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Solar PV Pumping Technology for the development of Agriculture in Mustang, Nepal (A case study of Tiri, Kagbeni)

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Abstract
Agriculture is not only the main source of food but it is also the main source of earning. Human being cannot imagine the better life without the food security and this food security is more concern with the energy security.Mustang lies in the Himalayas region of the country.The land of Himalayas is remaining barren due to the lack of the irrigation facility. So pumping is the one of the potential technology which can irrigate the barren land for the overall development of Agriculture in Mustang, Nepal.Development of Crop depends on maximum and minimum temperature, humidity, wind speed, sunshine and evaporation and transpiration so the climatological data interpretation using cropwat 8.0 is studied under which it shows that the average monthly total reference evapotranspiration during 2005 - 2014 of Tiri village is 88.25 mm whereas the average monthly effective rainfall is 23.58 mm. The irrigation water requirement of Tiri is calculated considering the highest precipitation deficit in the month of April with $880m^3/day$ whereas least in the month of November with $84m^3/day$. The complete design of the solar PV pumping system for the development of Agriculture in Tiri Village, Kagbeni is covered. The height is measured from the source sump well to the reservoir as 66 m and the required solar PV peak power to uplift the water $880m^3/day$ is estimated as 32kW. The financial feasibility is performed comparing with different scenarios. Scenario I (subsidy/donors 0%, Debt 60%, Equity 40%); Scenario II (subsidy/donors 20%, Debt 50%, Equity 30%); Scenario III (subsidy/donors 50%, Debt 30%, Equity 20%) and Scenario IV (subsidy/donors 80%, Debt 10% and Equity 10%). The NPV, IRR, B/C and simple payback of respective scenario I, II, III and IV are calculated for both Solar PV pumping and Diesel pumping system where in both the scenario IV are more feasible than other scenarios. Solar PV Pumping is more feasible than diesel pumping system as per the affording capacity of farmers where per m^3 rate of water is 2.7 times higher in diesel pumping system than the solar pv pumping.

Keywords
Reference Evapotranspiration, Crop water Requirement, irrigation water requirement, crop coefficient, Solar PV power

1. Introduction

The solar energy is the main source of the energy where all the living and non living creatures are able to survive and transform into different states directly and indirectly. Water is the second need according to Maslow's hierarchy need which is used for drinking, cooking, irrigation and other purpose. In the present scenario with the advent of science and technology human beings are able to generate the intense energy and converted into the end use energy form with the use of Solar PV technology. Solar PV pumping is the best alternative for the diesel and irregular supply of electricity. In Nepal solar PV pumping technology has mostly been used for drinking purpose and few are practiced for irrigation and government also provide subsidy not exceeding NRs. 2,000,000 for the irrigation project using solar pv pumping managed by community or private company [1]. Mustang is one of the Himalayan district of Nepal where the land is barren and many number of small human habitat areas. This district is totally different with respective to climate,

geography and demography standards. It is known as the cold desert place of Nepal. In spite of the limited cultivable land and cold environment the crops, vegetables, fruits grown here have a good markets and grown in a high quality levels. Around 75% of the total population is dependent on agriculture and 40% of the district income is contributed from Agriculture and reported that tax of the Rs. 4 Lakhs has been collected from the Agricultural sector in 2070-2071 B.S [2]. According to the Energy consumption situation in Nepal, the energy consumption in Agriculture sector has just 1.17% in 2011-12 [3].
The distribution land of Mustang, Nepal where according to the report from the Department of Agriculture of Mustang very limited land are cultivated with the area of 3,662 hectors and uncultivable land of 3,60,296 ha, irrigated land is 2,499 ha [2]. There is a traditional irrigation system. Some where there are no accessible water resources but abundant cultivable land. Some where there is water resource but not technically feasible accessible technology for water supply.Even though Pumping through electricity has been practiced but due to the irregular supply and low voltage supply of electricity, the farmers aren't able to irrigate the land at the require time. So there is no energy security.
To overcome the irrigation problem in Mustang "Solar PV pumping technology for development of Agriculture in Mustang" is the research that helps the farmer of Mustang to optimize their agriculture production through energy security. Bring the environment of commercialization in Agriculture to overcome the problem of limited water.

2. Methodology

In order to introduce pumping technology the basic needs and the study of the behavior with different aspects needed to look thoroughly throughout of Tiri village, Nepal as shown Figure 1. The interpretation of the climatology data and crop calendar preparation and interpretation of the irrigation water demand of the Tiri village fall under the methodology and detail designed of the pumping technologies of the Tiri Village is covered. From the collection of the data to the survey of the fields a certain methodology are followed.

