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Socio-Economic Assessment of Solar Irrigation System in Saptari, Nepal

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Abstract

Agriculture is one of the major contributors in the Nepalese economy.And irrigation is important for better agriculture yield.Traditional irrigation systems including diesel pumps, large irrigation conveyance for small land holder are costly and hence an optional system like solar pumps offers a clean and simple alternative to fuel-burning engines and generators for domestic water,livestock and irrigation.The study carries out socio-economic assessment of photovoltaic based water pumping systems in agricultural sector to produce the yield with low cost in Rupani Rural Municipality of Saptari district.The study is primarily based on people perception with heavily relied on the review of secondary data relating to agriculture,socio-economic and climatic data recorded over time and space.FGD, KII and question survey were done,processed, tabulated and analyzed.

The study findings reveal that the overall costs and energy consumption of PV pumping system is lower despite higher initial investment compared to the diesel pumping system.The initial investment cost for solar-based pumping system is high as Rs 291,113.Life cycle cost (LCC) analysis was conducted to assess the economic viability of the system was found to be Rs 54,487,that of diesel water pump was Rs 1,46,691 and that of electric system was Rs 21,264/-.

Based on crop pattern analysis,crop water requirement per year was found to be 58 million m3.The unit cost per m3 required for solar water pump,diesel water pump and Electric Water Pump were estimated to be Rs 24.46,Rs 65.85 and Rs 9.546 respectively.Using the solar WP as compared to diesel WP,farmers can save for about Rs 2,185 million per year annually.Per HH, they can save about Rs.436,000 in general.The savings can be increased if the irrigation systems,agriculture procedures and crop pattern are optimized.The study estimated that HH income from agriculture in existing condition is Rs 103,258.If the solar based irrigation is used the income will increase to Rs. 195,874.This study hence recommends using solar irrigation system for water pumping application to irrigate cultivable land in the study areas in general

Keywords
Solar Water Pump – Financial Analysis – SPSS – Cropwat

1. Introduction

1.1 Background

Agriculture is the main stay of Nepalese economy and around 74%of Nepal's population is engaged in agriculture [1] pre-dominantly of subsistence nature which provides food and livelihood security to a substantial section of the Nepalese population accounting 40% of GDP [2].The livelihood of the Nepalese depends on forest,grassland and mostly agriculture,for this reason Nepal is identified a highly vulnerable country to Climate Change[3].Any extent of change in climatic variables therefore directly affects agriculture performance.However,change in climatic variability and uncertainty has been posing increasing threats on agriculture.Such trend has seriously threatened the livelihood and food security of those who depend on agriculture [4].Nepal's agriculture is largely rain fed and food security is dependent on the characteristics of the monsoon rain.To overcome the dependency on monsoon there is need of new technology for long time solution.

The technology to pump groundwater in ways that are economic and environmentally friendly should be developed.Solar pumps offer a clean and simple alternative to fuel burning engines and generators for domestic water, livestock and irrigation.Solar pumps are most effective during dry and sunny seasons and require no fuel deliveries,minor maintenance,easy to install, naturally matched with solar radiation as usually water demand increases during summer when solar radiation is a maximum,and less expensive than other alternative sources of energy.There are opportunities for increased use of clean energy technologies to enhance agriculture production and value.Not only is there an identified need for technology development,but also for creative approaches to bring clean energy innovations to commercial scale.The consumption of fossil fuels also has a negative environmental impact,in particular the release of carbon dioxide(CO2)into the atmosphere. CO2 emissions can be greatly reduced through the application of renewable energy technologies,which are already cost competitive with fossil fuels in many situations.

1.2 Introduction to Rupani Rural Municipality

Figure 1 shows that the study area,the area of municipality is 5,808 ha with total cultivable land area of 4,548 ha,which consisted of 3,929 ha cultivated area. The rural municipality is covered with forest land of 1,014 ha.Total population and HH of the municipality are 26,387 and 5012 respectively[1].Most of the population has adopted their main occupation as agriculture in their own land,and small segments of the population have adopted their main occupation as agriculture in the basis of salary/wage work.

