity meter. The probe of conductivity meter was dipped in sample water and the displayed reading was noted down.

3.4.2.3 Total Dissolved Solids:

50 ml of water sample was taken and filtered using whatmann's filter paper number 42 of known weight. The filtrate was poured into a dry porcelain basin of known weight and was dried in the oven at 105^{0}C. After drying; it was put into desiccators for cooling and then weighed. This gave the weight of total dissolved solids present in the given water sample.

Total dissolved Solids was calculation by formula as:

$$\text{TDS (mg/l)} = \frac{A - B \times 1000 \times 1000}{V}$$

Where, A=Final weight of the dish in g

B= Initial weight of the dish in g

V= Volume of sample taken in ml

3.4.2.4 Chloride

Chloride in water sample was determined by titrimetric method. It was done by titrating 50ml of sample containing 4-5 drops of potassium chromate with 0.02N silver nitrate solution. The yellow colour produce by indicator was converted to brick red at the end point. Concurrent readings were noted for all samples.

Chloride was calculated by the formula as:

$$\text{Chloride (mg/lit)} = \frac{\text{ml x N of } AgNO_3 \text{ x 35.5 x 100}}{\text{Volume of sample taken}}$$

3.4.2.5 Total Hardness

Total hardness in water was determined by titrimetric method. 50 ml of sample water was taken in a clean conical flask and added 1ml of buffer solution and pinch of Erichrome black T indicator in it. The content was shaken well and titrated with standard EDTA solution until the wine red colour of solution turned blue. Concurrent readings were noted for all samples.

Total hardness was calculated by using formula as:

$$\textbf{Total hardness (mg/l) as } CaCO_3 = \frac{\text{ml of EDTA used x 1000}}{\text{Volume of sample taken}}$$

3.4.2.6 Calcium Hardness

Calcium hardness in water was determined by titrimetric method. 50 ml of sample was taken in a conical flask and 2 ml of NaOH was added into it.100 – 200 mg of mureoxide was added which gave pink colour. Then it was titrated against 1 N EDTA solution until the end point was indicated by the appearance of purple colour and the burette reading was noted.

Calcium hardness was calculated by using formula as:

$$\textbf{Calcium}^{++} \text{ (mg / l)} = \frac{\text{ml of EDTAP400.8}}{\text{Volume of sample taken}}$$

3.4.2.7 Magnesium Hardness:

The magnesium hardness in water samples was determined by subtracting the calcium hardness from total harness in the same volume of sample taken

Magnesium was calculated by formula as:

$$Mg^{++} \text{ (mg/l)} = \frac{y-x \times 400.8}{\text{Volume of sample} \times 1.645}$$

3.4.2.8 Total Alkalinity

Total alkalinity in water was determined by titrimetric method. 50 ml of sample was taken in a clean conical flask and added few drops of phenolphthalein indicator to it there was no any colour change then methyl orange indicator was added (2drops) and the content was titrated against 0.01 N HCl until the yellow colour changed into pink.

The total alkalinity was calculated by using formula as:

$$\textbf{Total alkalinity (mg/lit) as } CaCO_3 = \frac{\text{ml x N of HCL x 1000 x 50}}{\text{Volume of sample taken}}$$

3.4.2.9 Phosphate

For the determination of phosphate, 100ml of filtered sample was taken in a volumetric flask. 4ml of ammonium molybdate was added to the sample, also 10 drops of stannous chloride was added. Blue colour was appeared and the absorbance was measured after 10 minute and before

12 minute of adding the $SnCl_2$. The absorbance was measured by using Spectro – photometer of 690nm using distilled water as blank. The concentration of phosphate was directly calculated from the standard calibration curve. Calibration of standard curve was prepared by plotting a graph of absorbance against concentration.

Calculation:

Mg/l of (PO_4) in water= mg of (PO_4) as found by interpolation on calibration curve × dilution factor

3.4.2.10 Nitrate

Nitrate in the water samples is determined by phenol disulfonic acid method. 50ml of sample was taken and equivalent amount of $AgSO_4$ was added and slightly warm. Thus the chlorides are removed from the sample. Then filtrate in the porcelain basin was evaporated to dryness. The dried sample was dissolved in 2ml of phenol disulfonic acid and 48ml distilled water and to this content 6ml ammonia solution was added. Then yellow colour was developed. The absorbance of sample and the reagent blank were measured on Spectrophotometer at 410nm within 3 minutes of colour development. The level of nitrate in the sample was determined from the standard calibration curve.

Calculation:

Mg/l of (NO_3-N) in water= mg of (NO_3-N) as found by interpolation on calibration curve × dilution factor

3.4.2.11 Sodium (Flame photometric method)

To test for dissolved sodium the water samples were filter through a filter paper to remove any suspended matter. Then the sample and the blank were measured on flame photometer by the sodium filter paper. The level of sodium in the sample was determined from the standard calibration curve.

Calculation:

Mg/l of Na in water= mg of Na as found by interpolation on calibration curve × dilution factor

3.4.2.12 Potassium (Flame photometric method)

To test for dissolved potassium the water samples were filter through a filter paper to remove any suspended matter. Then the sample and the blank were measured on flame photometer at 768nm wave length instead of sodium filter. The level of sodium in the sample was determined from the standard calibration curve.

Calculation:

Mg/l of K in water= mg of K as found by interpolation on calibration curve × dilution factor

3.4.2.13 Sodium Absorption Ratio (SAR)

The calculation of SAR of water sample is as follows:

$$SAR = \frac{Na^{+}}{\sqrt{Ca^{++} + Mg^{++}}}$$

Where, Na+, Ca++ and Mg++ are in meq/l.

3.4.2.14 Sodium Percent (Na %)

The calculation of (Na %) of water sample is as follows:

Na %=(Na +K)/ (Ca +Mg +Na +K)

Where, Na, K, Ca and Mg are in meq/l.

3.4.2.15 Residual Sodium Carbonate (RSC)

The calculation of RSC of water sample is as follows:

RSC= (CO_3+HCO_3) - (Ca +Mg)

Where, CO_3, HCO3, Ca and Mg are in meq/l.

3.4.3 Data Treatment and Classification Methods:

Sodium Absorption Ratio, Sodium percentage, Residual sodium carbonate and Electronic conductivity were calculated to evaluate the suitability of water quality for agricultural purposes. The technique and methods followed for analysis, calculation and interpretation are those given by Ayers and Westcot (1994), Tiwari and Manzoor (1988a, b), ISI (1974), Duffer and Backer (1964), Wilcox (1954), Doneen (1954, 1962, 1964), Paliwal (1967, 1972), Vogel (1961), APHA et.al (1998).

Table 1: Water Quality Classes for Agricultural Purposes

Parameters	Rate of Hazard	Water Class
pH	6.5-8.4	No problem
	5.1-6.4	Moderate
	8.5-9.5	Moderate
	0-5.0 and 9.5+	Severe
EC	<250	Excellent
(us/cm)	250-750	Good
	750-2250	Permissible
	2250-5000	Unsuitable
TDS (mg/l)	<200	Excellent
	200-500	Good
	500-1500	Permissible
	1500-3000	Unsuitable
Cl (meq/l)	<4	No problem
	4-10	Moderate
	>10	Severe
NO3-N(mg/l)	<5	No problem
	5-30	Moderate
	>30	Severe
Hardness (mg/l)	0-60	Soft
	60-120	Mod. Soft
	120-180	Hard
	>180	Very Hard
Na%	<20	Excellent
	20-46	Good
	46-60	Permissible
	60-80	Doubtful
	>80	Unsuitable
SAR	<10	Excellent
	10-18	Good
	18-26	Fair
	>26	Poor
RSC (meq/l)	<1.25	Safe
	1.25-2.50	Permissible
	>2.50	Unsuitable

Sources: Ayers and Westcot (1994), Tiwari and Manzoor (1988a, b), ISI (1974), Duffer and Backer (1964), Wilcox (1954), Doneen (1954, 1962, 1964), Paliwal (1967, 1972)

3.5 Methods of Water Balance Study:

This study is based on the secondary data collected from Government of Nepal's Department of Hydrology and Meteorology (DHM). Kakani station was selected for the analysis of water balance since it is the adjoining station of study area. The station index no is 1007 which lies on the $27^0$48'N latitude and $85^0$15'E longitude and at the height of 2064m above the sea level. 34 years (1963-1996) data were used to calculate the long term mean of various parameters. The field capacity of the station is assumed to be 200mm (Upadhya, 1985). These data are used to estimate first the potential evapotranspiration with Thronthwaite method, and then water balance analysis is conducted.

3.5.1 Methods of Determining Potential Evapotranspiration by Thornthwaite:

American climatologist, C.W.Thornthwaite (1948) developed a formula to estimate potential evapotranspiration, PE involving only the mean air –temperature, is calculated as given below:

$PE=1.6\times b\,(10T/I)^{a}$...3.1

Where PE is the monthly potential evapotranspiration in cm/month, T is the mean air-temperature in ^{0}c, and I is the summation of 12 monthly heat indexes which is given by:

$i= (T/5)^{1.514}$..3.2

"a" is the exponential power function of I for a given location and is given by:

$a=6.75\times10^{-7}I^3+7.7\times10^{-5}I^2+1.79\times10^{-2}I+0.49$.............................3.3

This formula gives the unadjusted rates of monthly potential evapotranspiration for a month of 30 or 31 day, each day having twelve hours duration of bright sunshine hour. Therefore, to adjust the number of hours in a day for a particular month, the correction factor "b" is calculated as given below.

. ...3.4

Following steps are involved to determine potential evapotranspiration (PE),

1. From mean monthly air temperature, monthly values of heat index i are obtained (Appendix).
2. Summing up these monthly values of these heat indexes i to obtain annual heat index (I) is calculated.
3. Knowing the latitude of the station, monthly correction factors from Appendix are multiplied by the corresponding values of unadjusted potential evapotranspiration to get adjusted potential evapotranspiration (PE) for each month.

3.5.2 Water Balance Computation Procedure:

The water balance accounting procedure begins with the subtraction of potential evapotranspiration (PE) from precipitation (P) in each month.

The remaining terms for the water balance is calculated from Throinthwaite water Balance Model. The procedure for the calculation of monthly Evapotranspiration (ME), water surplus (WS) and water deficiency (WD) are given below:

The essential calculated parameters for Kakani station are given below

Monthly values of precipitation (P_m) in mm
Monthly values of potential evapotranspiration (PE_m) in mm
Assumed field capacity (AFC) for the soil

Soil moisture storage (St_m) and actual evapotranspiration (AE_m) in any month 'm' are calculate depends on the value of P-PE i.e. whether precipitation is higher or lower than potential evapotranspiration in the particular month.

For Pm >PE_m (Climatic surplus)

In this case there is enough water for evaporation to be at the maximum potential rate i.e. Am=PE and the soil moisture storage will either increase or stay the same. Using the water balance equation for a unit area of soil we obtain

St_m = {st_m -1+ $e^{(P-PE)*}$/ AFC}.............................3.5
$t_{m=\,.}$ $e^{(P-PET/fc)}$ min^{-1}

Thus, the soil storage in the month 'm' is calculated as the sum of soil storage in the preceding month and total precipitation in the month 'm' minus total potential evapotranspiration in month 'm'. However, the soil storage can never be higher than the field capacity (AFC). If the former expression is higher than AFC, the soil storage st_m=AFC and a soil water surplus (WS) will accumulate.

If st_m -1 + (P_m-PE_m) >AFC then

WS_m= st_m -1 + (P_m-PE_m) –AFC=(P_m-PE_m) ΔSt_m....................................3.6

Where,

ΔSt_m=ΔSt_m=St_m-St_{m-1}..3.7

For PEm>P_m (Climatic deficit)

In this case soil water is used to make up all or part of the climatic deficit, and soil water deficit will develop or increase. This means $AE_m > PE_m$. Let us now assume that precipitation and evapotranspiration are evenly distributed throughout the month and that is the following calculations P_m, PE_m and AE_m are instantaneous values given in mm/month. Thus by using the instantaneous water balance equation for within the month "m" we obtain,

$P_m-AE_m=d\ (St_m)/\ dt$..3.8

From the Throinwaite's curve we have

$AE_m-P_m/PE_m-P_m=St_m/AFC$.......................................3.9

The equation of straight line with a slope 1

By isolating (P_m-PE_m) and inserting in equation (4.3) we obtain,

$(P_m-PE_m)St_m/AFC=d\ (St_m)/dt$

Or, $1/St_m\ d\ (St_m) = P_m-PE_m/AFC$..4.0

By integrating over one month we obtain,

$St_m=St_m-1\exp\ [P_m-PE_m/AFC]$..4.1

The actual evapotranspiration is found from the water balance equation for month 'm' i.e.