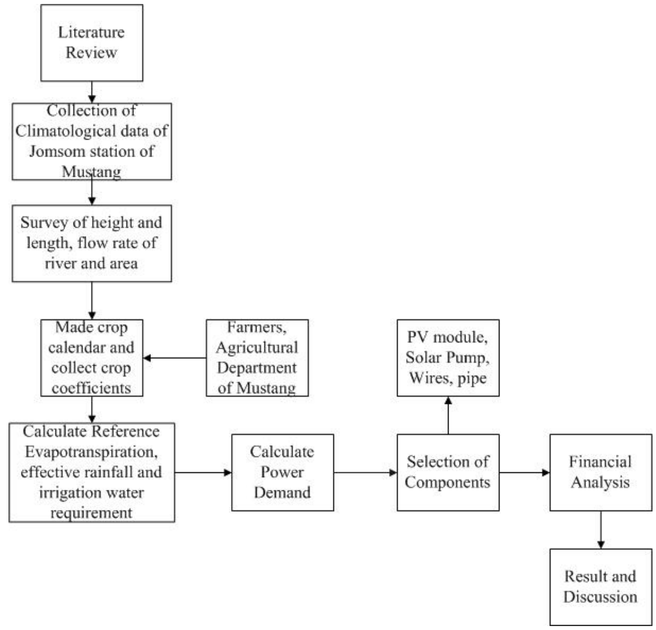

Figure 1: Block diagram of Methodology

2.1 Tiri Village

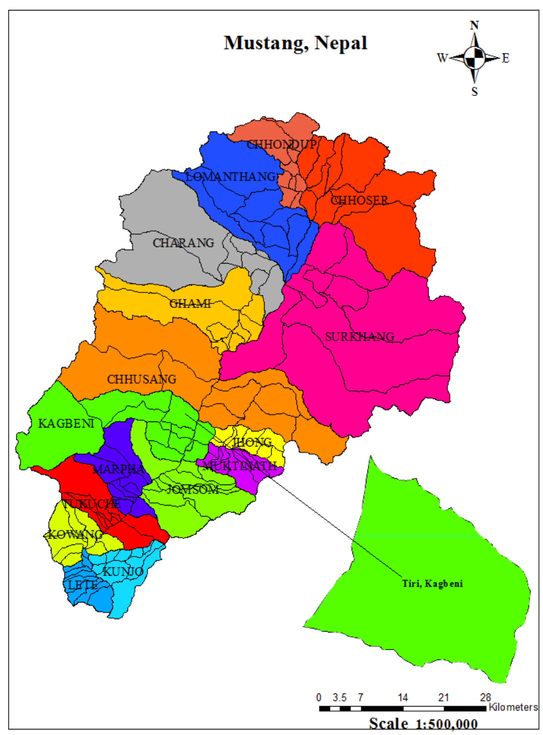

Figure 2: Tiri Village

Among many places of Mustang, Nepal which are deprived of good irrigation in spite of the fertile land Tiri village is been selected for the design of water pumping for the development of Agricultural. Tiri is a small village which lies in the opposite of Kagbeni located in the Valley of Kaligandaki River. The latitude and longitude of this village are 28 ° 51' 0.6" N and 83° 47' 4.58" E respectively and at altitude of 2,870 m from the sea level. It falls under Barha Gaun Muktishetra Gaunpalika. It is a small village where around 18 households with 110 people. Gurung are the main people living over here. They are mainly involved in agriculture, horticulture and animal husbandry for livelihood. This place is famous with some religious monastery and monk.

Kahare Khola is the main source of irrigation in this village. According to the survey the total agriculture land of this village is 12.85 hectors where only the 8 to 10 ha are used for agriculture. These are arrival land of Tiri village. The geographical structure of this land is slope. The soil is loamy skeleton[4]. The human habitats lie at the aside of the land. Due to the lack of water they are unable to increase their production. In spite of the land they got they aren't able to do anything because of the lack of water. Kahare khola alone doesn't meet irrigation demand for the crops. They are deprived from doing agriculture at the drought seasons. The Kahare khola has a irregular flow of water. Along the village the perennial river kali gandaki is flowing which is the potential source for the irrigation with the solar PV pumping.

2.2 Collection of Data

Department of the Hydrology and climatological (DHM) is the governmental organizational body where climatological data are obtained and similarly from the ICIMOD the sun shine hour is obtained. There are only three meteorological stations in Mustang, they are at Chosser, Jomsom and Lete. The humidity, rainfall, maximum and minimum temperature data from 2005 to 2014 are obtained of the station Jomsom and then the trends analysis for Tiri is performed. The wind data is not available from DHM so the data at 2m is obtained from the 10m height data obtained from Kagbeni (AEPC, Solar and Wind Energy Resource, 2008). Figure 3 is the GIS map of the Mustang showing the climatological and agro stations of Mustang. In order to

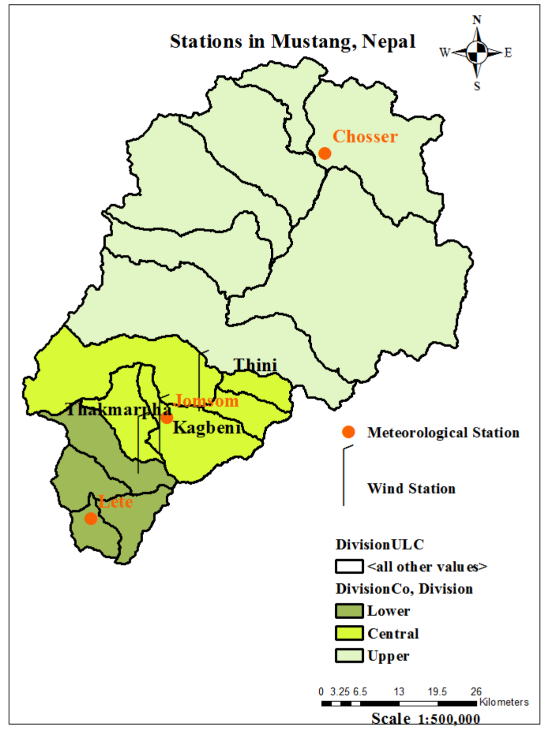

Figure 3: Meteorological stations of Mustang

calculate the evapotranspiration and irrigation water requirement the Meteorological datas like Humidity, Temperature and Precipitation/Rainfall, wind speed and sunshine hour and whereas the crop pattern with respective crop coefficients are needed to be collected.

2.2.1 Humidity

Relative Humidity is required as the input for the calculating reference crop water requirement. Two relative humidity are provided from the station whereas the mean humidity is needed. Humidity are taken at the two different times one in the morning 8:45 am, and other in the evening at 5:45 pm.

2.2.2 Temperature

The minimum and maximum temperature of each month are required to calculate the Reference Evapotranspiration. The minimum and maximum temperature are taken from the Department of Hydrology and Meteorology in the daily wise.

2.2.3 Rainfall/Precipitation

The rainfall in Mustang occurs occasionally. In the past there was no rainfall whereas due to the change in climate the rainfall occurred in Mustang nowadays. The daily wise data of the stations are needed to be collected. The effective rainfall is needed to be calculated which is 80% of the total rainfall [] automatically calculated by the Cropwat software.

2.2.4 Wind Speed

Wind Speed is measured by the anemometer. The data of the wind speed should be collected at the height of 2m. Since the wind data at 2m is not available so factors are used to convert the wind speed at the standard 2m which is calculated as mentioned in [5]: $u_a = u_z x \frac{4.87}{\ln(67.8xZ - 5.42)}$ where, u_a is the wind speed at the 2m, u_z is the wind speed at any height and Z is the height.

2.2.5 Sunshine hour

The interval between the sun rise and sun set where the sunshine recorder make marks through which the time interval is measured. The sunshine hour of the Mustang has been taken from the report published by ICIMOD [6].

2.2.6 Crop coefficient

Crop Coefficient is the relative ratio of the evapotranspiration of the crop to the reference evapotranspiration or it is a factor to determine the evapotranspiration of the crop with the reference evapotranspiration. The crop coefficient is calculated by using below formula. $ET_c = K_c x ET_0$. Crop coefficient is also define as the factor which shows the relationship between the reference grass crop and the crop actually grown [7]. The different crops that are grown under different climatic condition require the different amount of water. The crop coefficient is collected from the department of the irrigation, Jawalakhel which is under the prescribed value of Food Agricultural Organization value. The crop coefficient is different for the different stages of the plants. They are initial stage, development stage, mid stage and late stage. Different crops have different periods for cultivation, flowering and harvesting and the respective crop coefficient is also different. The crop coefficient is also different under different humidity and wind speed. It is also affected when there are more than one crops in the same field.The crop coefficient can be derived from FAO Irrigation and Drainage Paper No. 24.