1.3 Objectives of the Study

The main objective of this is to carry out assessment of feasibility study of solar irrigation system in Nepal.The field study has been carried out at Rupani rural municipalities in Saptari district.The specific objectives would be:

1. To technical feasibility study of solar based irrigation system in Nepal. - Comparison of Solar irrigation with diesel generators and electric water pump.
2. Conduct financial analysis of solar,diesel and electric pump based irrigation system.

Figure 1: Rupani rural municipality

3. To assess the socio economic impacts of solar irrigation system.
4. Provide policy recommendations for the wider implementation of Solar Irrigation Systems in Nepal.

2. Methodology

Figure 2 show that the is illustrates the research design,methods,tools and approaches adopted for the fulfillment of the objectives.

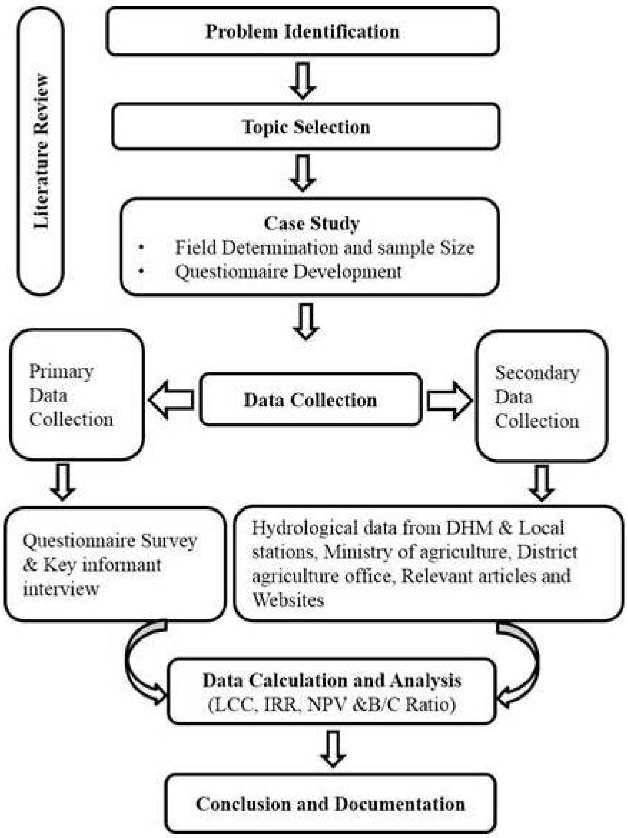

Figure 2: Methodological framework

2.1 Sample Size Determination

The minimum number of Households was calculated to be 67 from the formula for sample size calculation. Survey was conducted on 75 households of Saptari district,Rupani Gaunpalika.[5]

$$S = (X^2 * N * P * (1-P))/(d^2(N-1) + X^2 * P(1-P))$$

Where, S = sample size for finite population
X^2 = table value of chi square for 1 degree of freedom at the desired confidence level, N = population proportion, P = population proportion, d = the degree of accuracy expressed as a proportion (e.g. 1.96 for 95% confidence level)

3. Findings and Result

This section deals with the descriptive results obtained during the questionnaire survey and processing of secondary data.Carrying out the primary data analysis

3.1 Cultivated Land Available on study Area

Figure 3 illustrates the existing cultivated land of Rupani municipality which has been created by combining several shape file using Arc GIS from the data of department of Survey. The land area of 3,929 ha is cultivated in this municipality.