$AE_m=P_m+ (St_{m-1}-St_m)$

Or, $AE_m=P_m-\Delta St_m$..4.2

The difference of PE and AE gives the value of water deficit for the month, i.e.

$WD_m=PE_m-AE_m$...4.3

3.6 Methods of Determining the Climatic Types:

The climatic type of the study area is determined by Throinthwaite classification on the basis of moisture regime and thermal efficiency in following equations below:

$I_m=I_h-I_a$

Where, I_h= Humidity index,

$I_h=WS/PE\times100$

I_a= Aridity index

$I_a=WD/PE\times100$

The monthly and annual values of potential evapotranspiration, water deficit and water surplus are obtained from the water balance table.

After then, the climatic type and subtype of station is obtained from table given below.

Table 2: Limits for Nine Climatic Moisture Types

Symbol	Climatic Type	Moisture Index%
Humid climates		
A	Per humid	100 and above
B4	Humid	80 to 100
B3	Humid	60 to 80
B2	Humid	40 to 60
B1	Humid	20 to 40
C2	Moist sub humid	0 to 20
Dry climates		
C1	Dry sub climate	-33.3 to 0
D	Semiarid	-66.7 to -33.3
E	Arid	-100 to -66.7

Table 3: Seasonal Variation of Effective Moisture

Symbol	Moist climates (A,B,C2)	Aridity index(Ia)
r	Little or no water deficiency	0 - 10
s	Moderate summer water deficiency	10-20
w	Moderate winter water deficiency	10-20
S2	Large summer water deficiency	Above 20
W2	Large winter water deficiency	Above 20
Symbol	**Dry climates (C1,D &E)**	**Humidity index (Ih)**
d	Little or no water surplus	0-16.7
s	Moderate summer water surplus	16.7-33.3
w	Moderate winter water surplus	16.7-33.3
S2	Large summer water surplus	Above 33.3
W2	Large winter water surplus	Above 33.3

Table 4: Thermal Efficiency and Climatic Types

Symbol	Climatic Types	Thermal efficiency (cm)
E'	Frost	Below 14.2
D'	Tundra	14.2-28.5
C2'	Micro thermal	28.5-42.7
C1'	Micro thermal	42.7-57.0
B1'	Meso thermal	57.0-71.2
B2'	Meso thermal	71.2-85.5
B3'	Meso thermal	85.5-99.7
B4'	Meso thermal	99.7-114.0
A1'	Mega thermal	114.0-128.0
A2'	Mega thermal	128.0-142.5
A3'	Mega thermal	142.5-156.7
A4'	Mega thermal	156.7-171.0
A5'	Mega thermal	171.0-185.2
A6'	Mega thermal	185.2-199.5
A7'	Mega thermal	Above 199.5

Table 5: Summer Concentration and Climatic Sub –Types

Summer Concentration of Thermal efficiency	Climatic Sub -type
Above 88.0	d
76.3-88.0	c_1
60.8 -76.3	c_2
61.6-68.0	b_1
56.3-61.6	b_2
51.9-56.3	b_3
48.0-51.9	b_4
44.6-48.0	a_1
41.1-44.6	a_2
38.8-41.1	a_3
36.3-38.8	a_4
34.0-36.3	a_5
31.9-34.0	a_6
29.9-31.9	a_7
Below 29.9	a_8

(Source: Carter and Mather, 1966)

CHAPTER – IV

4. DATA ANALYSIS AND RESULTS

4.1 Analysis of Irrigation Water Quality:

The water quality of irrigation water has been thoroughly examined and the results are given in the following articles.

4.1.1 pH in Irrigation Water:

The pH in irrigation water was found to be variable with site as well as season wise during the period of investigation. The average values of pH in the irrigation water for strawberry cultivation in Okharpauwa VDC ranged from 7.68 $\pm$ (.187) during pre monsoon season to 7.38 $\pm$ (0.12) during post monsoon season. (Fig 6)

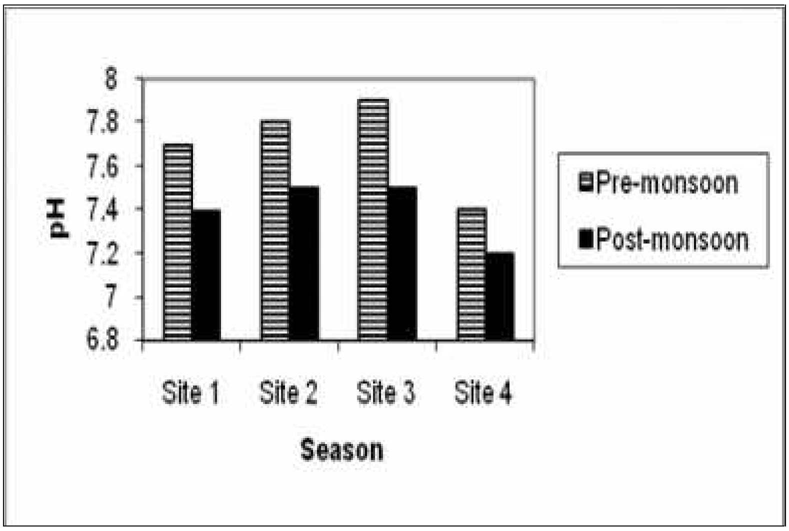

Figure 6: Seasonal Variation of pH in Streams of Okharpauwa VDC

Throughout the investigation in two seasons the pH value was found maximum in site-3 during pre-monsoon season and minimum in site-4 during post monsoon season. In pre monsoon season, the pH value was 7.9 in site-3 followed by 7.8 at site-2, 7.7 at site-1 and 7.4 at site-4. In post monsoon season, the pH value was 7.5 at both site-3 and site-2 followed by 7.4 at site-1 and site-4.

4.1.2 Electrical Conductivity in Irrigation Water:

The electrical conductivity in irrigation water was found to be variable with site as well as season wise during the period of investigation. The average values of electrical conductivity in the irrigation water for strawberry cultivation in Okharpauwa VDC ranged from 35.1 µs/cm ± (13.92) during pre monsoon season to 29.73µs/cm ± (13.52) during post monsoon season. (Fig 7)

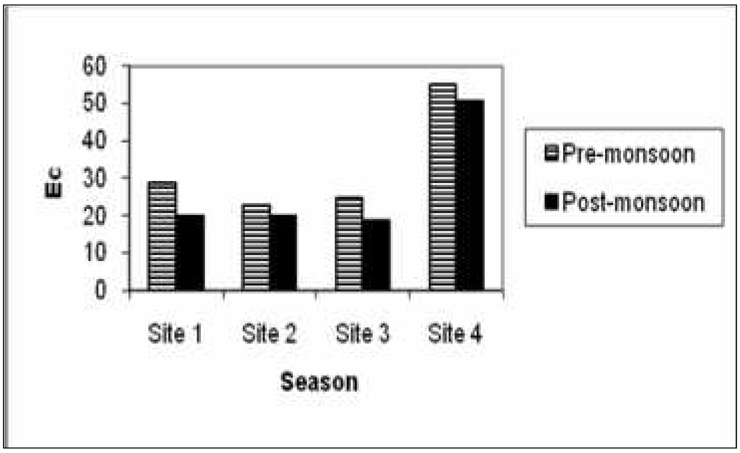

Figure 7: Seasonal Variation of Electrical conductivity in Streams of Okharpauwa VDC

Throughout the investigation in two seasons the conductivity value was found maximum at site-4 during pre-monsoon season and minimum at site-3 during post monsoon season. In pre monsoon season, the maximum value of conductivity was 55.3 µs/cm at site-4 followed by 29µs/cm at site-1, 25 µs/cm at site-3 and 23 µs/cm at site-2. In post monsoon season; the maximum value of conductivity was 50.7 µs/cm at site-4 followed by 20 µs/cm at both sites 1 & 2 and 18.4 µs/cm of conductivity at site-3.

4.1.3 Chloride in Irrigation Water:

The chloride in irrigation water was found to be variable with site as well as season wise during the period of investigation. The average values of chloride in the irrigation water for strawberry cultivation in Okharpauwa VDC ranged from 0.64 ± (.019) meq/l to 0.55 ± (.033) meq/l during pre monsoon season to post monsoon season. (Fig 8)

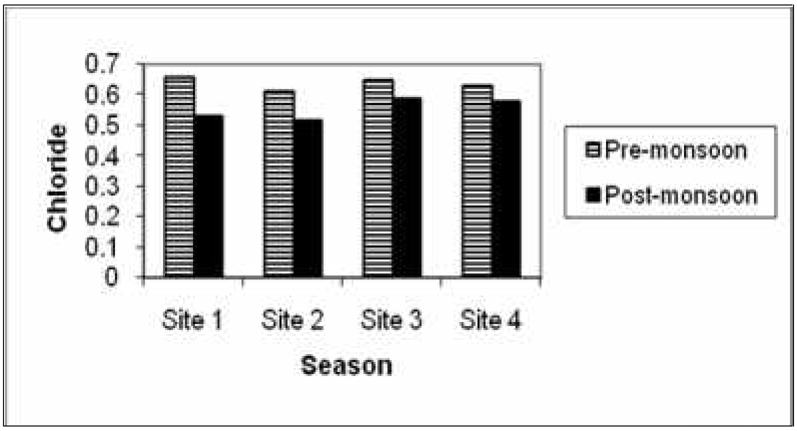

Figure 8: Seasonal Variation of Chloride in Streams of Okharpauwa VDC

Throughout the investigation in two seasons the chloride value was found maximum at site-1 during pre-monsoon season and minimum at site-2 during post monsoon season. In pre monsoon season, the maximum value of chloride was 0.66 meq/l at site-1 followed by 0.65 meq/l at site-3 0.63 meq/l at site-4 and 0.61 meq/l at site-2. In post monsoon season, the maximum value of chloride was 0.59 meq/l at site-3 followed by 0.58 meq/l at site-4, 0.53 meq/l at site-1 and 0.52 meq/l at site-2.

4.1.4 Total Dissolved Solid in Irrigation Water:

The total dissolved solid in irrigation water was found to be variable with site as well as season wise during the period of investigation. The average values of total dissolved solids in the irrigation water for strawberry cultivation in Okharpauwa VDC ranged from 22.83 $\pm$ (8.5) mg/l to 19.33 mg/l $\pm$ (8.81) during pre monsoon season to post monsoon season. (Fig 9)

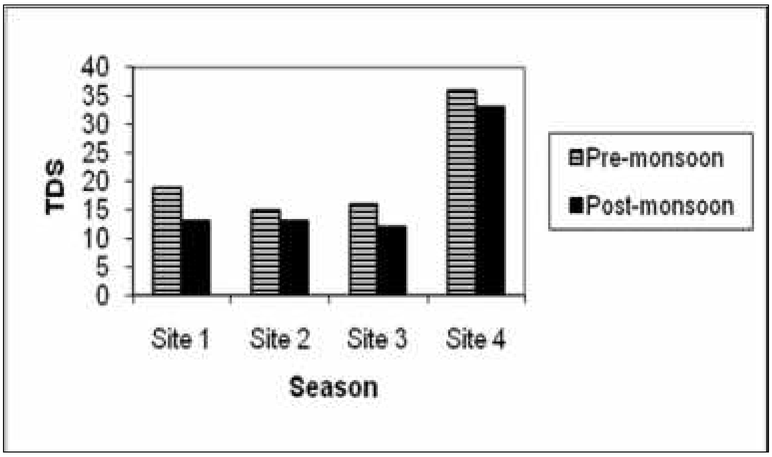

Figure 9: Seasonal Variation of TDS in Streams of Okharpauwa VDC

Throughout the investigation in two seasons the TDS value was found maximum at site-4 during pre-monsoon season and minimum at site-3 during post monsoon season. In pre monsoon season, the TDS value was 36 mg/l at site-4 followed by 19 mg/l at site-1, 16 mg/l at site-3 and 15 mg/l at, site-2. In post monsoon season; the TDS value was 33 mg/l at site-4 followed by13 mg/l at site-1, 13 mg/l at site-2 and 12 mg/l at site-3.