2.2.7 Soil characteristics and soil type of Mustang

The total area of Mustang is divided into four different soil characteristics zones as Alluvial Plain, Past glaciated mountainous terrain above the elevation limit of arable land, Past glaciated mountainous terrain below the elevation limit of arable land and river/gravel bed/boulder where the most of the human settlement area of mustang lies in Alluvial Plain. Mustang district has the four different soil type zones according to the soil texture based on the Land System. The percentage of the area based on the soil types are river (0.91), fragmental loamy (61.86), loamy skeleton (36.98) and loamy (0.26) [4]. The soil of the upper mustang is found to be river and loamy skeleton whereas the central has loamy skeleton and lower has the loamy and loamy skeleton. It has prepared the GIS map too which is attached in the Appendix 2. This soil mapping is used in the crop water demand calculation of the Mustang, Nepal.

2.3 Crop calendar

Defining Crops those are grown in different places are important for the water demand calculation. The crop can be dry or wet. The study is to be made about the different crops that are grown by the people at the different region of Mustang and the survey village of Tiri. The field survey and interaction with the farmers of the Tiri, Mustang is indeed so that the crop calendar is prepared. The crops should be included that are grown throughout the year. In Mustang the commercialization is not practice where the people cultivated for their livihood whereas in the few years now with the good market price of some cereals they are changing their crop patterns.

2.4 Water demand calculation

In order to calculate the crop water requirement it is very important to calculate the reference evapotranspiration, ET_0 whereas Cropwat 8.0, the software has made the work more easy where by

providing the input of meteorological datas the output evapotranspiration is obtained whereas by providing the input of crop coefficient, soil properties and the days of different growing stages of the crops provide the irrigation water requirement or the precipitation deficit in mm per ha per day throughout the year.
The crop water requirement is calculated as [8]:

$$ET_0 = \frac{0.408\Delta(R_n - G) + (\frac{900}{T_a + 273})v_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34v_2)}$$

where,
ET_0 = Reference Evapotranspiration (mm/day)
R_n = the monthly average daily net radiation at the soil surface $MJ/m^2/day$
G = the soil heat flux density $MJ/m^2/day$
T_a = the monthly average daily air temperature ($^\circ C$)
Δ= the saturation slope of the vapour pressure curve at T(kPa/$^\circ C$)
γ= the psychometric constant (kPa/$^\circ C$)
e_s = the saturation vapour pressure (kPa)
e_a = the monthly average daily actual vapour pressure (kPa)
v_2 = the monthly average daily wind speed at 2m above ground (m/s)
The Crop Water Requirement (CWR) is given by the difference between Evapotranspiration under standard cultural conditions, ET_c (mm/day), and Effective Precipitation, P_e (mm/day):

$$CWR = ET_c - P_e = ET_o K_c - P_e$$

Where,
K_c = the cultural coefficient dependent on crop growth stage.
The effective precipitation Pe was calculated as 80% of total precipitation [9].
The Irrigation Water Requirement (IWR) has been obtained with the following equation:

$$IWR = \frac{CWR}{\eta_{irr}(1 - LR)}$$

Where,
η_{irr} = the Efficiency of the Irrigation System assumed to be equal to 80% [10];
LR = the leaching requirement needed to remove residual salts from the root zone, assumed to be equal to 18% [11] .
Hourly simulations of the IWR can be performed by adjusting equations above to hourly time step [8].

2.5 Height and length measurement

The height measurement is done with the fly wheel measurement method. Since there will be the use of the pipe so pipe loss will be added in the total height measurement.
Total Dynamic Head for pump (TDH) = level difference between sump well and service reservoir head loss + suction head
The length is measured with measuring tape from the source of the water to the reservoir tank.

2.6 Loss in the pipe

The head loss of the pipe should be calculated in order to calculate the total height of the system. There are major and minor losses in the pipe. The major loss is the head loss with the friction factor whereas the minor losses are joint loss, elbow loss. Since the friction factor for the different pipe is different. The friction factor is obtained from the moody diagram and head loss is calculated according to the to the Darcy's Weisbach formula [12]. The head loss depends upon the type of the selection of the pipe. The height is measured including the head loss with the minor and major loss. The coefficient of friction is calculated using jain's equation formula whereas Darcy's Weisbach formula has been used for the calculation of the head loss as mentioned [13]. The respective formula are in equations below.

$$\frac{1}{\sqrt{f}} = -0.869\ln(\frac{\frac{\varepsilon}{D}}{3.7} + \frac{2.523}{R\sqrt{f}})$$

Where,
f= coefficient of friction,
ε= roughness(mm) ,
D = diameter of the pipe(mm) ,
$\frac{\varepsilon}{D}$ = relative roughness ,
R= Reynolds number

$$H_1 = \frac{fLv^2}{2gD}$$

Where,
f = coefficient of friction,
L= length of the pipe,
v=velocity of the flow in pipe,
g= acceleration due to gravity,
D = diameter of the pipe

2.7 Power Demand Assesment

The SPVWP power peak $P_(p, pvwp)$ (kWp) can be calculated based on the following equations (Campana, 2015)

$$IWR^{PCC}_{t,m} = \sum_{j=1}^{x} IWR^{IPCC}_{t,m}, m = Jan, Feb, \ldots Dec$$

IWRt,m represents total monthly average daily irrigation water requirement $(m^3/ha/day)$ given by the sum of the IWR of the j-th crops with x equal to total number of irrigated crops

$$P_{p,pvwp}(kWp) = \frac{0.0027TDH}{f_m[1-\alpha_c(T_{cell}-T_{STC})]\eta_p} max_(m) \frac{IWR^{IPCC}_{t,m}}{E_{s_m}}$$

where,
0.0027 a conversion factor that takes into account the density of water ρ $(1000kg/m^3)$
g = gravity acceleration $(9.8m/s^2)$
f_m = the matching factor assumed to be equal to 0.9 (the matching factor can be adjusted to also consider power losses during the lifetime of the PV generator and other derating factors, such as soiling or shading)
α_C = the temperature coefficient of the PV power, equal to 0.45 $\%/°C$
T_{cell} = the PV cell temperature $°C$
T_{STC} = the temperature under standard test conditions $(25°C)$
η_p = the efficiency of the pump (%);
E_{s_m}= Monthly average daily solar irradiation hiting PV array