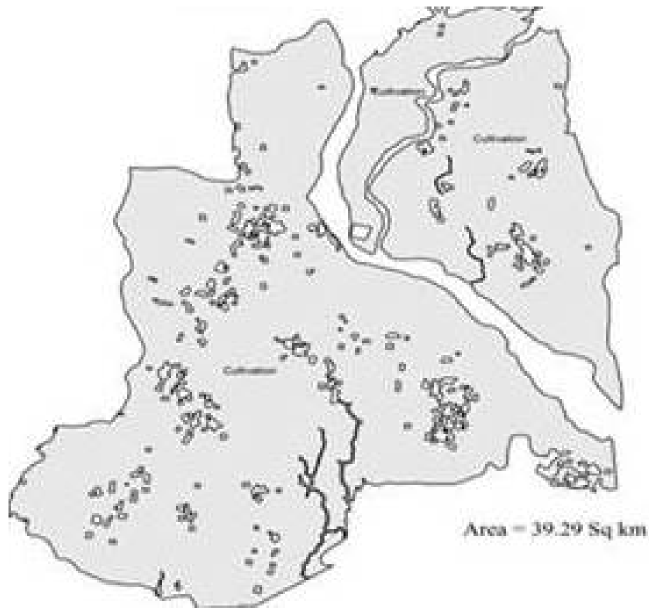

Figure 3: Cultivated land of Rupani municipality

3.2 Socio-Economic Activities

The major occupation is agriculture,animal husbandry, labor,abroad etc.Food crops like Paddy, wheat,maize,Oil seeds and etc are grown.Varieties of vegetables are being practiced such as potato,onion,brinjal,ladies finger,pointed guard,bottle guard,cauliflower and etc. Major livestock of the people are cattle,buffalo and goat.Mango, banana,peach are major fruits. Besides, people have out migrated from hill to earn for better living. Countries of destination for earning are Malaysia, Qatar,Kuwait,Iraq,Dubai,Korea and etc.

3.3 Ownership of Irrigation System

The figure 4 shows that 65.3% of farmers had own irrigation system.10.7% farmers were taken as hire. 1.3% farmers wants to take hire but they were taken from other village and paid more money,18.7% farmers had own electric WP and hire in DWP.4% (missing) farmers depends on rain.

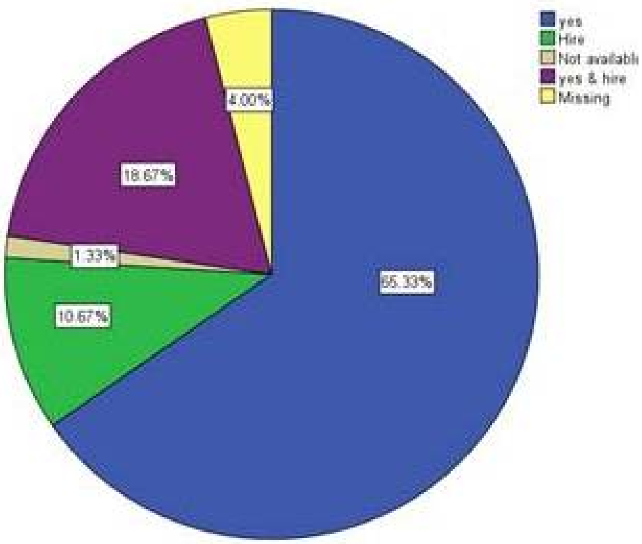

Figure 4: Ownership of irrigation system

3.4 Types of Irrigation System Used

The figure 5 shows that 41.3 % farmers had electric motors and most of the electric motors were used for loan farming and distribution of electric line were only in settlement areas, 20% farmers had electric and diesel/kerosene generators and 20 % farmers had own electric motor and hire to DWP/KWP.8% farmers had depend on hire to DWP/KWP,1.3 % had electric motor and solar and 9.33 % missing means farmers depend on rain.They had no any irrigation systems.

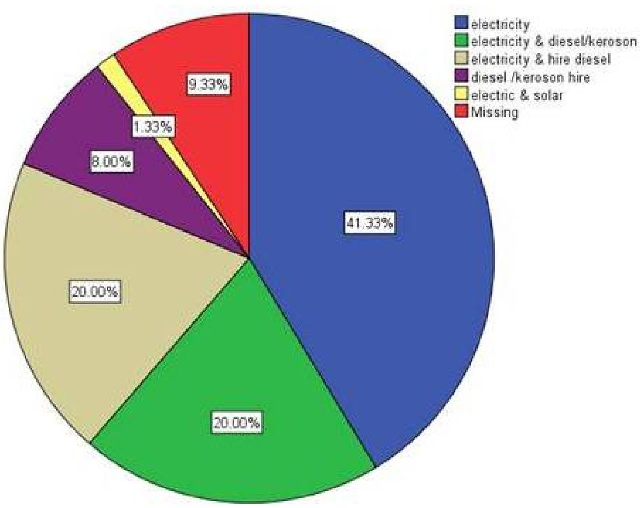

Figure 5: Types of Irrigation System Used

3.5 Family Income from Agriculture Products as Respondents

Figure 6 shows that average family income from agriculture in per year is NRS 35,133 and minimum and maximum incomes are NRS 5,000 and NRS 200,000 and deviation from mean is 31,528.It means high variation in income from agriculture.