4.1.5 Hardness in Irrigation Water:

The hardness in irrigation water was found to be variable with site as well as season wise during the period of investigation. The average values of hardness in the irrigation water for strawberry cultivation in Okharpauwa VDC ranged from 13.71 mg/l $\pm$ (2.085) to 10.62 mg/l $\pm$ (2.35) during pre monsoon season to post monsoon season. (Fig 10)

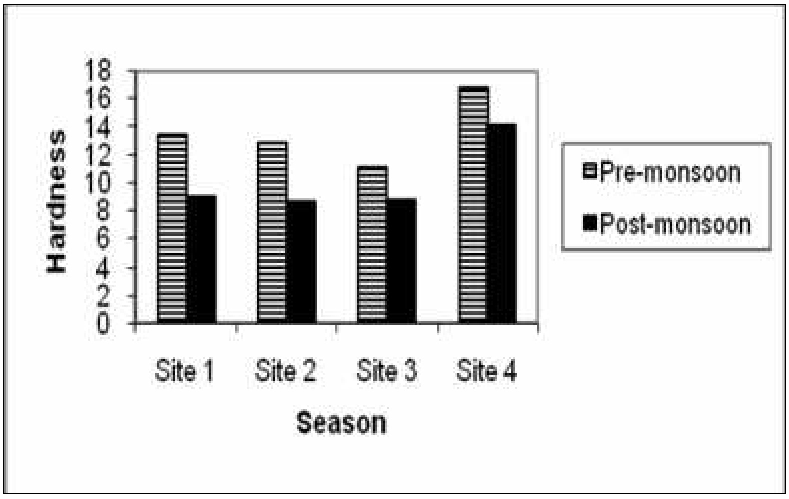

Figure 10: Seasonal Variation of Hardness in Streams in Okharpauwa VDC

Throughout the investigation in two seasons the hardness value was found maximum at site-4 during pre-monsoon season and minimum at site-2 during post monsoon season. In pre monsoon season, the hardness value was 16.85 mg/l at site-4 followed by 13.5 mg/l at site-1, 12.85 mg/l at site-2, and 11.1 mg/l at site-3. In post monsoon season; the hardness value was 14.2 mg/l at site-4 followed by 9 mg/l at site-1, 8.7 mg/l at site-2 and 8.8 mg/l at site-3.

4.1.6 Sodium Absorption Ratio (SAR) in Irrigation Water:

The sodium absorption ratio in irrigation water was found to be variable with site as well as season wise during the period of investigation. The average values of SAR in the irrigation water for strawberry cultivation in Okharpauwa VDC ranged from 0.54 $\pm$ (.929) to 0.458 $\pm$ (.09) during pre monsoon season to post monsoon season. (Fig 11)

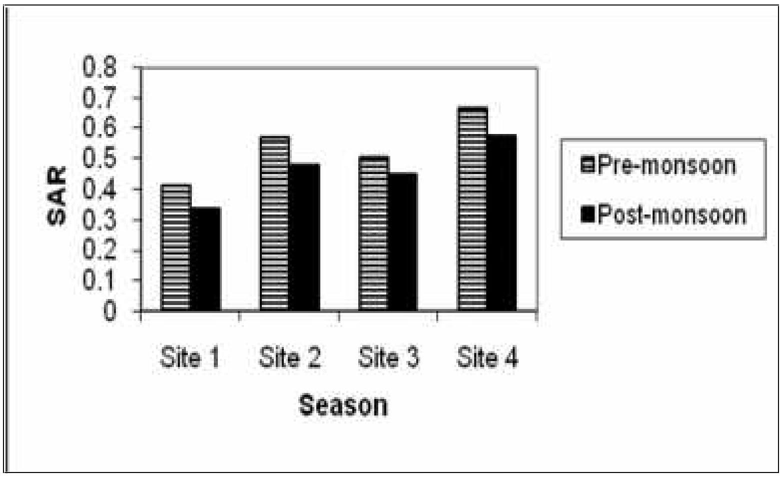

Figure 11: Seasonal Variation of SAR in Streams in Okharpauwa VDC

Throughout the investigation in two seasons SAR value was found maximum at site-4 during pre-monsoon season and minimum at site-1 during post monsoon season. In pre monsoon season, SAR value was 0.67 at site-4 followed by 0.571 at site-2, 0.507 at site-3, and 0.415 at site-1. In post monsoon season, SAR value was 0.577 at site-4 followed by 0.477 at site-2, 0.448 at site-3 and 0.334 at site-1.

4.1.7 Sodium in Irrigation Water:

The sodium percent in irrigation water was found to be variable with site as well as season wise during the period of investigation. The average values of sodium percent in the irrigation water for strawberry cultivation in Okharpauwa VDC ranged from 45.37% ± (.42) to 43.967% ± (.81) during pre monsoon season to post monsoon season. (Fig 12)

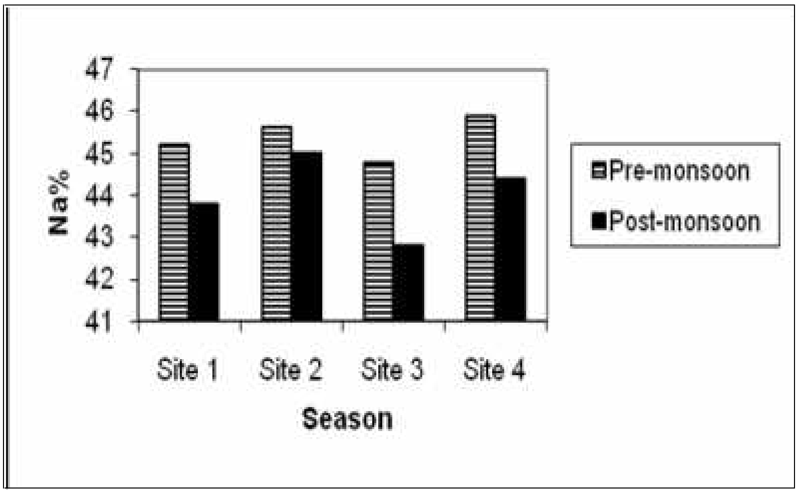

Figure 12: Seasonal Variation of Na% in Streams of Okharpauwa VDC

Throughout the investigation in two season's sodium percent was found maximum at site-4 during pre-monsoon season and minimum at site-3 during post monsoon season. In pre monsoon season, sodium percent was 45.9% at site-4 followed by 45.64% at site-2, 45.2% at site-1, and 44.8% at site-3. In post monsoon season, sodium percent was 45% at site-2 followed by 44.4% at site-4, 43.8% at site-1 and 42.8% at site-3.

4.1.8 Residual Sodium Carbonate (RSC) in Irrigation Water:

The residual sodium carbonate in irrigation water was found to be variable with site as well as season wise during the period of investigation. The average values of RSC in the irrigation water for strawberry cultivation in Okharpauwa VDC ranged from 0.24 ± (.025) to 0.116 ± (.08) during pre monsoon season to post monsoon season. (Fig 13)

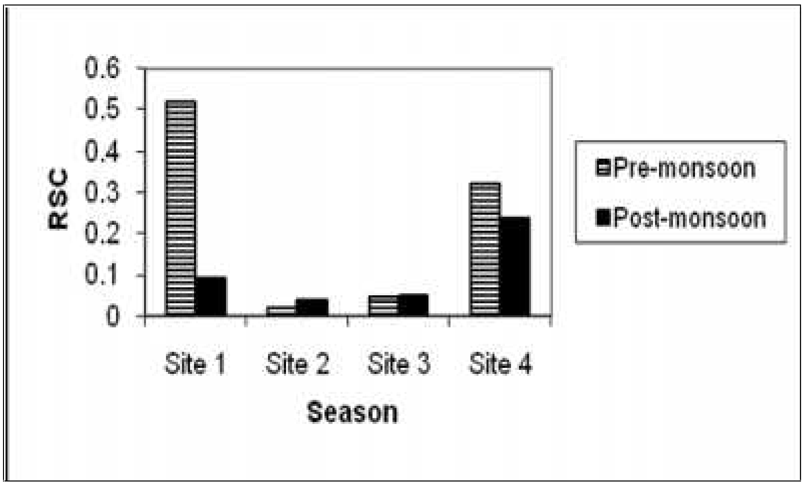

Figure 13: Seasonal Variation of RSC in Streams in Okharpauwa VDC

Throughout the investigation in two season's RSC was found maximum at site-4 during pre-monsoon season and minimum at site-2 during post monsoon season. In pre monsoon season, residual sodium carbonate was 0.324 at site-4 followed by 0.241 at site-1, 0.047 at site-3 and 0.024 at site-2. In post monsoon season; residual sodium carbonate was 0.236 at site-4, followed by 0.091 at site-1, 0.051 at site-3 and 0.04 at site-2.

4.1.9 Nitrate (NO_3) in Irrigation Water:

The nitrate in irrigation water was found to be variable with site as well as season wise during the period of investigation. The average values of NO_3 in the irrigation water for strawberry cultivation in Okharpauwa VDC ranged from 3.52 mg/l $\pm$ (.756) to 3.007 mg/l $\pm$ (.64) during pre monsoon season to post monsoon season. (Fig 14)

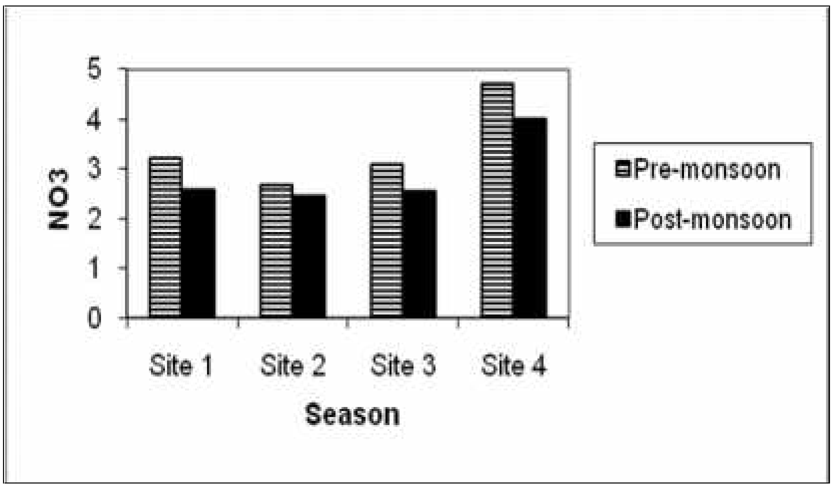

Figure 14: Seasonal Variation of NO_3 in Streams in Okharpauwa VDC

Throughout the investigation in two season's NO_3 was found maximum at site-4 during pre-monsoon season and minimum at site-2 during post monsoon season. In pre monsoon season, nitrate was 4.7 mg/l at site-4 followed by 3.24 mg/l at site-1, 3.1 mg/l at site-3 and 2.7 mg/l at site-2. In post monsoon season, nitrate was 4.0 mg/l at site-4, followed by 2.58 mg/l at site-1, 2.54 mg/l at site-3 and 2.46 mg/l at site-2.

4.2 Water Balance Parameters Determination:

The monthly as well as annual values of the water balance parameters have been calculated for Kakani station and are presented in Table 6. The graphs of precipitation, potential evapotranspiration are also drawn. The parameters of water balance are potential evaporatraspiration, actual evapotranspiration, soil moisture storage, water deficiency and water surplus. The seasonal and annual distribution of these parameters in the study areas are discussed below.