2.8 Array Sizing

The current delivered can be determined by

$$I_{array} = \frac{P_{p,pvwp}(kWP)}{V}$$

Where,
$P_(p, pvwp)(kWp)$ = the total power required for the pumping system ,
V= system voltage
A single module cannot deliver the require current so a number of modules are needed to connect in parallel. The number of required modules to be connected in the parallel is calculated using

$$N_p = \frac{I_{array}}{I_{mp}}$$

Where,
I_{mp} = the current at maximum power of the module,
I_{array} = total current delivered by the array of panel
The system voltage depends upon the selected pump/power conditioner to be used. So the number of panels need to be connected in strings in order to obtain the system voltage which is calculated using

$$N_s = \frac{Nominal\ system\ voltage}{Nominal\ module\ voltage}$$

Where,
Nominal module voltage = the output voltage given by the panel
Finally, the total number of modules can be determined by:

$$N_t = N_p x N_s$$

The efficiency of the solar panel is also effected by the shadow. In order to remove the shadow problem that might appear due to improper installation of solar panel arrays so the gap should be maintained between them. Distance between consecutive string is calculted by:

$$a = d(cos\beta + sin\beta x cot\alpha)$$

Where,
d=breadth of a module,
β= tilt angle of panel,
α= 66.5°-lattitude of location, also called as solar altitude angle in December 21st
With the basic gap the area required to install the array of the panel can be calculated.

2.9 Solar Insolation

Solar insolation is a measure of solar radiation energy received on a given surface area in a given time. It is commonly expressed in kilowatt-hours per square meter per day (kWh/m^2/day). It is the factor which variant the efficiency of the solar PV performance. The solar insolation of the different place is different. The annual global solar insolation of the Mustang district lies in the range of 5.063 kWh/m2/day and the annual tilt solar insolation is 6.379 kWh/m2/day [14].

2.10 Components Selection

Solar Panel: There are different types of the panel used for the energy generation. The panel should be higher efficiency with the good payback periods. The solar panel with the compliance is to be selected. The solar panel with the certified tag should be selected. For the efficiency the Form Factor, $FF = (V_{mp} * I_{mp})/(V_{oc} * I_{sc})$,where Voc, Isc, Vmp and Imp are the factors that need to be considered. The unit of power is Watt peak (Wp). Charge controller: There are different types of charge controller available. The charge controllers are PWM and MPPT type. For the solar pumping modulation the MPPT should be selected because the MPPT charge controller check the PV module voltage with the battery voltage and fixed the best voltage that PV module can charge the battery convert the voltage from the PV module to the best voltage so that it can charge the battery. MPPT can works at the cold weather, cloudy and hazy days.In the solar PV pumping there is a solar drive which helps to convert the dc to ac and helps in driving the solar pump. Some company has inbuilt solar charge controller and the converter. Solar Pump:Solar Pump is the mechanical device which is used to lift the water from well to the reservoir tank. There are different types of pump available. They are centrifugal, horizontal pump. They can be cascaded to lift at the most height. Solar Pump available in Nepal are Grundfos, Lorentz pump, Mono pump and Shakti Pump. It is available in Hz or kW capacity. It converts the electrical energy into mechanical energy. Some pumps are submersible and some are surficial type. In the submersible pump there is no suction head whereas the surficial pump has the suction head. Some are DC drive and some are AC drive Solar Pump. Selection of Solar Pump is based on the height and discharge of water required. Along with it the drive controller selection is important whereas the manufacturer provide the system in different package.

2.11 Wire Sizing

There are different types of wires required while designing the solar PV pumping system. The connecting wires are different for connecting the PV and the controller, from controller to motor. There are different theories for wire sizing. Ampacity theory and voltage drop theory. Nowadays different web page softwares are available for the selection of the wire size. Some wire sizing web pages for either the single phase or three phases are done (engineeringtoolbox.com, 2017) and (wiresizecalculator.net, 2017) with links. For the DC current the wire sizing can be done using the formula in equation (21).

$$s = \frac{\rho L I_m}{\Delta V}$$

Where,
ρ = resistivity of the copper conductor ($1.68x10^{-8}$ Ω m),
L= Length of the wire (m),
I_m = maximum current flow through the wire (A),
ΔV = voltage drop (V)

2.12 Discharge Measurement by the Area Proportion Method

The Area Proportion method has the significant role in measuring the discharge of the ungauged site of river. If there is the gauged data of the river then the discharge of the ungauged places can be calculated with the Area Proportion method. Catchment area is measured. The linear and Non linear discharge can be obtained where alpha factor is obtained by taking the log of the ratio of the two gauged station catchment areas (A1,A2) and beta factor is calculated by log of discharge proportion(D1,D2) of known gauge station divided by the log of the respected area proportion. The nonlinear is calculated with the beta factor whereas the linear without beta factor [15].

$$\alpha = \log \frac{A1}{A2}$$

,

$$\beta = \frac{\log \frac{D1}{D2}}{\alpha}$$

Nonlinear discharge=$\frac{A1}{A2}^{\beta}$ x monthly average long term discharge)
Linear discharge=$\frac{A1}{A2}$x monthly average long term discharge

3. Results and Discussion

3.1 Survey and primary data collection

The total area without the human settlement with the use of the Google Earth and from the data collection from the survey the total land of the field is found to be 12.85 ha. The distance from the source of water (sump) to the upper reservoir is measured as shown in Figure 4 which is measured to be 544 m.

Figure 4: Measuring the length from the source to reservoir

According to survey with the leveling device the static height of 57m between the level of water from the intake and reservoir is calculated whereas the total head loss is calculated to 9 m. Hence the total dynamic head is 66 m.

The source of water is Kali gandaki river and according to the area velocity method for the flow measurement for December 2nd is found to be about 6.32 m^3/sec whereas using the unpublished data of two stations obtained from DHM 403 and 403.5 station of Kaligandaki river from the year 2005 to 2014 using area proportion method (McMahon et al), it is found that the average discharge in December is 10 m^3/sec for linear and 8.68 m^3/sec for non linear. The river is able to meet the water demand for the crops which is calculated as 0.02 m^3/sec. Non linear and linear discharge of Kaligandaki river is shown in figure 5.