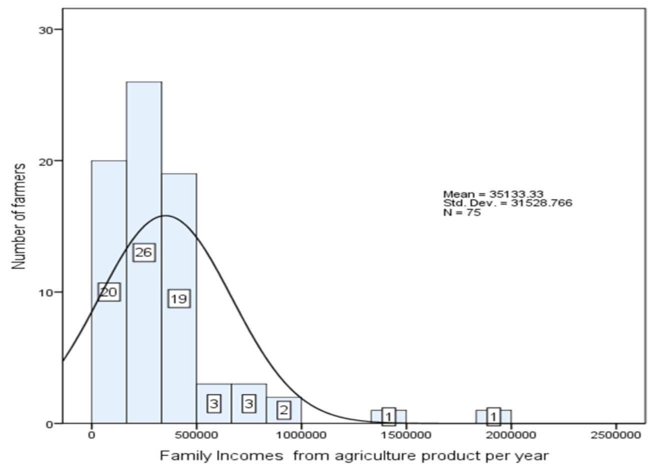

Figure 6: Family income from agriculture product

3.6 Monthly Energy Charge

Figure 7 shows that the minimum and maximum costs pay of monthly energy charge for agriculture purpose are Rs 100 and 2,000 respectively and average pay Rs 697 and deviation from mean is 276.It means high variation in energy charge.

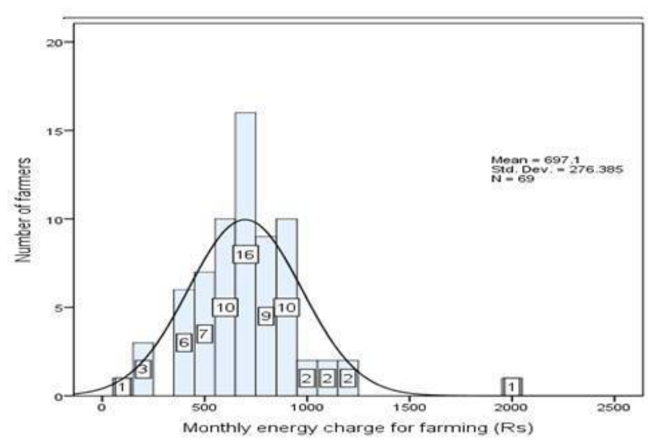

Figure 7: Monthly energy charges

3.7 Electricity Available hrs/day

Figure 8 shows that 14.7 % claimed that electricity is available for less than 4 hrs/day, 57.35 % claimed electricity available for 4-8 hrs/day and 28 % claimed that electricity available 8-12 hrs.Thus use of electric pump is not always possible.