Station no: 1007

Station name: Kakani

Assumed field capacity: 200mm

Table 6: Parameters for Water Balance Analysis

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Temperature	8	10	14	17	18	19	19	19	18	16	13	10	181
Rainfall	17	26	45	58	174	471	676	752	445	84	11	15	2774
PET(mm)	20	28	49	72	84	93	92	90	75	62	38	25	728
P-PET(mm)	-3	-1	-5	-14	89	378	584	662	371	22	-27	-10	2046
St	164	162	159	148	200	200	200	200	200	200	175	166	2174
ΔSt	-3	-1	-4	-11	52	0	0	0	0	0	-25	-9	0
AET(mm)	19	27	48	69	84	93	92	90	75	62	36	24	719
WD(mm)	1	1	1	3	0	0	0	0	0	0	2	2	10
WS(mm)	0	0	0	0	37	378	584	662	371	22	0	0	2054

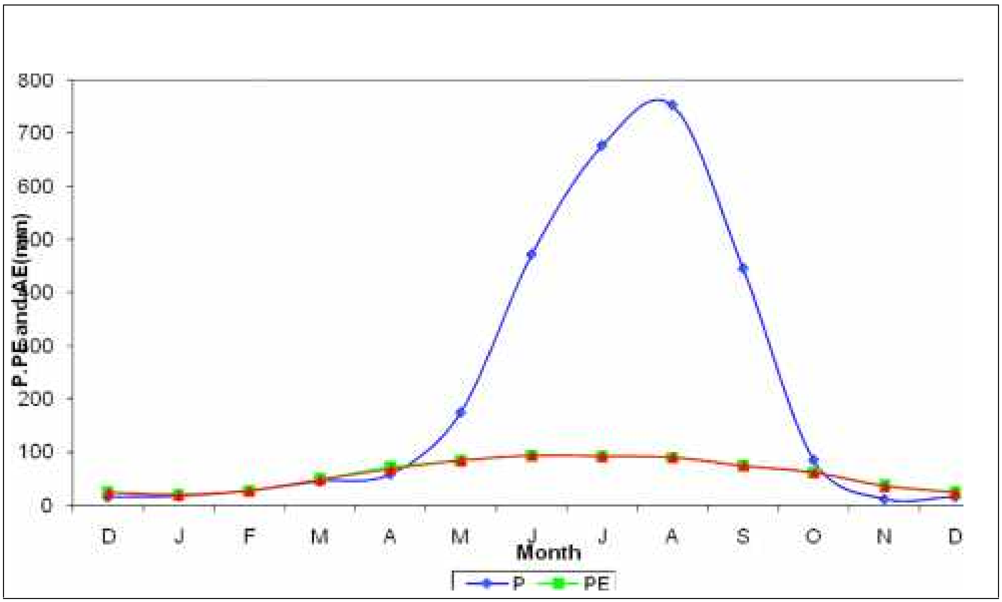

Figure 15: Water Surplus and Water Deficit Months for Kakani Station

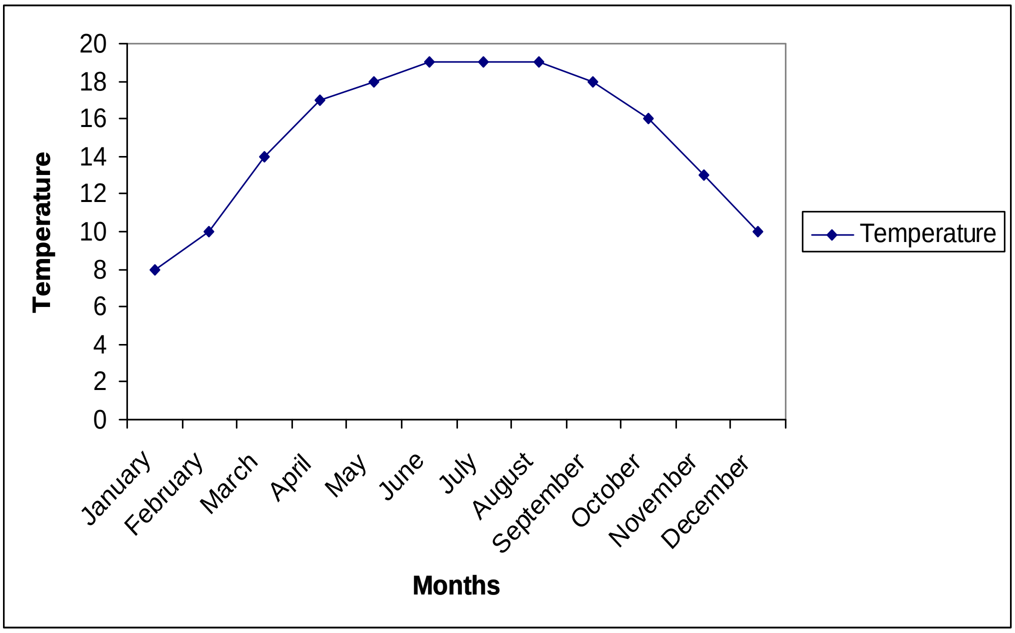

Figure 16: Mean Monthly Temperature of Kakani Station

4.2.1 Potential Evapotranspriration:

The maximum value is about 93 mm during June (monsoon) and 20 mm is the lowest value during January (winter season). Potential evapotranspiration decreases with increasing elevation and it increases with temperature.

During winter season, the value of potential evaptranspisation becomes lower than just before pre monsoon season and in monsoon season.

4.2.2 Soil Moisture Storage:

In Kakani station, soil moisture is at field capacity 200 mm during monsoon season, slightly below from field capacity during post monsoon as 175 mm and reaches about 148 mm. Soil moisture storage is about 7.7 % of field capacity during pre monsoon season which is the driest period in the year.

4.2.3 Actual Evapotranspiration:

The highest value of actual evapotranspiration at Kakani station is 93 mm in June and the lowest value of actual evaportranspiration is 19 mm in January is less than potential evapotranspiration in winter and pre-monsoon season. But in the monsoon season the AE and PE values are same because of the excess rainfall in that season.

4.2.4 Water Deficiency:

The water deficiency represents the amount by which precipitation is not able to meet the demands of evapotranspiration due to the strong seasonal concentration of precipitation in summer monsoon season and very low rainfall during rest of the year. Maximum value of monthly water deficiency was found as 3 and 2 mm in pre monsoon season & post monsoon and no water deficit in monsoon season.

4.2.5 Water Surplus:

Water surplus is the excess of water from precipitation after the soil is replenished and the demand of PE is met. Thus, this water that contributes to river flow partly by surface and partly by sub surface routes.

In Kakani station the highest mean monthly water surplus was 499 mm in monsoon and no water surplus in rest of the month.

4.3 Climatic Classification:

Climatic classification of Kakani station is found with the help of water balance and mean monthly climatic data of temperature and precipitation recorded during year (1963-1996).

The distribution of climatic type is based on moisture regime and thermal regime. The Table 7 shows that there are 282.14% humidity index (Ih), 1.1% aridity index (Ia), 281.04% moisture index (Im) 72.8cm thermal efficiency and 36.95% summer concentration of thermal efficiency. The result obtained for the climatic type of the Kakani station is found to be AB'_2ra_4 (Table 8).

Table 7: Values of Moisture and Thermal Index of Kakani Station

S. N.	Station Name	Humidity Index (Ih)%	Aridity Index (Ia)%	Moisture Index (Im)%	Thermal Efficiency (cm)	Summer concentration of thermal efficiency
1.	Kakani	282.14	1.1	281.04	72.8	36.95

Table 8: The Climatic Type and Subtype of Kakani Station

S. N.	Station Name	Climatic type based on				Climatic formula
		Moisture Regime		Thermal regime		
		Type	Subtype	Type	Subtype	
1	Kakani	A	r	B'_2	a_4	AB'_2ra_4

4.4 Socio-Economic Condition:

4.4.1 Population:

In the survey, a total of 35 household constituted population of 278 and the status by age and sexes are shown in Fig 17. It shows that 56.7% people fall on 15-59 aged groups which contain 54.62% of male and 57.64% of female. They are economically active people. The age group of 0-14 constitutes 35.25% of total population with 38.8% male and 32.9% female. Age group of 60 and above constitute of 8.27% with male 6.48% and 9.41% female. Both of these ages are dependent group.

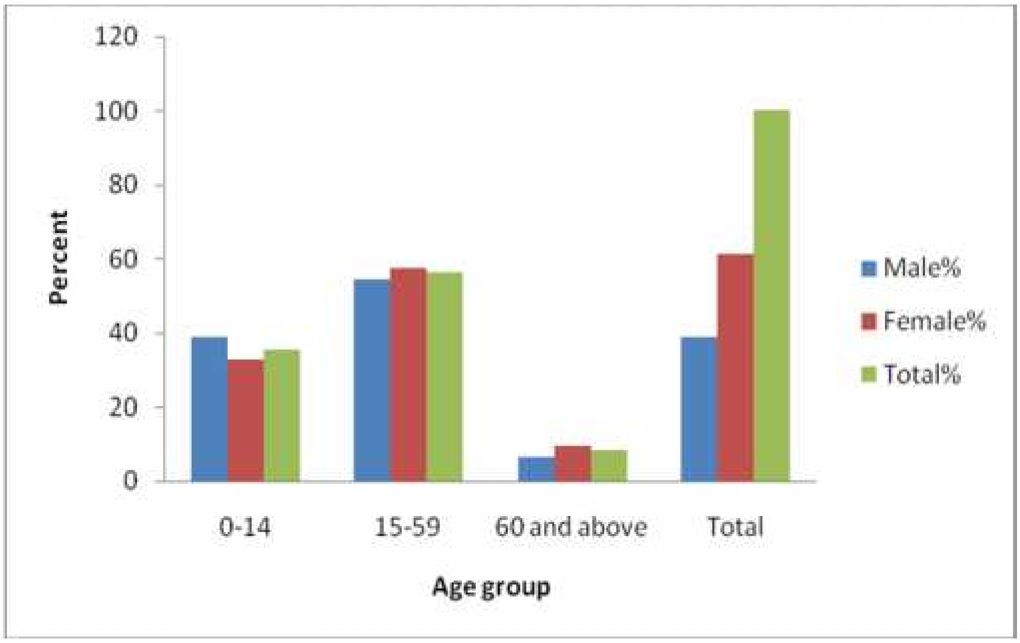

Figure 17: Population with Age and Sex Structure

4.4.2 Occupation and Energy Consumption :

Out of the total 35 sampled respondent, 85.71% of household were fully dependent on agricultural activities along with strawberry while 8.57% of remaining households were involved in small industry and 5.71% are labour. Occupation and energy used by respondent are presented in Fig 18.

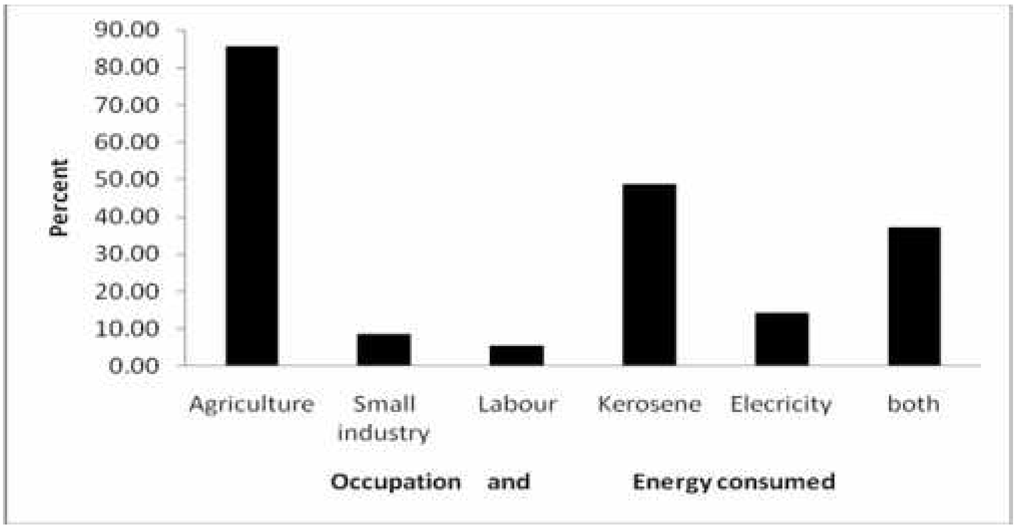

Figure 18: Occupation and Energy Used by Respondent

Out of the total 35 sampled respondents, about 48.57% of respondent used energy as kerosene, 14.29% used electricity and 37.14% used both kerosene and electricity.