3.1.1 Crop calendar

Tiri, Kagbeni is a small village. The potential agricultural area is 12.85 ha. There is a similar agricultural farming in Jomsom. The necked barley, barley are grown in the winter seasons whereas the beans, potato, summer vegetables are grown in the summer seasons and apple is the fruit which is in the farming strategy in the huge area. At the present stage the area of apple and maize are not included as shown in figure 6 whereas the area for the apple and maize are

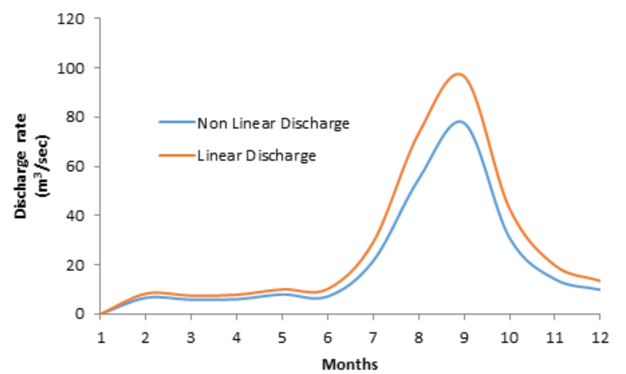

Figure 5: Non Linear and Linear discharge of Kaligandaki at the Kagbeni, 9

included with the solar pumping system which is shown in figure 7. In the winter during snowing seasons crops like Naked Barley and barley are sowed which takes 210 days from the sowed to harvest likewise buckwheat (90 days), potato (105 days), maize (125 days), beans (105 days) are the cash crops that are grown in the summer, there is the potential for growing the fruits like apple in the bank of the Tiri village where plantation of the plant in the December middle and harvest the fruits in the end of the September The apple plant only start to produce the fruits at the age of 5 years whereas the after 10 to 15 years it start to produce large quantity of apples. There are 20 numbers of apple plants in 1 ropani [16]. Legend: S=Sowing, E= End/Harvest

SN.	Crop	Days	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
1	Necked Barley	210						E					S	
2	Barley	210						E					S	
3	Buck wheat	90							S				E	
4	Bean	105						S				E		
5	Potato	105						S				E		
6	Summer Vegetables	90				S				E				

Figure 6: Crop Calendar without pumping system

SN.	Crop	Days	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
1	Necked Barley	210						E					S	
2	Barley	210						E					S	
3	Buck wheat	90							S				E	
4	Bean	105						S				E		
5	Potato	105						S				E		
6	Summer Vegetables	90				S				E				
7	Maize	125							S				E	
8	Apple	290										E		S

Figure 7: Crop calendar with the pumping system

3.1.2 Interpretation of climatological data

Since there is no available of meteorological data of Tiri Village till the date so some data related to rainfall, humidity are taken from Jomsom station whereas the temperature has been calculated with the lapse rate equation. Using the FAO Cropwat 8.0 software the monthly wise reference evapotranspiration, effective rainfall and irrigation required of Tiri Village are obtained are shown in Table 1, Table 2 and Table 3 where l/s/h stands for liter per second per hector, IAA stands for Irrigation required for actual area

Considering the water deficient month of year, April it is found that the Irrigation water requirement is $880.07m^3/day$ for the total land of the 12.85 h whereas the least deficit is on November with $84.62m^3/day$. There is a drastic change in the water demand throughout the year.

3.2 Solar PV pumping design component selection

3.2.1 Power demand calculation

The power required of solar panel for the irrigation of the Tiri village is calculated where solar PV peak power is 31.82 kW is obtained with the solar insolation of 5 kWh/m2/day which is slightly less insolation than that of the 5.1 $kWh/m^2/day$ (AEPC, 2008), with the cell temperature of 30 $°C$, 2016 obtained from the primary data for the month November, with the total monthly average daily irrigation water requirement of 439.9 $m^3/ha/day$. But with the water demand capacity of April which is $880m^3/day$ and height of 66 m as referring to catalog available in the (alldocs.net/50hz-solardc-catalog-24june2016-pdf, 2016) , the array power required is obtained as 32 kWp. The selection of the solar panel. There are different panel among them poly type Trina solar panel is selected.

3.2.2 Array sizing

: Single panel cannot meet the current and voltage so the panels are connected in the string and in the parallel or in the array. Using the equation 15, 16 , 17 and 18 with the selected panel of 315 Wp as mentioned in above, the number of panel in string (Ns) is calculate 17, whereas the number of panel in the parallel (Np) is 6. Hence the total number of the panels (Nt) required is 102. The connection of the panel is shown in the figure 8.

3.2.3 Solar Pump

Here the system is designed with the single pumping since the water demands during the drought month, April is $880m^3/day$, which is the highest water demand throughout the year for 12.85 hectors of land. The water pump is selected with reference to the height and water demand capacity. So in order to uplift the required water demand the pipe of diameter 200 mm HDPE pipe is required to withstand pressure of 10 kg/cm2. In Nepal there is no any industry to build the water pump so have to depend on the other countries. The Shakti pump is selected in the design which is manufactured in India as it has DC controller inbuilt converter which converts the DC to AC current. The required model is DCSSP32000-67-23 which specifies that at the height of 67 m the pump can uplift water at the array power 32000 W with the rate of 23 l/watt (alldocs.net/50hz-solardc-catalog-24june2016-pdf, 2016). It is a 3p, 35 Hp pump with the 400 V, Initially there needs the high current in order to start the motor, required current to operate the pump is 47.108 A. Hence the solar controller is selected of the model DCSHAKTI-3P-60A.

3.2.4 Lightening Arrestor and Earthing Jam Chemical Earthing

Chemical Jam is used for the protection with grounding and earthing in the Solar PV system and Lightening Arrestor are used for the proctection from natural lightening.