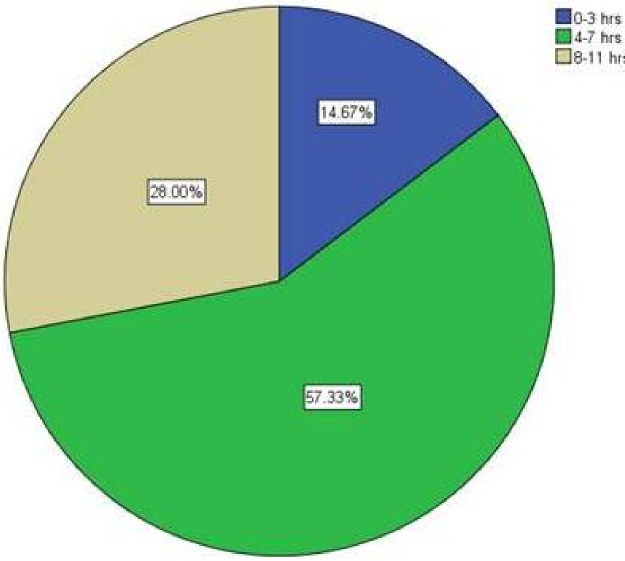

Figure 8: Electricity availability in par day

3.8 Crop Pattern Cycle

Figure 9 show that 70.67% farmers is done paddy wheat/fallow empty,12% paddy wheat/vegetable empty, 12% paddy wheat/barely S.Paddy empty and 5% paddy empty.This shows that paddy is the major crop.

4. Analysis and Discussion

The section of literature review and the descriptive result from the field survey gives the general and prevalent socio-economic scenario of the study area.This chapter further discusses the ability of the technology to feasibly fit into the context of community, the possible impacts it can make in social,economic and environmental dimension to assure the sustainability of the solar technology for effective irrigation.

4.1 Technical and Economic Analysis

Following assumptions were made to carried out the economic analysis of the system

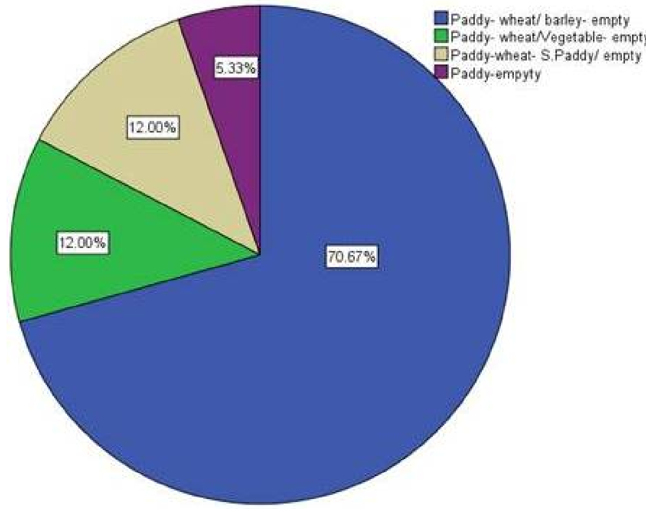

Figure 9: : Electricity availability in par day

1. The operating life of the PV panels was assumed to be 20 years and life of diesel engine assumed to be as 5 years.
2. Maintenance cost of PV system assumed to be a 0.5% of total capital cost per year.
3. Maintenance cost of diesel engine assumed to be a 15% of total capital cost per year.
4. Availability of sunshine hours considered to be a 300 days in a year.
5. Cost of 1 hp diesel engine is equal to Rs 20,000.00/- and it consumes 0.9 liter of diesel/hr
6. CO_2 emission per liter of diesel 2.7kg[6]
7. Operating hours= 5.5 hr/day
8. The replacement value is evaluated to be once during the life analysis for diesel that covers the diesel engine as well as the pump.
9. Salvage value of diesel engine was assumed to be a 1 % of capital cost of engine whereas electric and solar was taken as 0.1%

4.2 Cost Comparison of Irrigation Systems by Life Cycle Cost

As shown in table 1,the three irrigation systems assume to be 20 years life and solar, diesel and electric WP of life cycle cost are Rs 463,878,Rs 1248,864 and Rs 181,189 respectively. Among three systems life cycle cost of electric is least followed by solar and lastly diesel. Electric transmission and distribution line are on settlement area only not on farming area and electricity is not reliable or not schedule as it is generally available only 4-8 hrs per day per respondents and also observed for 8 days during the survey.Thus solar energy could prove to be better alternative technology for irrigation

Table 1: LCC comparison of water pumps systems

S.N.	Costs (NRS)	PV system	Diesel WP	Electric WP
1	Capital cost(CC) (Rs)	291,113	20,000	10,000
2	Maintenance cost (MC)) (Rs)	26,465	33,519	16,759
3	Fuel/Energy cost (EC)) (Rs)	None	1,147,424	130,469
4	Replacement cost (RC)) (Rs)	146,922	48,230	24,115
5	Salvage cost (SC)) (Rs)	622	309	154
6	Life cycle cost (LCC)) (Rs)	463,878	1,248,864	181,189

4.3 Break-even point of water pumps

The figure 10 shows that the life cycle cost of solar, diesel and electric WP,out of these gradient of diesel and solar of life cycle cost intersect each other at 2.5 years,which indicates that for short time irrigation need diesel WP is appropriate however for more than 2.5 years installation of solar is economic than diesel WP even electric WP is cheaper than solar.