4.4.3 Caste:

Out of the total 35 sampled respondent, 71.43% were Tamangs, 14.29% were ethnic groups, and 8.57% were Bhramins and 5.71% were Newars. (Fig 19)

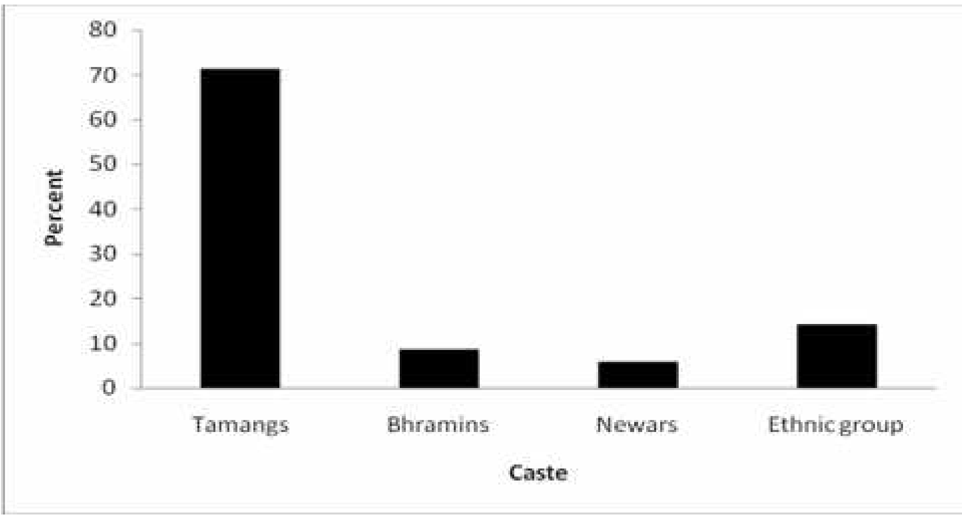

Figure 19: Caste of Respondent

4.4.4 Education:

Out of total 35 sampled respondent, 11.8% were literate and about 43.17% were illiterate, 34.17% had primary education, 8.99% had secondary education and 1.80% had higher education. (Fig 20) shows that 14.11% of male and 8.70% of female were literate, 31.90% male and 59.13% female were illiterate, 39.88% male and 26.09% female had primary education, 11.66% male and 5.22% female had secondary education and 2.45% male and 0.87% female had higher education. (Fig 20)

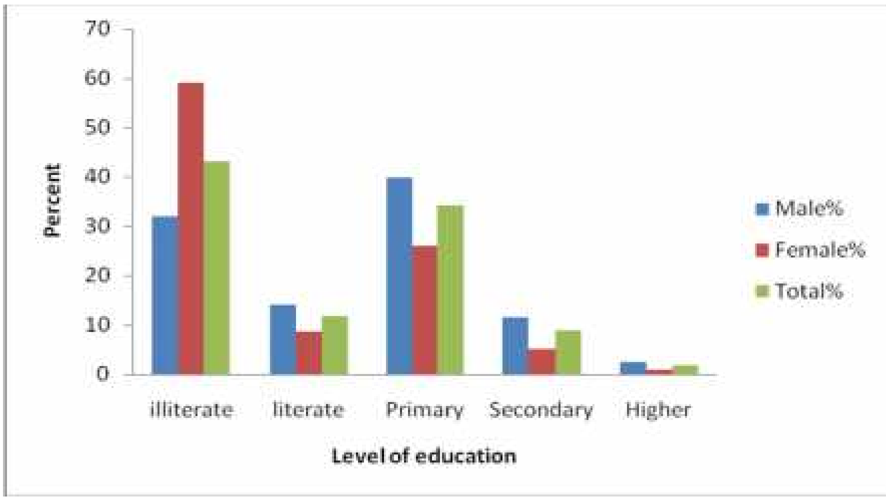

Figure 20: Education Status of Respondent

4.4.5 Total and Strawberry Land of the Respondent :

Out of total 35 sampled respondents, about 34.29% of the respondent owned 1 to 5 ropanies, about 25.71% owned between 5 to 10 ropanies, about 17.14% had 10 to 15 ropanies, about 14.29% had land between 15 to 20 ropanies and only about 8.57% of the total respondents had more than 20 ropanies land.(Fig 21)

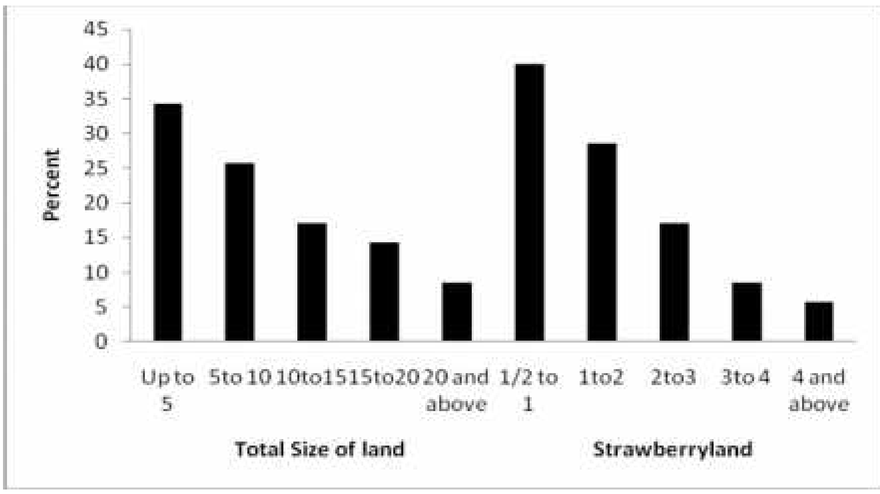

Figure 21: Total Cultivated Crop Land and Strawberry Land of Respondent

Out of total 35 sampled respondents, about 40% of respondent had cultivated strawberry on the land between 1/2 to 1 ropani lands. About 28.57% of respondent had cultivated strawberry on the land between 1 to 2 ropani lands. About 17.14% of the respondents had cultivated strawberry between 2 to 3 ropani land and about 8.57% of respondent had cultivated strawberry on the land between 3 to 4 and 5.71% of respondent had cultivated strawberry above 4 ropani.

4.4.6 Investment and Income Amount from Strawberry Cultivation:

Out of the total 35 sampled respondents, 34.29% of respondent had invested the amount of money between 1000 to 5000 rupees, 31.43% of respondent had invested the amount of money between 5000 to10000 rupees. About 14.29% of respondent had invested 10000 to 15000 rupees and about 11.43% of respondent had invested the money above 15000 rupees. (Fig 22)

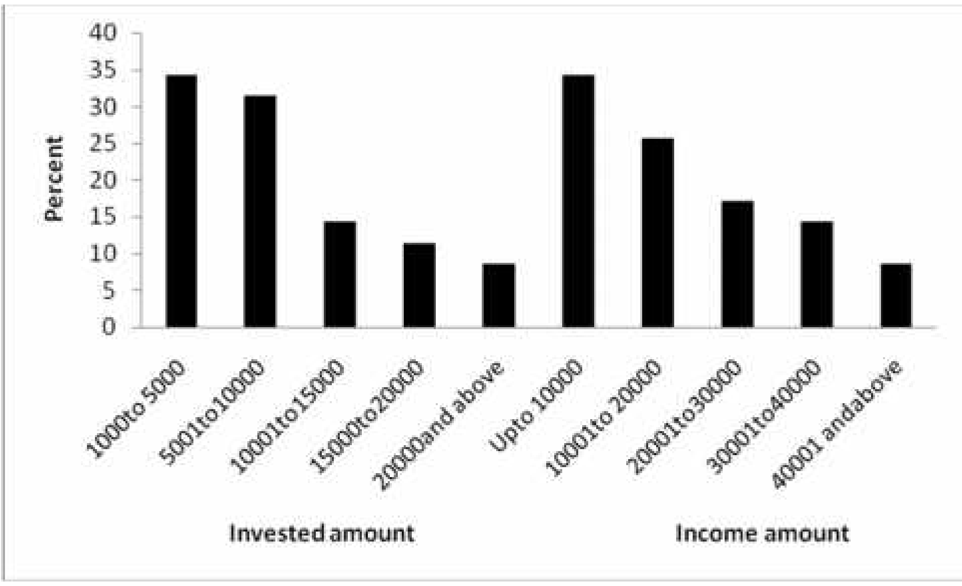

Figure 22: Invested and Income Amount by Strawberry Cultivation

Out of total 35 sampled respondents, 34.29 % of respondent earned up to 10000 rupees about, 25.71% earned between 10001 to 20000 rupees, about 17.14% earned between 20001 to 30000 rupees, about 14.29% earned between 30001 to 40000 rupees and about 8.57% earned the money above 40001 rupees.

4.4.7 Training, Use of Pesticide & Chemical Fertilizer and its Effects in Strawberry Cultivation:

Out of total 35 sampled respondents, 28.57% had taken training to cultivate strawberry and 71.43% had not taken training to cultivate strawberry.

Out of total 35 sampled respondents, 100% of respondent used fertilizer and pesticide. About 77.14% of them applied 6 to 8 times pesticide and fertilizer on strawberry farm during the strawberry planting, fruiting up to the harvesting period. About 22.86% used 8 and above times of pesticides and fertilizers on strawberry land.

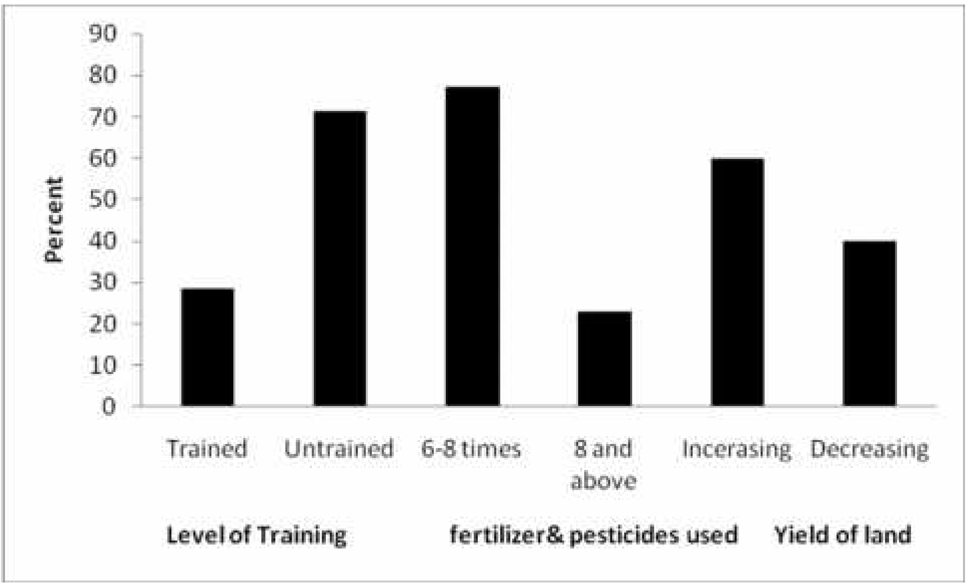

Figure 23: Training, Use of Pesticide & Chemical Fertilizer and its Effect in Strawberry

Fig 23 shows that about 60% of respondent viewed increasing the land and about 40% of respondent viewed decreasing the land by the use of these pesticides and fertilizers.

4.4.8 Selling and Market of Strawberry Fruit:

Out of total 35 sampled respondents, about 37.14% of respondent sold the strawberry fruit in Kathmandu bazaar, about 42.86% sold them in local bazaar and about 20% sold them both in Kathmandu city and local bazaar.

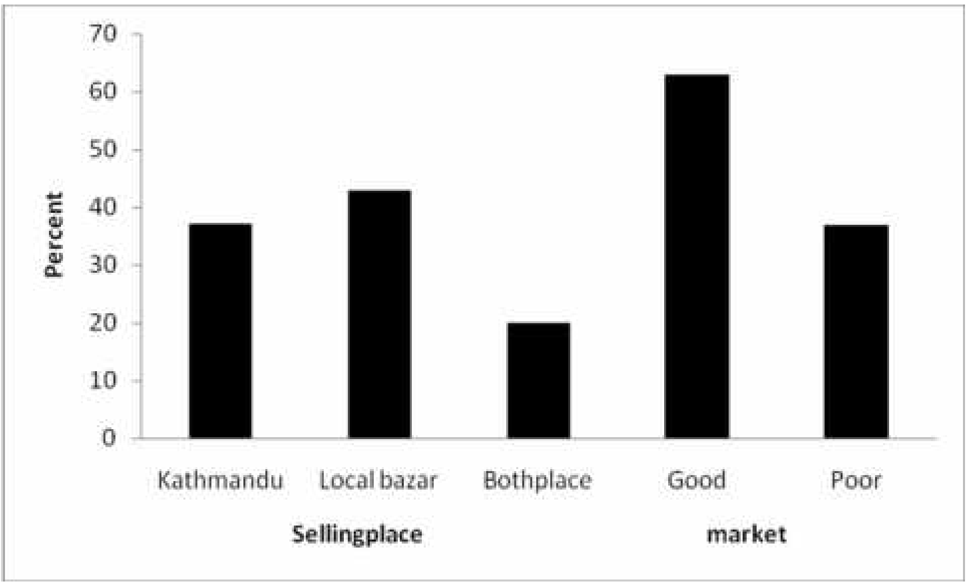

Figure 24: Selling and Market of Strawberry

About 35% of the total sampled respondents, 62.86% viewed that strawberry market was good and 37.14% of respondent viewed strawberry market was poor. (Fig 24)

4.4.9 Environmental Problem in Strawberry Cultivation:

Out of total 35 sampled respondents, about 42.86% of respondent faced the problem of landslide & erosion on strawberry farm, about 57.14% did not face the problem.