3.2.5 MCB

The MCB switch is required in the system in order to save from any accident like short circuit. There are different types of MCB available in the market. Single Pole (SP) MCB, Double Pole (DP) MCB, Triple Pole (TP) MCB, TPN MCB. The selection of the switch is done in the Ampere rating. We can use number of MCB as needed. With the system voltage 600 V in this design the MCB switch voltage rating is greater than equal tp $1.20xV_{oc}xN_s = 930.24$ V(for each 17 number of panels in string) switch amp rating is greater than eaual to $2x(1.56xI_{sc}) = 28.08$A, where

Table 1: Reference evapotranspiration,ET0 (mm/day) of Tiri Village

Tiri	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ET0(mm/day)	1.17	2.16	2.91	3.55	3.97	4.05	3.37	3.29	3.15	2.87	2.24	1.97

Table 2: The Effective Rainfall (mm) of monthly rainfall, the average from 2005 to 2014 of Tiri

Tiri	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Effective Rainfall(mm)	9.4	22.3	20.5	19.6	20.3	32.4	55.4	36.7	33.6	28.7	1.3	2.7

V_oc = open circuit voltage
I_sc= short circuit
current rating MCB 1000V,32A SL7-63 is selected to be used in each six row. The selection of the solar dc controller where some system has inbuilt MCB where the current flow of 57.7 A so DCSHAKTI-3P-75 is selected with the MPPT range (Vdc) 320-700 V and maximum input voltage of solar array 780 V. From controller to pump with the delta connection the AC molded MCCB is designed with the 480 V and 49 A current where selected switch model is DG VL Bre 480 V.

3.2.6 Wire sizing

Wire sizing were down with the help of the software available in the internet and cost of the wire is estimate. With the voltage drop 3%, 3% and 5% from panel to combiner, combiner to controller and controller to motor respectively, from Panel to Combiner wire size of 0.45 mm is required, from Combiner to Controller wire size of 0.57 mm, from Controller to Motor wire size of 2.5 mm is required. From panel to combiner ultra violet wire should be used in order to protect from the sun and rain and increase its durability.

3.2.7 Area calculation to install the panels

For the Direct Single Pump lifting it requires 102 panels and therefore the solar panels should be arrange in such a ways that it has less effect to the winds and shadow effect from the consecutive array.The dimension of the solar panel is of 1956 mm*992 mm*40 mm. The required number of the panel in the string is calculated 17 panels whereas the required number of the panels in the parallel is 6. In order to remove the shadow effect the certain gap should be maintained between the rows. The calculated gap is 3 m between the rows with the solar panel tilt angle 30 ° and latitude of location 28.8 °, the calculated area required to install the panel is 287 m^2 (nearly 9 anna). The schematic wiring design connection of the solar pv pumping system is shown figure 8.

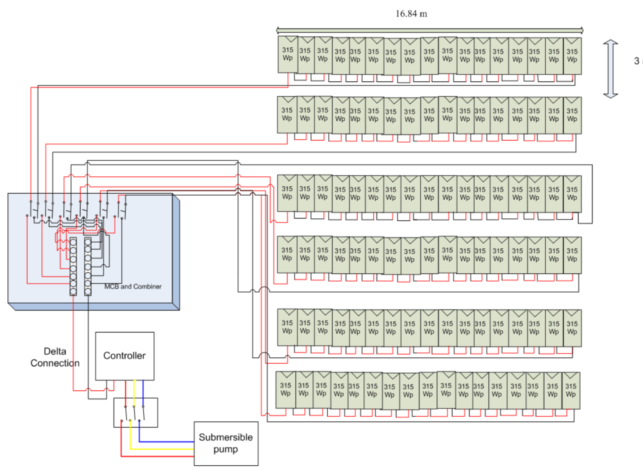

Figure 8: Design of the Solar PV pumping wiring connection

3.3 Diesel pumping system design

Diesel is the fossil fuel which is imported from aboard. The initial cost of the project with the diesel pumping is cheaper than the solar PV pumping. The system includes diesel generator, the supplier of power which is specified in the VA or kW range with the flow rate capacity (m^3/h). Since it generates the AC current so there is no need of the inverter/converter to operate the ac pump. The operating cost includes the fuel cost. In mustang there are no oil stations so the cost of the diesel fuel per liter is NRs. 120 which is NRs. 72 in Kathmandu in 2017. According to the trend of the diesel oil price from the year 1994 to 2005 the average increase rate is 7%, (NRB, 2007). The Diesel pumping system is design for the same water demand where the system includes three phase Diesel Generator with controller, pump and wiring system. The same AC Shakti pump is used for the diesel

Table 3: Irrigation water requirement of Tiri

Tiri	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
mm/day	1.4	1.8	3.0	3.8	4.4	2.3	1.8	2.9	3	1.2	0.4	0.9
mm/month	43.1	51.4	91.7	114.0	135.5	69.4	54.5	88.9	90.7	36.6	10.6	27.8
l/s/ha	0.16	0.21	0.34	0.44	0.51	0.27	0.2	0.33	0.35	0.14	0.04	0.10
IAA(l/s/ha)	0.19	0.25	0.4	0.52	0.51	0.27	0.21	0.33	0.35	0.14	0.05	0.12
IWR (l/s/ha)	0.29	0.38	0.61	0.79	0.78	0.41	0.32	0.50	0.53	0.21	0.08	0.18
$m^3/ha/day$	25.02	32.93	52.68	68.49	67.17	35.56	27.66	43.46	46.10	18.44	6.59	15.80
12.85 ha	321	423	676	880	863	456	355	558	592	36	84	203

pump which is 35 hp and voltage of 400 V, three phases.

3.3.1 Diesel Generator

Diesel generator is required to generate the power supply to the pump. The power of generator is designed in such a way that it can provide the rate current to operate the pump where with the thumb hand rule, the required power of the generator is 29.5 kW with the voltage of 400 V. It means it requires the 37 kVA, three phase generator with the voltage of 400 V whereas this generator is not available so design of 40 kVA generator with the rate current 57.7 A is used whereas the required current for the pump is 47.10 A. The selected diesel generator is the Bhojani model, BG-03, which has the specification of fuel consumption of 6 liter/hours, operated in the frequency of 50 Hz where the rated power of 50 A according to the catalog, which is sufficient to operate the pump. The total diesel consumed by the generator for the 12 hours is 72 liters per day.

3.3.2 Diesel Wire sizing

From generator set to the pump the wire is required to connect. The calculated size of the wire is 2.05 mm.

3.4 Financial Analysis

The initial cost of the Solar PV pumping System is more than other irrigation system. In order to make a system more economical the design of the single pumping system is used. The total initial cost of the project is NRs. 9,988,165. The financial analysis is done for 25 years. The cost include the electromechanical cost (solar pump, panel, wire, pipe, controller, land, construction of the storage tank, transportation and miscellaneous cost. The pie chart shown in figure 9 shows the proportion of the total cost.