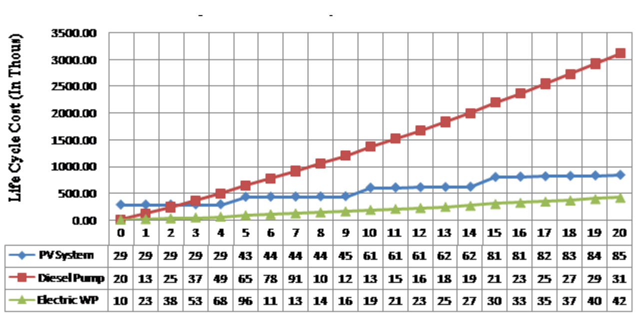

Figure 10: Breakeven point of solar, electric and diesel WP

4.4 Internal Rate of Return (IRR) for Solar Water Pumping System

The internal rate of return for solar water pumping system was calculated and found to be 47.29% for 20 years.The higher percentage of internal rate of returns indicated the good commercial return of the investment,the investment is economically viable.

4.5 Net Present Worth

The net present worth for the system was calculated on the basis of present investment and the interest rate considered for the system and the profit achieved in each year.The life of PV system was consider for 20 year thus the NPW for the water pumping system was Rs 881,216/- .Others two WP systems were found negative,it indicated that the systems was not viable economically.

4.6 Cropping pattern in existing condition

Table 2: Cropping pattern in existing condition

SN	Crops	Cropped Area %	Cropped Area (Ha.)
A	Monsoon Crops		
A.1	Paddy-1	35	1375.15
A.2	Paddy-2	35	1375.15
Coverage Area		70	2750
B	Winter Crops		
B.1	Wheat	26.64	1046.69
B.2	Potato	5.69	223.56
B.3	Mustard	1.1	43.22
B.4	Vegetable	8.38	329.25
B.5	Pulses	0.89	34.97
Coverage Area		43	1678
C	Spring Crops		
C.1	Maize	0.45	17.68
C.2	Vegetable	2.0	78.58
C.3	Paddy	3.67	144.19
Coverage Area		6.12	240.45
	Total	118.82	4668.44
Total cultivated Area			4668 Ha
Cropping Intensity (CI)			118.82 %

4.7 Cropping Patterns with Solar Based Irrigation

In the lift system of this existing system mainly paddy,wheat,potato,vegetable,pulses and maize are the major crops grown in the command area at present condition. Area covered by each crop in the proposed system is shown in table 3.Coverage area of monsoon crops is 91%, coverage area of the winter crops is 60% and that of spring crops is 19.58%.Total cultivated area is 6,693.4 ha while the remaining land is fallow land.In all the seasons the cropped area intensity was found to be satisfactory.

4.8 Socio economic Impact of Solar Water Pump

Solar water pumps contribute to social development in several ways such as increasing agriculture product, replacement of fossil-fuel pumps to environmental conservation by reducing CO2 emissions,saving on subsidy expenditures for diesel fuel,electricity,foreign exchange savings resulting from reduced diesel imports,improved crop yields and increased agricultural