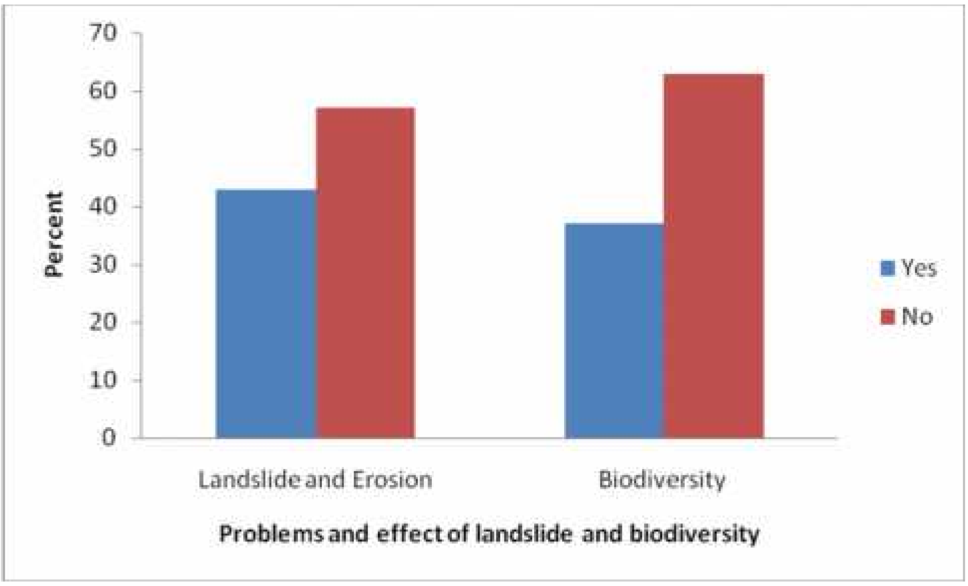

Figure 25: Environmental Problem in Strawberry Cultivation

Out of total 35 sampled respondents, about 37.14% of respondent faced the effect of biodiversity on strawberry farm; about 62.86% did not. (Fig 25)

4.4.10 Irrigation Applied on Strawberry:

i) Sources, Method and Irrigation System:

Out of the total 35 sampled respondent about 80% respondent used the stream for irrigation and 20% of respondent had reservoir as a source of irrigation water. 100% of the respondents used piped water for irrigation in strawberry farms.Out of the total 35 sampled respondents, 100% have sprinkler system of irrigation. (Fig 26)

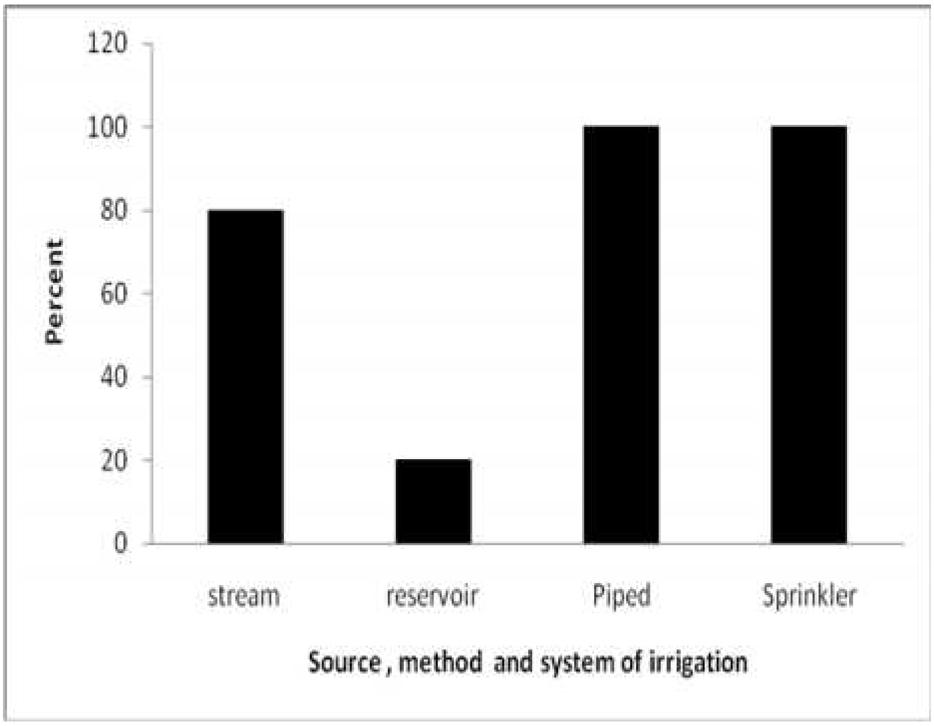

Figure 26: Irrigation Applied on Strawberry

ii) Importance of Irrigation in Strawberry:

Out of the total 35 sampled respondents, 91.43% of respondent viewed that irrigation increased the strawberry production. About 60% of the respondent used the sprinkler irrigation by themselves, 22.86% used the system by the inspiration from others and 17.14% used it as instructed by organization.

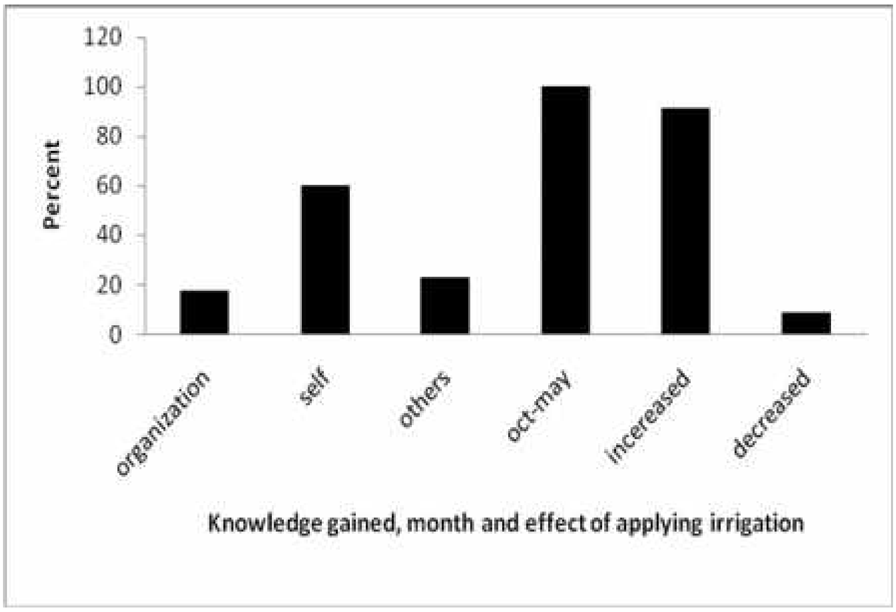

Figure 27: Importance of Irrigation in Strawberry Cultivation

The entire respondent applied the irrigation on strawberry field in the months from October to May. The entire respondents knew the importance of irrigation in strawberry cultivation. (Fig 27)

iii) Problems Faced on Applying Irrigation:

Out of total 35 sampled respondents, 74.29% of respondent faced problems on applying irrigation water due to infeasibility source, technical knowledge, financial constraint and hilly features in strawberry land and 25.71% of respondent did not face any problems on applying irrigation water in strawberry land. (Fig 28)

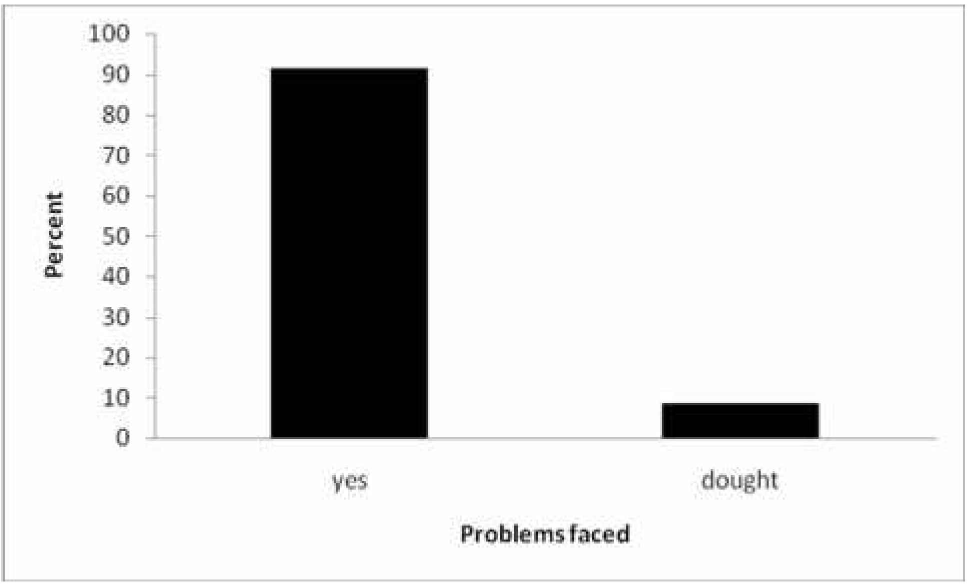

Figure 28: Problems Faced on Applying Irrigation

CHAPTER – V

5. DISCUSSION OF RESULTS

5.1 Quality of Irrigation Water:

The suitability of river water for irrigation depends upon the mineral constituents present in the water. The major physico-chemical parameters, which decide the suitability of river water for irrigation, are pH, EC, TDS, hardness, chloride, carbonate, bicarbonate, nitrate, sodium, potassium, calcium, magnesium, etc. Silica, iron and boron are usually present in very small amounts and are determined in special circumstances, for example when industrial waste alone is to be used for irrigation (Deo and Ali 1993).

The normal pH range for irrigation water is from 6.5 to 8.4. An abnormal value is a warning that the water needs further evaluation. Irrigation water with a pH outside the normal range may cause a nutritional imbalance or may contain a toxic ion. The pH of the samples analyzed was slightly alkaline in nature with an average value of during pre-monsoon, and during post-monsoon season. The pH value of all water samples lies in the range from 6.54 to 8.10, which implies that waters are suitable for irrigation purposes with respect to pH, i.e. there is no alkalinity hazard (Ayers and Westcot, 1994) as shown in Table 1.

Electrical conductivity is the most important parameter in determining the suitability of water for irrigation use. Salinity in river water is determined by EC, which is used as a surrogate measure of total dissolved solids (TDS) concentration in water. TDS refer to any minerals, salts, metals, cations or anions dissolved in water. This includes anything present in water other than pure water (H_2O) molecules and suspended solids. Table 1 shows the guidelines for EC and TDS values in waters used for irrigation. On the basis of EC and TDS, water samples of the study area come under the excellent to good category (Table 1) for irrigation purposes (Ayers and Westcot 1994).

The most common toxicity is from chloride in the irrigation water. Chloride is not absorbed or held back by soils, therefore it moves readily with the soil-water. If it is taken up by the crop, it moves up in the transpiration stream, and accumulates in the leaves. If the chloride concentration in the leaves exceeds the tolerance of the crop, injury symptoms develop such as leaf burn or drying of leaf tissue. Normally, plant injury occurs first at the leaf tips (which is common for chloride toxicity), and progresses from the tip back along the edges as severity increases. Excessive necrosis (dead tissue) is often accompanied by early leaf drop or defoliation. Since the chloride concentration in fresh water samples lie in the range from 0.12 to 2.84 meq/l, hence the sample water of the stream of Okharpauwa (Table 1) is free from chloride hazard and it is in the ‘no problem’ water class for irrigation purposes(Ayers and Westcot1994).

The nitrogen concentration in the form of nitrate is very low varying from 2.46 to 4.7 mg/l, which indicate that water sample, is free from nitrate-nitrogen hazard (Table 1). Nitrogen is a plant nutrient and stimulates crop growth. Natural soil nitrogen or added fertilizers are the usual sources, but nitrogen in the irrigation water has much the same effect assoil-applied fertilizer nitrogen and an excess will cause problems, just as too much fertilizer would. If excessive quantities are present or applied, production of several commonly grown crops may be upset because of over-stimulation of growth, delayed maturity or poor quality. Sensitive crops may be affected by nitrogen concentrations above 5 mg/l. Most other crops are relatively unaffected until nitrogen exceeds 30 mg/l (Ayers and Westcot 1994).

Hardness is the property of water which prevents the lather formation with soap and increases the boiling point of water. Hardness is due to the presence of divalent metallic cat ions like calcium, magnesium, strontium, ferrous iron and manganese ions. Durfer and Backer 1964 classified the water samples in terms of degree of hardness as (1) soft (0 to 60 mg/l), (2) moderately hard (60 to 120 mg/l), (3) hard (120 to 180 mg/l) and (4) very hard (>180 mg/l). The sample water is classified as soft water in both pre monsoon (48.72–104.58 mg/l) and post-monsoon (34.67–100.25 mg/l) seasons as in Table 1.