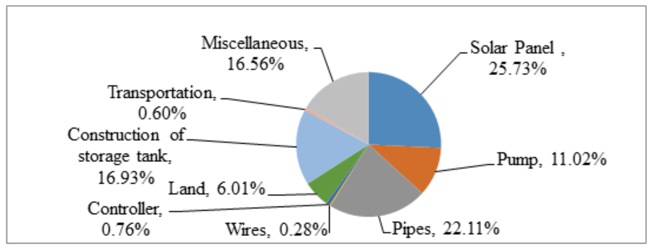

Figure 9: Investment cost proportion of the Solar PV pumping system

Similarly the initial investment cost of the diesel pumping system has been calculated. It is found to be less than that of the solar PV pumping. The initial cost of the diesel pumping is Rs. 7,299,543.84. The pie chart shown in the Figure 10 shows the proportion of the total cost in the diesel pumping system.

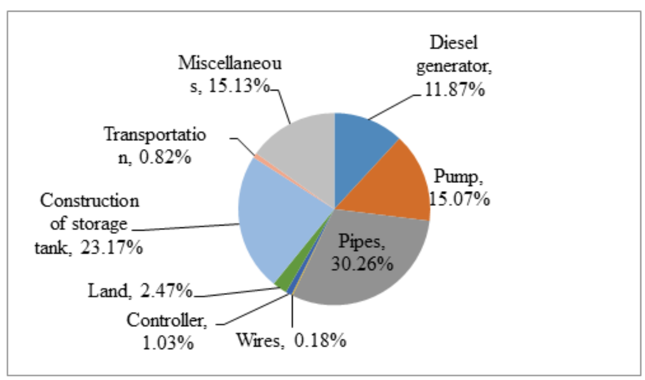

Figure 10: Investment cost proportion of the Diesel pumping system

In order to understand wheather this project is feasibile with the financial point of view this project is studied under three scenarios as shown in chart below figure 11.

Table 4: Summary of the financial feasibility of solar PV pumping system

SN.	Scenarios	NPV(NRs.)	IRR(%)	B/C	Payback Periods
1	Scenario I	(3,837,256)	6	0.82	27
2	Scenario II	(2,838,439)	7	0.86	15
3	Scenario III	(840,806)	9.02	0.96	6
4	Scenario IV	1,156,827	11.43	1.07	2

Table 5: Summary of the financial feasibility of diesel pumping system

SN.	Scenarios	NPV(NRs.)	IRR(%)	B/C	Payback Periods
1	Scenario I	(3,509,509)	3%	0.93	17.10
2	Scenario II	(2,779,554)	5%	0.95	10.70
3	Scenario III	(1,319,646)	7.29%	0.97	4.7
4	Scenario IV	140,263	10.30%	1.00	1.43

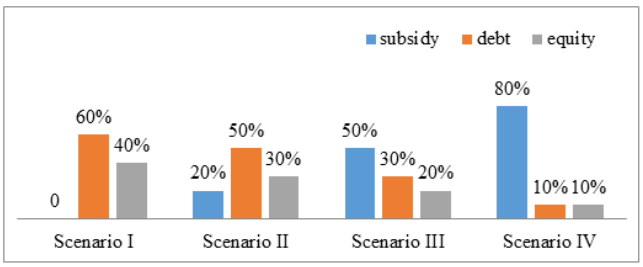

Figure 11: Four different scenarios

The system is designed for 12.85 hectars of land. Since there are 14 land owners in the village with respect to the portion of their land and the debt is taken at 10% interest rate whereas the discount rate is taken at 10% as per the data taken from the thesis report [17] and civil depreciation rate of 3% and the electromechanical depreciation rate of 5%. The NPV and cost of water per m^3 were calculated at the affording revenue collection. At the affording capacity of the villager in the solar PV pumping if they are able to collects the revenue of NRs. 20 lakhs annual which goes on decreasing with the rate 0.5% then it is feasible with the scenario IV where the price of the water per m^3 is NRs 121 and NPV is positive but the rest of the scenarios are found to be not feasible. Similarly the calculation of the the internal rate of return, benefit cost ratio and simple payback are calculated of each scenarios. Since this project is based on the non profit community based so there is no tax system and electromechanical part, solar pump has been proposed to repair every 5 years. The Table 4 shows the summary of the financial feasibility factors of solar PV pumping system.

The Scenario IV will be the best scenario for the farmers as it is affordable. Similarly the financial feasibility factors are summarised in the Table 5 of the diesel pumping system.

It is found that the rate of water per m^3 is less for the scenario IV where as the Scenario I has the highest one. The Scenario IV will be the best affordable scenario for the farmers only if the revenue collection per year cross the twenty lakh. The debt is taken 10% interest rate whereas the discount rate is taken 10% as per the data taken from the thesis report [17].

3.5 Agriculture benefits

Considering the crop calendar and data of crop production in metric tons (Mt) per hectors of Kagbeni VDC from the annual agricultural development program and statistics book (2013/14) [16] the crop production of Tiri has been calculated. The production rate is defined as how much the crops are produced in metric tons from the unit area. With the given production rate the total production from different crops with respect to covered area of the total production of Tiri village are calculated. Table 6 shows the different productivity rate of different crops in Kagebni. The Figure 12 shows the cultivable land of Tiri village with and without the pumping system. It shows that the exploitation of the land from maize, beans, potatoes and apple are increased whereas the buckwheat, naked barley and summer vegetables are reduced and barley is constant.

Table 6: Productivity rate of different crops in Kagbeni

SN	Crops	Area (A) ha	Production (P) Mt	P/A
1	Maize	36	46	1.28
2	Buckwheat	43	70	1.63
3	Naked Barley	33	66	2.00
4	Barley	16	30	1.88
5	Beans	3	3	1.00
6	Summer Vegetables	14	178	12.71
7	Potatoes	30	375	12.50
8	Apples	39	498	12.77

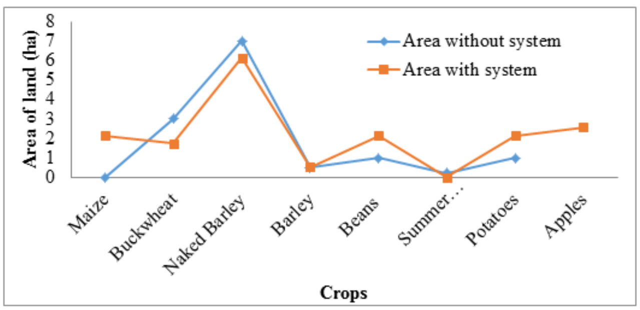

Figure 12: Cultivated land of respective crops with and without pumping system

In the present context the cultivated land is 10.74 ha only whereas the rest land is barren. With the use of technology the cultivated command area is calculated to 12.85 ha with the increase in the apple farming land whereas the naked barley command area is decreased. With the production of maize and apple farming the crop intensity is appeared to be increased.