Table 3:Cropping pattern with solar irrigation system

SN	Crops	Cropped Area		Jan		Feb		March		Apr		May		June		Jul		Aug		Sep		Oct		Nov		Dec	
		%	(Ha)	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
				Paus	Magh		Falgun		Chaitra		Baishak		Jestha		Asadh		Shrawan		Bhadra		Aswin		Kartik		Mangsir		Paus
A	Monsoon Crops																										
A1	Paddy-1	45.5	1787.7												■	■	■	■	■	■	■	■	■				
A2	Paddy-2	45.5	1787.7													■	■	■	■	■	■	■	■	■			
Coverage Area		91	3575.4																								
B	Winter Crops																										
B1	Wheat	37	1465.4	■	■	■	■	■	■																■	■	■
B2	Potato	8	313.0	■	■	■	■	■																	■	■	■
B2	Mustard	2	60.5	■	■	■	■																			■	■
B3	Vegetable	12	461.0	■	■	■	■																		■	■	■
B4	Pulses	1.25	49.0	■	■	■	■	■	■	■														■	■	■	■
Coverage Area		[illegible]	[illegible]																								
C	Spring Crops																										
C1	Maize	0.9	35.4						■	■	■	■	■	■													
C2	Vegetable	4.0	157.2					■	■	■	■	■	■	■													
C3	Paddy	14.7	576.8						■	■	■	■	■	■	■												
Coverage Area		[illegible]	[illegible]																								
	Total	170.4	6693.4																								
Total cultivated Area			6693.4	Ha																							
Cropping Intensity (CI)			170.4	%																							

outputs and development of relevant technology and industry which in turn results in increased employment, substantial savings for the government in terms of drought relief costs and the people such as improved houses for farmers,better nutrition,self independence. Other benefits to social development are the improvement of social cohesion within the community, reduced migration out of the community and increased community interaction in social events due to increased time availability.

4.8.1 Income from Agriculture

The figure 11 shows the net returns for different crops,both with existing scenario and replacement by Solar Irrigation.Here potato is the only crop that gives good return under both existing and solar irrigation systems. However,the net return per hectare gets almost doubled (NRs/hectare 281,385)of the amount in existing condition if the farmers can install solar irrigation. It is to be noted that just growing potato can not only recover all the losses from the crops that are grown by farmers for feeding their families but also earn surplus. Total loss incurred for growing crops including vegetable are estimated to be NRs. 85,885

4.8.2 Cost Saving on Fuel

Using the solar WP as compared to diesel WP, farmers can save for about Rs 2,185 million (i.e.annually per HH)saved about Rs. 436,000 on energy used on fuel per year annually and also consumption of 38 million liter diesel could be avoided.

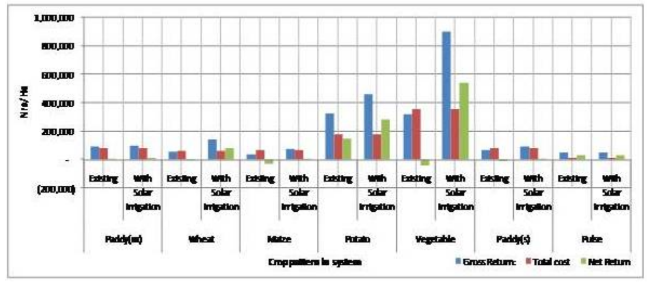

Figure 11: Net returns (Nrs. per hectare) from the existing and solar irrigation

4.8.3 Agricultural Production

The most direct benefit is the increased revenue and income that come with the greater yields of irrigated crop land rain-fed land.Stable water supplies allow additional growing seasons per year,massively increasing output.Table 4 shows that the increase in production of the different crops after the use of the solar system is compared with that of the existing situation.Significant increment was noticed in paddy, wheat,Potato,vegetable and wheat.

Table 4: Production comparison and their increment per HH

Systems	Monsoon Crops in ton		Winter Crops in ton					Spring Crops in ton		
	Paddy-1	Paddy-2	Wheat	Potato	Mustard	Vegetable	Pulses	Maize	Vegetable	Paddy
Existing	0.82	0.82	0.34	0.73	0.01	0.53	0.005	0.00	0.13	0.10
With solar irrigation	1.14	1.14	1.17	1.44	0.01	0.92	0.01	0.02	0.31	0.52
Increamental product by solar (ton)	0.32	0.32	0.83	0.71	0.01	0.39	0.005	0.01	0.19	0.42

4.8.4 Employments

Agriculture includes activities such as field preparation, planting, cultivating, pollinating, harvesting, seed processing,crop protection,field purity and irrigation,etc. The entire farming hires labor to assist in land preparation, weeding and harvesting. Payment is made in cash and/or in kind.Farming that grow high value horticultural crops generate much more labor than that focus on grain crops. This indicates if farmers could shift to horticultural crops, this would provide more labor than other option.