The sodium hazard of irrigation water is usually specified as two sodium related indices named as sodium adsorption ratio (SAR) and sodium percentage (Na %).

Excess sodium in water produces the undesirable effects of changing soil properties and reducing soil permeability (Kelly 1951). High Sodium concentration leads to development of an alkaline soil. The sodium or alkali hazard in the use of water for irrigation is determined by the absolute and relative concentration of cat ions and is expressed in terms of sodium adsorption ratio (SAR). SAR is a calculated value and an indicator of sodium hazard of water.

There is a significant relationship between SAR values of irrigation water and the extent to which sodium is absorbed by the soil. SAR gives a very reliable assessment of water quality of irrigation waters with respect to sodium hazard, since it is more closely related to exchangeable sodium percentages in the soil than the simpler sodium percentage (Tiwari and Manzoor 1988a). Sodium replacing adsorbed calcium and magnesium is a hazard as it causes damage to the soil structure. It becomes compact and impervious. SAR is an important parameter for the determination of the suitability of irrigation water because it is responsible for the sodium hazard (Todd 1980).The waters were classified in relation to irrigation based on the ranges of SAR values (Richards1954).

The value of SAR found in water sample is 0.415 to 0.67 in pre monsoon season and .334 to .458 in post monsoon season. According to Richard's classification all the samples in the study area water have been classified as excellent for irrigation (Table 1). It is due to low concentrations of sodium in soils affect slowly on its physical condition and soil structure resulting in formation of crusts, water-logging, reduced soil aeration, reduced infiltration rate, and reduced soil permeability.

The role of sodium in the classification of river water for irrigation was emphasized because of the fact that sodium reacts with soil and as a result clogging of particles takes place, there by reducing the permeability (Todd 1980; Domenico and Schwartz 1990; Nagaraju et al. 2006). Percent sodium in water is a parameter computed to evaluate the suitability for irrigation (Wilcox 1948; Tiwari and Manzoor1988a). The value of sodium percent in the study area was found to be 45% to 45.9% in both pre monsoon season and post monsoon season. The water samples in study area in both seasons are categorized as 'excellent' to 'good' classes with respect to Na % values; this is due to the low input of sodium, carbonate, chloride and sulphate contain in soil.

According to the US Salinity Laboratory (1954), RSC value < 1.25 meq/l is safe for irrigation, a value between 1.25 and 2.5 meq/l is of marginal quality and a value more than 2.5 meq/l is unsuitable for irrigation. The RSC found in water sample 0.52 to 0.236. All the samples have RSC values much less than 1.25 meq/l (safe for irrigation), which revealed that all samples are of safe quality categories for irrigation. This is due to low amount of total carbonate levels exceed the low amount of calcium and magnesium and the water quality may not be diminished.

5.2 Water Balance:

Thronthwaite's book keeping procedure provides the information on soil moisture status, like its magnitude, seasonal variation, magnitude of moisture deficiency and moisture surplus. It treats soil moisture as the balance between precipitation and evapotranspiration.

A comparison of the marches of potential evapotranspration and precipitation (Fig 15) shows that soil moisture storage decrease from October and reaches the minimum value in the month of May, because potential evapotranspration exceeds precipitation in the station. From post monsoon season (Oct – Nov) soil moisture status starts to decrease from field capacity and becomes unsatisfactory during pre monsoon season.

During winter (Dec – Feb) magnitude of soil moisture is about 48.2% of field capacity. In this season there is a need of irrigation on strawberry farm. During pre monsoon (March – May) water is also needed for agriculture purpose.

While from June to September precipitation exceed potential evapotranspiration, depleted soil moisture again recharges till 1st week of July. From the second week of July plenty of water is available in the strawberry farm and there is no need to irrigate the land. These shows Okhaurpauwa VDC have favorable agricultural situation during all seasons but due to slopes of mountainous terrain other crops except strawberry are difficult to grow in Okhaurpauwa VDC.

In the Himalayan region, frost occurs during winter & soil moisture status is very low during pre monsoon season. Also due to the complex topography this region is less suitable for agriculture, only limited crops (1 crop/year) can be cultivated during summer monsoon (Dhakal, 1996).

Kakani and its surrounding area receive higher rainfall compared to loss due to evapotranspiration and hence the soil moisture is at field capacity from May to October. So sprinkler irrigation is recommended for strawberry farm, keeping in view of topography, erosion and economy of water.

The comparison of potential evapotranspriration and precipitation indicates the necessity of supplemental irrigation for the study area during at least half of the year for better agricultural production.

Water deficiency, obtained from the water balance procedure indicates the water needed for irrigation. The agricultural yield is highly dependent on the availability of the correct amount of water that is needed and applied at the proper time. Hence, the patterns of water deficiency of the region, obtained from the water balance procedure, provide the information of water required for supplemental irrigation at different times.

From (Fig 15) it is observed that sufficient moisture is available for strawberry plant in monsoon season, so no supplemental irrigation is needed for cultivation. For winter and pre monsoon season, strawberry need higher amount of supplemental irrigation.

Hence, from this regarding study of the magnitude of water deficiency it is found that water conservation is essential for providing irrigation water in the dry periods.

5.3 Climatic Classification:

Throinthwaite used the indices of humidity or aridity for indicating the seasonal variation of effective moisture and for the sub classification of the moisture regime of climate as shown in

(Table 7). Based on moisture index in study area has Per humid zone with sub type "r" climate. It indicates that there is little water deficiency. According to thermal regime, the study area has meso thermal climate. For the summer with concentration of thermal efficiency the study area has symbol "a' signifying that only less than 48% of the total annual thermal efficiency is accumulated during summer season (Critchfield, 1987).

The Kakani station is assigned with climatic type which is indicated by four letters, in which the two letters represent the moisture regime and other two represent the thermal regime. From Table 8, climatic classification of Kakni station is AB'_2ra_4 which means per humid meso thermal type of climate with little water deficiency and having summer concentration of thermal efficiency to meso thermal of type fourth.

5.4 Socio-economic Conditions of Strawberry Farming Community:

In the Okhaurpauwa VDC, the socio economic status of strawberry farmers is poor. Most of the houses in Okharpauwa VDC are made up of earth, mud and dung. Most of the household don't have facility with electricity. Most of the houses don't have facility with sanitation. Few of the houses have sanitary facility with simple latrine. Most of the entire sampled households dispose solid waste by open dump. All most all of the Okharpauwa community consumed either kerosene or electricity. The socio economic condition is better than past due to the strawberry cultivation. Therefore, strawberry farming can uplift the socio – economic conditions of the local people.

The population of strawberry producer community is dominated by 15-59 age groups. They are economically active groups. The female population is higher than the male population in this community. The Fig 17 indicates that the community gets the highest percentage of active population. Age group below 14 yrs and above 60 years is dependent on this population. All the dependent groups are supported by the age groups 15-59.

Agriculture is the predominant occupation of the study area. Out of the total 35 sampled respondent 87.51 % are fully dependent on agricultural activities, while 8.57% are engaged in small industry and 5.71% were labourer.

The education status of the community is very poor. Because 43.17% were illiterate, only 11.87% were literate, only 34.17 % had passed the primary level and 8.99 % had secondary education. The living standard of this community is poor because of poor education affects the characteristics and quality of the living standard of the population.

Although the community is dominated by Tamang caste group but still people like Newars, ethnic group, Brahmin live together in harmony.

The cultivated land of the study area is very small because the highest percentage of respondent owned 1 to 5 ropanies of land and the minimum percentage of respondent owned more than 20 ropanies land.

The land is cultivated for cereal crops rather than for strawberry. Although the soil condition and climate of Okharpauwa are suitable for strawberry cultivation, the strawberry cultivation is less than cereal crops. This is because of the poor economic status, education and technical knowledge in the people.

Most of the strawberry farmers practice strawberry cultivation with the knowledge got from their neighbours without taking training. Only few of the farmers took training for strawberry cultivation. They took training from JAITI, Nepal. The farmers had not receiving any encouragement from the government and any other institution. Strawberry farmers get more profit than other crop cultivation. Therefore, the strawberry cultivation has helped to improve the socio-economic condition of the people.

Kathmandu city is the suitable place for selling strawberries produced in Okhaupauwa VDC because of easy access to Kathmandu. But the farmers of Okharpauwa sell their strawberries in local market.

Due to lack of education & knowledge, people thought that the yield of land would increase by the use of chemical fertilizers & pesticide. So, most of the farmers applied fertilizers & pesticides by 6-8 times on strawberry farm. Most of the farmers viewed that, this monoculture practice doesn't affect the local plants.

Irrigation plays important role in the better production of strawberry. Although it increases the strawberry production, sometimes due to lack of drainage, scarcity of water, slopy land, economic problem, illiteracy and source of water far from land the production of strawberry may decrease. The main source of water for the strawberry cultivation is got from streams of the Okharpauwa VDC. The farmers used pipes for irrigation. The sprinkler irrigation system has been applied on the strawberry land to limited extent. During pre monsoon season and post monsoon season irrigation is needed for strawberry cultivation. Most of the farmer faced problems in applying irrigation water due to economic problem, financial constraint and education.

CHAPTER – VI

6. CONCLUSION AND RECOMMENDATIONS:

6.1 Conclusions:

The water quality of streams which is used for irrigation in strawberry field in both pre monsoon season and post monsoon season was not varying for the different sites. Water parameters like pH, conductivity, TDS, chloride, nitrate, SAR, RSC, Na%, hardness were higher in pre monsoon season than in post monsoon season. But in both seasons the quality of water was in "Excellent to good" category. It reveals that water quality of streams used in strawberry farming is suitable for irrigation purpose for the strawberry farming. Therefore, it is concluded that the "excellent to good" irrigation water quality found in the study area has given production of strawberry fruit and will further increase the yield with more irrigation facilities.

The study of water balance of the Okharpauwa showed that the value of potential evapotranspiration, rainfall& temperature were variable. The highest and lowest values of PE & rainfall were found in monsoon season and in pre-monsoon respectively. Due to this variation, water deficiency and surplus occurred in pre- monsoon and winter season, and in monsoon season respectively. The study area suffered from shortage of rainfall from October to May while rainfall exceeded from June to Sept. So, it is concluded that irrigation is needed for at least half of the year. Temperature is strongly related to altitude and precipitation in this area.

The climatic type of the Okharpauwa region according to moisture regime is Per- humid climate with little or no water deficiency. The climate in this region according to thermal efficiency is meso thermal with summer concentration of thermal efficiency of fourth type.

The study of water balance and climatic type indicated there was less water deficiency in Okharpuawa region, but strawberry is a shallow rooted plant and the roots are found within 15-25 cm of soil surface. Thus, it requires frequent but less amount of water in each time of irrigation. In Okharpauwa, strawberries are grown on sandy soil on slopy lands so they require more irrigation. So, it is concluded that the timing and amount of irrigation are important for strawberry farming in Okharpauwa.

From the socio-economic study in Okharpauwa strawberry farming community it is concluded that the farmers are economically poor. Strawberry cultivation has indeed improved the economic and livelihood conditions of the farmers. Strawberry cultivation is increasing year by year and it has given employment to many people of the VDC. Due to lack of education &

technical knowledge, they have to face many problems relating to marketing, selling, planting, farming, irrigating, and using pesticides & chemical fertilizers. Sprinkler irrigation system is the most favourable in Okharpauwa because in this area strawberries are grown in sandy soil and sloping lands. Most of the farmers know the essentiality of irrigation for strawberry but due to lack of financial support, technical knowledge and distant water source with rugged topography, they are facing problems in the irrigation sector. The irrigation applied in strawberry farm is through sprinkler technique with pipes from sources. Summing up, it is concluded that this study on water balance, water quality, climatic type are all essential for irrigation. Training and economic support are needed for effective strawberry cultivation in the study area for further social benefit.

6.2 Recommendations:

A few recommendations have been considered for improving irrigation requirements for the strawberry farming.

- ❖ Small reservoir or tank should be built to conserve surplus water to provide irrigation for strawberry farming.
- ❖ Other cash crop as profitable as the strawberry suitable in the existing climatic condition of the study area should be explored.
- ❖ Co- ordination of local farmers with the government level is essential to solve the major issues on strawberry farming.
- ❖ Collection and transportation of the strawberry fruit from different parts of Okharpauwa to the market will indeed uplift the socio-economic status of local farmers.
- ❖ Awareness programs, provision of loan facility and training should be launched focusing on the sustainable agriculture management, so that the local people could benefit.
- ❖ Frequently monitoring on the faming of such high value cash crop should be done by the authorized body, so that such farming scheme could be started in different parts of the country.