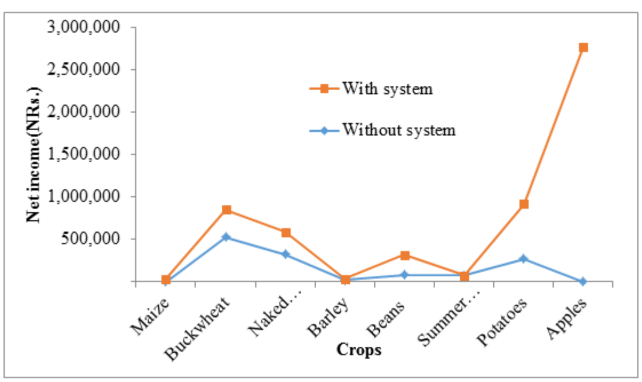

Figure 13: Agricultural net income with and without pumping system

The agricultural balance sheet of the Tiri village is calculated and comparison of the income without and with the system has been done. According to the calculation considering labour cost, fertilizer cost and pesticide cost and with the present price of the crop the net income were calculated where there is the net income of NRs. 1,282,457 without the system where as the net income of NRs. 4,306,495 is generated with the system where the crop intensity is increased to 136% from 99%. Figure 13 shows the agricultural net income with and without technology.

4. Conclusion

For the interpretation of the climatological data of the Tiri village the data of Jomsom station is considered. Below are the enlisted point of finding. An appropriate crop calendar of Tiri with pumping system and without system, with frequent site visit and discussion with farmers and Department of Agricultural, Mustang has been prepared where the crops are found to be feasible for harvesting throughout the year. The reference evapotranspiration of the Tiri has been calculated using the secondary data from Department of Hydrology and Meteorology from year 2005 to 2014 where the monthly average reference evapotranspiration is 88.25 mm and the monthly effective rainfall is 23.58 mm. The trend of reference evapotranspiration of Tiri is higher throughout the year except November to February whereas the rainfall is maximum in July and least during November and January. The water demand of the crops of Tiri is calculated with the help of the software Cropwat 8.0. During drought month (April) the highest irrigation water demand of the crop is 880 m3/day whereas in the November the demand is least with 84 m3/day. Power demand assessment has been done with respect to the irrigation water demand where theoretically the solar PV pumping power required is found to be 31.82 kWp whereas using the water drought month with the height 66 m and discharge rate of 880 m3/day for the duty of 9 hours the required power is 32.13 kWp. Diesel pumping system of 40 kVA (32 kW) is the required for the same purpose. The financial feasibility is performed comparing with different scenarios. Scenario I (subsidy/donors (0%), Debt (60%), Equity (40%)); Scenario II (subsidy/donors (20%), Debt (50%), Equity

(30%)); Scenario III (subsidy/donors (50%), Debt (30%), Equity (20%)) and Scenario IV (subsidy/donors 80%, Debt 10% and Equity 10%). The NPV, IRR, B/C and simple payback of respective scenarios I, II, III and IV are calculated for both Solar PV pumping and Diesel pumping system where in both the scenario IV are more feasible than other scenarios. Even though the intial investment cost of the diesel pumping system is less by 1.3 times but the cost per m3 of the water is higher than the solar PV pumping. The cost of fuel(energy) is added annually in the expenditure in the diesel system whereas it is free in the solar PV pumping. Even though the duty cycle of the diesel pumping system is 12 hours more than the solar PV pumping, there is no change in the capacity of pump and the rate of water per m^3 is found to be more in the diesel pumping system by 2.7 times. In Mustang, the price of the fuel is higher than the other region by 2 times so the cost of the fuel is higher. Hence the solar PV system is better than the diesel pumping system in Tiri Village.

5. Recommendations

Further attempts can be done to calculate the crop coefficient of different crops that are not included in the FAO data based on Nepal climatic region. It would be more accurate and effective if all the climatological data available of the Tiri Village. Similar analysis can be done for other places of the mustang. This Projects can be further study for the electrification and grid connection in the Tiri Village from the solar panel array system.

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References

[1] Alternative Energy Promotion Center. Renewable energy subsidy policy, 2073 bs. Technical report, 2016.

[2] District Development of Committee. District profile of mustang. Technical report, 2013-14.

[3] Water and Energy Commission Secretariat. *LNational Energy Strategy of Nepal*. GoN, 2012.

[4] Krishna KC, K. R. Poudel, N Poudel, R. P. Pokharel, and S. Koirala. ”resource mapping report-2014”. 2011.

[5] FRENKEN K. SAVVA A. P. *Crop Water Requirements and Irrigation Scheduling*. FAO, 2002.

[6] S. R. Chalise, M. L. Shrestha, K. B. Thapa, B. R. Shrestha, and B. Bajracharya. *Climatic and Hydrological Atlas of Nepal*. ICIMOD, 1990.

[7] M. Heibloem C. Brouwer. *Irrigation Water Management Training manual no. 3*, 2001.

[8] R. G. Allen, L.S. Pereira, D. Raes, and Smith M. *Crop evapotranspiration-Guidelines for computing crop water requirements*, 1998.

[9] L Tanasijevic, M Todorovic, LS Pereira, C Pizzigalli, and P Lionello. Impacts of climate change on olive crop evapotranspiration and irrigation requirements. 2014.

[10] Penning de Vries FWT Karlberg L. Exploring potentials and constraints of low cost drip irrigation with saline water in sub-saharan africa. 2004.

[11] Simunek J Corwin DL, Rhoades JD. Leaching requirement for soil salinity control: Steady-state versus transient models. 2007.

[12] Bedford Streeter, Wylie. *Fluid Mechanic*. ninth edition.

[13] Karki R Shrestha JN, Jha AK. *Training Manual on Solar PV Pumping*, 2014.

[14] Alternative Energy Promotion Center. Solar and wind energy resource assessment in nepal final report (gis part). Technical report, 2008.

[15] TA McMahon, JD Fenton, MJ Stewardson, J Costelloe, and BL Finlayson. Estimating discharge at an ungauged site.

[16] District Agriculture Development Office. *Annual Agriculture Development Programme and Statistic Booklet*. GoN, 2013-14.

[17] Sapkota B K. Techno-economic analysis of solar photovoltaic based water pumping system for drinking water in dhanding district of nepal. Master’s thesis, 2014.