4.8.5 Food Availability

The availability of adequate and stable supply of food, the additional irrigated land dedicated to vegetable production significantly altered local vegetable availability. The use of the irrigation systems did not displace other agricultural production,as over the long rainy season farmers planted their traditional staples of paddy,wheat,maize and etc. This is a land of plenty.

4.8.6 Food Utilization

Food utilization is defined as the ability to consume and benefit from nutritious foods.there would be possibility of increase in vegetable intake in the community.It would be hard to directly quantify the health and nutrition status impacts of the irrigation systems.From the sale of vegetables, family have increased purchasing power and are likely to be able to buy food and educate their children with ease.As a result,health status,school enrollment and retention were reported to have increased.

4.9 Environmental Impact Emission / Climate Protection

Consumption of 38 million liter diesel could be avoided by using of solar based irrigation which in turns can avoid emission of 102,527 ton/year of CO2.

4.10 Distribution of Solar Irrigation System

It is proposed that the house having land less than 1.5 ha should be supplied with a community based irrigation system which includes about 85% of the household while the rest holding more than 1.5 ha area should be provided with individual irrigation system.

5. Conclusion and Recommendation

5.1 Conclusion

From the result and analysis we see that electric water pump is more beneficial than solar water pump in the case of electric line would be available on cultivated land but during the survey I was not found that only the settlement area was and not reliable (only available of electricity(4 to 8)hour but not scheduled as per survey and observed) and second alternative is solar water pump is more socially,economically,energy self reliant and environmentally better than the diesel water pump for long run.The economic analysis of water pumps shows that life cycle cost for 20 years of solar WP is Rs.4,64,500 while that of diesel WP was Rs.1,249,172 which means solar PV water pump is cheaper by 269% in long run whereas IRR was 47.29% compare to diesel water pump.The NPW solar WP system was Rs 881,216 at interest rate 10%.Others two WP systems were found negative,it indicated that the systems was not viable economically and also decentralized solar WP helps the rural municipalities to be energy self reliant.Similarly the unit water cost for water pumps solar,diesel and electric was estimated to be Rs 24.46,Rs 65.85 and Rs 9.85 respectively.Consumption of 38 million liter diesel could be avoided by using of solar based irrigation which in turns can avoid emission of 102,527 ton/year of CO2. Using the sustainable irrigation system i.e.solar based irrigation as compared to existing irrigation system, significant increment was obtained i.e.paddy 0.32 ton,wheat 0.83 ton, Potato 0.71 ton,vegetable 0.39 ton and etc per HH and fallow land decrease i.e.cropping intensity increase(119% to 170%).Annually farmers saved for energy charge is about 2,185 million rupees per year i.e.annually per HH saved about Rs.436,000 on energy used.As existing condition per house hold income from agriculture will be Rs 103,258 however with using solar based irrigation total income from crops will be Rs 195,874,they can increase their earnings per HH to NRs.92,616 per year(income increase by 90%).Through the saved money,they can spend of it for the dept payment(Rs 3,3020 per year for installment of bank as per calculation) ,goods, basic services,education and also they can used for upgrading their tools and equipment and increase the productivity of land.In return they can enhance their socio economic status rapidly.This study hence recommends using solar irrigation system for water pumping application to irrigate cultivable land in the study areas in general.

5.2 Recommendation

1. Solar based irrigation systems, as per this study, are feasible both technically and economically. Also,the life cycle cost of Solar water pump is comparatively lower compared to the diesel WP,solar WP should be promoted over diesel pump.

2. Government policies and plans should be developed in order to promote such systems in the areas where electricity is far-fetched and also makes easy way for loan mechanism in local level.

3. Environmental aspect should be carried out to generalize the findings on the systems.
4. Irrigation system should be provided in two ways by individual irrigation system and community based irrigation system.
5. Collective efforts for raising awareness and undertaking capacity building by state governments,NGOs and international institutions.

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