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ANNEXES

Annex 1: <u>Mean Monthly Temperature (0C) and Rainfall (mm) in Kakani Station (1987-2006)</u>

Months	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total	Avg.
Temp	8.46	9.99	14.2	17.3	18.42	19.14	19.22	19.32	18.77	16.37	13.15	9.95	184.29	28.31
Rainfall	20.25	26.19	42	68.5	222.86	476.73	749	780	419	76.41	10	16.14	2907.08	447.21

Annex 2: <u>Mean Monthly Temperature (0C) and Rainfall (mm) in Kakani Station (1962-1996) for Water Balance Calculation</u>

Months	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Temp	8	10	14	17	18	19	19	19	18	16	13	10	181
Rainfall	17	26	45	58	174	471	676	752	445	84	11	15	2774

Annex 3: <u>Calculation of Irrigation Water Quality Parameters</u>

Pre monsoon season									
Parameters	**Unit**	**Site1**	**Site2**	**Site3**	**Site4**	**Min**	**Max**	**Mean**	**St. dev**
pH	No	7.7	7.8	7.9	7.4	7.4	7.9	7.68	0.187
Ec25°c	µs/cm	29	23	25	55.3	23	55.3	35.1	13.012
Chloride	me/l	0.66	0.61	0.65	0.63	0.61	0.66	0.64	0.019
TDS	mg/l	19	15	16	36	15	36	22.83	8.500
Alkalinity(HCo3)	me/l	0.51	0.28	0.27	0.66	0.27	0.66	0.44	0.164
Hardness	mg/l	13.5	12.85	11.1	16.85	11.1	16.85	13.71	2.085
Calcium(Ca)	me/l	0.14	0.114	0.113	0.203	0.113	0.203	0.15	0.037
Magnesium (Mg)	me/l	0.129	0.142	0.11	0.133	0.11	0.14	0.13	0.116
Sodium(Na)	me/l	0.152	0.204	0.169	0.274	0.152	0.27	0.20	0.467
Potassium(K)	me/l	0.07	0.011	0.042	0.012	0.011	0.07	0.04	0.243
NO3	mg/l	3.24	2.7	3.1	4.7	2.7	4.7	3.52	0.756
SAR	No	0.415	0.571	0.507	0.67	0.415	0.67	0.54	0.929
Na%	No	45.2	45.64	44.8	45.9	44.8	45.9	45.37	0.420
RSC	No	0.521	0.024	0.047	0.324	0.024	0.52	0.24	0.205

Post monsoon season									
Parameters	**Unit**	**Site1**	**Site2**	**Site3**	**Site4**	**Min**	**Max**	**Mean**	**St. dev**
pH	No	7.4	7.5	7.5	7.2	7.2	7.5	7.383	0.12
Ec25°c	µs/cm	20	20	18.5	50.7	18.5	50.7	29.73	13.52
Chloride	me/l	0.53	0.52	0.59	0.58	0.52	0.59	0.555	0.03
TDS	mg/l	13	13	12	33	12	33	19.33	8.81
Alkalinity(HCo3)	me/l	0.27	0.21	0.22	0.52	0.21	0.52	0.325	0.13
Hardness	mg/l	9	8.7	8.8	14.25	8.7	14.25	10.62	2.35
Calcium(Ca)	me/l	0.121	0.06	0.091	0.171	0.06	0.171	0.112	0.04
Magnesium (Mg)	me/l	0.058	0.11	0.078	0.113	0.058	0.113	0.088	0.02
Sodium(Na)	me/l	0.1	0.139	0.13	0.236	0.1	0.236	0.157	0.05
Potassium(K)	me/l	0.04	0.005	0.037	0.01	0.005	0.04	0.023	0.02
NO3	mg/l	2.58	2.46	2.54	4	2.46	4	3.007	0.64
SAR		0.334	0.477	0.448	0.577	0.334	0.577	0.458	0.09
Na%		43.8	45	42.8	44.4	42.8	45	43.967	0.81
RSC		0.091	0.04	0.051	0.236	0.04	0.236	0.116	0.08

Annex 4: <u>Potential Evapotranspiration Calculated From Climatic Data</u>

Year	**Temp**	**i**	**a**	**%p**	**Sunshine hour.**	**b**
January	8	2.08		7.39	324	0.9
February	10	2.72		7.12	312	0.9
March	14	4.52		8.47	371	1
April	17	6.2		8.81	386	1.1
May	18	6.8		9.62	422	1.1
June	19	7.4		9.58	420	1.2
July	19	7.4		9.76	428	1.1
August	19	7.36		9.31	408	1.1
September	18	6.95		8.43	369	1
October	16	5.81		8.08	354	1
November	13	4.05		7.28	319	0.9
December	10	2.72		7.23	317	0.9
Total	181	64.01	1.5			

Annex 5: <u>Calculation of Socio-Economic Survey</u>

Population with Age and Sex Structure							
S.N	Age Groups	Male	%	Female	%	Total	%
1	0-14	42	38.8	56	32.9	98	35.25
2	15-59	59	54.62	98	57.64	157	56.47
3	60 and above	7	6.48	16	9.41	23	8.27
4	Total	108	38.8	170	61.15	278	100

Occupation and Energy used by Respondent						
S.N	Occupation	No. of Respondent	%	Type of energy	No. of res	%
1	Agriculture	30	85.71	Kerosene	17	48.57
2	Small industry	3	8.57	Electricity	5	14.29
3	Labor	2	5.71	both	13	37.14
4	Total	35	100.00	Total	35	100.00

Caste of Respondent			
S.N	Caste Group	No. of Households	%
1	Tamangs	25	71.43
2	Bhramins	3	8.57
3	Newars	2	5.71
4	Ethnic group	5	14.29
5	Total	35	100

Education Status of Respondent							
S.N	level of education	Male	%	Female	%	Total	%
1	illiterate	52	31.90	68	59.13	120	43.17
2	literate	23	14.11	10	8.70	33	11.87
3	Primary	65	39.88	30	26.09	95	34.17
4	Secondary	19	11.66	6	5.22	25	8.99
5	Higher	4	2.45	1	0.87	5	1.80
6	Total	163	100	115	100	278	100

Total Cultivated Crop Land and Strawberry Land of Respondent						
S.N	Size of Land	No. of household	%	Strawberry land	No. of households	%
1	Up to 5	12	34.29	1/2 to 1	14	40.00
2	5to 10	9	25.71	1to2	10	28.57
3	10to15	6	17.14	2to3	6	17.14
4	15to20	5	14.29	3to 4	3	8.57
5	20 and above	3	8.57	4 and above	2	5.71
6	Total	35	100	Total	35	100.00

Invested and Income Amount by Strawberry Cultivation						
S.N	Amount(in rupee)	No. of respondent	%	Income per year(Rs)	No. of respondent	%
1	1000to 5000	12	34.29	Up to 10000	12	34.29
2	5001to10000	11	31.43	10001to 20000	9	25.71
3	10001to15000	5	14.29	20001to30000	6	17.14
4	15000to20000	4	11.43	30001to40000	5	14.29
5	20000and above	3	8.57	40001 and above	3	8.57
6	Total	35	100.00	Total	35	100.00

Training, Use of Pesticide & Chemical Fertilizer and its Effect in Strawberry Cultivation									
S.N	Particular	No. of respondent	%	No. of times	No. of res	%	Yield of land	No. of res	%
1	Trained	10	28.57	6-8 times	27	77.14	Increasing	21	60
2	Untrained	25	71.43	8 and above	8	22.86	Decreasing	14	40
3	Total	35	100.00	Total	35	100	Total	35	100

Selling and Market of Strawberry						
S.N	selling place	No. of respondent	%	Market	No. of respondent	%
1	Kathmandu	13	37.14	Good	22	62.86
2	Local bazar	15	42.86	Poor	13	37.14
3	Both	7	20	Bad	0	0
4	Total	35	100	Total	35	100

Environmental Problem in Strawberry Cultivation						
S.N	landslide and erosion	No. of respondent	%	biodiversity	No. of resp.	%
1	Yes	15	42.86	Yes	13	37.14
2	No	20	57.14	No	22	62.86
3	Total	35	100	Total	35	100

Irrigation Applied on Strawberry									
S.N	Sources	No. of respondent	%	Method	No. of resp.	%	type of system	No. of respondent	%
1	stream	28	80	Piped	35	100	Sprinkler	35	100
2	reservoir	7	20	Pumped	0	0	gravity irrigation	0	0
3	other	0	0	Canal	0	0	lift irrigation	0	0
4	total	35	100	total	35	100	total	35	100

Importance of irrigation in Strawberry Cultivation									
S.N	Knowledge gained	No. of respondent	%	Month	No. of res.	%	production	No. of res.	%
1	organization	6	17.14	Oct-May	35	100	increased	32	91.43
2	self	21	60	May-Sept	0	0	decreased	3	8.57
3	others	8	22.86	whole year	0	0	no effect	0	0
4	total	35	100	total	35	100	total	35	100

Problems Faced on Applying Irrigation			
S.N	problems	No. of respondent	%
1	yes	26	74.29
2	no	9	25.71
3	total	35	100

Annex 6: <u>Questionnaire for the socio-economic analysis of strawberry farming community of Okharpauwa VDC (2008)</u>

Name of Data Collector:... Date: ....

HOUSEHOLD SURVEY

A. **Household Information**

GPS Position : ....
Respondent Name : ....
Caste/Ethnic Group : ....
Sex : ....
Age : ....
Education : ....
Occupation : ....
Current Address
(VDC/Ward) : ....
Residence period : ....
Family structure : a) Nuclear b) Joint

B. Main material of floor

a. Earth, Mud, Dung B. Wood Planks C. Linoleum/ Carpet D. Ceramics, Tiles, Marbles
E. Cement F. Others (Specify) …………………

C. Does Your Household Have

a. Electricity B. Radio C. Television D. Telephone E. Bicycle
F. Motor Vehicles G. Computers H. Others (Specify)…………..

D. A. Sanitation Facilities

a. Open/Indiscriminate B. Simple Latrine C. Pour Flush Latrine D. Septic Tank

B. Water Supply System

A. Lake B. Streams C. Indoor Piped Water D. Piped Water in Yard E. Public Tap
F. Ground Water G. Bottled Water H. Others (Specify)……………….

E. Solid Waste Disposal

a. Open and Indiscriminate B. Open Dump C. Public Container D. Household Collection
E. Burning In Yard F. Bury In Yard G. Others…………………..

Strawberry farming:

1. Do you cultivate strawberry? If yes why and if not why?

2. Is strawberry farming the main income source of your family?

   a) Yes b) No c) Others

3. Why did you switch over to strawberry farming?
   ....
4. Do you get training for strawberry farming?
   a) Yes b) No

   If yes, who gives you training?

   ....

5. What is the amount do you invest in farming?

....

6. What is the amount do you get from strawberry farming?

....

7. What is the income from your traditional crops per ropani?
....

8. Are you using chemical pesticides in your farm?

a) Yes b) No

9. If yes, names of brand of pesticide...

....

10. How many times and how much do you apply such fertilizers in the crop life periods per ropani?
....

11. What is the yield from the strawberry per ropani?

....

12. How much of your agricultural yield increased from chemical fertilizer?

....

13. Is the yield of land increasing per year and why?

a) Yes b) No

....

14. Do you prefer terrace land or sloping land for cultivation?

....

15. Is there erosion problems?
....

19. Do you think this monoculture practices affected biodiversity in this area?

a) Yes b) No

If yes, a) Local herbs b) shrubs c) Tree d) Animal

(Name and importance)

....

20. How do you store the harvested crops?

....

21. Where are you going to sell the fruit?

a) Kathmandu.............b) Local bazaar.................

22. Is the market of strawberry good?

a) Yes b) No

If no, what are the difficulties do you face for the market for strawberry?

....

23. Is there any scheme providing loan for your farming?

a) Yes b) No

Irrigation Sector

24. What is the source of irrigation water?

a) Piped..... b) Well/tube well..........c) River...... d)Others......Reservoir/tank/pond

25. How do you apply irrigation water from the source to your farm?

a) Piped..... b) Pumped.....c) Canal (kulo)................

26. What type of irrigation system do you apply?

a) Sprinkler b) Gravity irrigation c) Pumped (lift irrigation)

27. Who gave you the knowledge of such irrigation system?

a) Government b) Organization c) Self d) Others

28. Are there problems of irrigation water?

a) Yes b) No

If yes, name the problems and give recommendations to solve them...

....

29. Do you find any differences in strawberry yield before and after applying irrigation? Give reasons

a) Yes b) No

....

30. What is your advice and recommendations to other farmers about this cash crop?

....
....