POTENTIAL AND PROSPECT FOR SUSTAINABLE CULTIVATION OF *Jatropha curcas* IN PALPA DISTRICT, NEPAL

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Abstract

Biofuel, an alternative energy source, has attracted great attention in the world and Nepal is also one of them. Government of Nepal has recognized biodiesel from *Jatropha curcas* at national level and they along with nongovernmental organisations are actively working for its promotion and extension in different parts of the country. However, there is no any land use policy on plantation, awareness and enough researches carried out on Jatropha in Nepal. Environmental, social and economic impact of Jatropha cultivation has been overlooked. So, for long term sustainability, it is worthy to evaluate potential of Jatropha cultivation. The objective of this study is to determine biophysical, social, environmental and economic potential of land for Jatropha cultivation. To meet these objectives, GIS based FAO framework for land suitability assessment, Analytical Hierarchical Processing (AHP), descriptive statistics, satisfaction index and cost and return analysis (NPV, IRR and BCR) was carried out. The result from the analysis shows that Jatropha cultivation is moderately suitable in Palpa. Biophysical, social, environmental and economic dimension evaluated were all moderately suitable. At this level of suitability, the yield from Jatropha is reasonably good. Cultivation of Jatropha should be limited to marginal lands only whether of farms or community lands and guidelines of land capability assessment (cultivation in Class I, II and III land types only) should be followed. These findings determine potential of Palpa for sustainable Jatropha cultivation and highlight the need of land evaluation that incorporates sustainability dimension.

Key words: biofuel, *Jatropha curcas*, potential, land suitability evaluation, Nepal

Table of Contents

List of Tables

List of Figures

Abbreviations

IEA	International Energy Agency
FAO	Food and Agricultural Organization
OECD	Organization for Economic Cooperation and Development
UNCTD	United Nations Conference on Trade and Development
IUCN	International Union for Conservation of Nature
HSD	High Speed Diesel
ATF	Air Traffic Fund
FFA	Free Fatty Acid
ISRC	Intensive Study and Research Center
EPFDL	Ecole Polytechnique Federale De Lausanne
UNESCAP	United Nation Economic and Social Commission for Asia and Pacific
NPC	National Planning Commission
AEPC	Alternative Energy Promotion Center
USDA	United States Department of Agriculture
SMCDA	Spatial Multi Criteria Decision Analysis
MCDM	Multi Criteria Decision Making
GIS	Geographical Information System
AHP	Analytical Hierarchial Processing
CI	Consistency Index
CR	Consistency Ratio
RI	Random Inconsistency
CBS	Central Bureau of Statistics
NLUP	National Land Use Project
DFO	District Forest Office
NPV	Net Present Value
BCR	Benefit Cost Ratio
IRR	Internal Rate of Return
SI	Satisfaction Index
VDC	Village Development Committee
LRMP	Land Resource Mapping Project
DDC	District Development Committee
SCOPE	Scientific Committee on Problems of the Environment

Chapter 1

Introduction

1.1 Background

The primary energy demand of the world is projected to rise by 52% during the year 2003-2030 which is expected to reach 16.3 billion tones of oil equivalent consumption by 2030. Oil is the single largest fuel in world economy and its share will nonetheless fall marginally from 35% in 2003 to 34% in 2030. However, the demand of the oil is expected to rise by 1.4 percent/year with an increase in its demand from 79mb/d (millions of barrels/day) in the year 2003 to 92mb/d in the year 2010 and 115mb/d in 2030 which means the rate of rise in demand is 1.6 percent/year in an average. Since both population and economic growth in developing countries is taking very rapidly, they are expected to use more than 2/3 rd of the total growth in the energy consumption of the world (IEA, 2005).

Being used in large quantities by different sectors like industry, transportation and agriculture, oil is the fundamental fuel for economic development of any country. However, these resources are scare due to which price of oil is increasing continuously, particularly after 1970 oil crisis. Same situation prevails in most of the countries, mainly in developing oil importing countries (IEA, 2005).With the increased evidence of adverse climate change, negative impact on global environment and human health, global community is facing one of the greatest threats to its existence. Due to the increasing demand of the oil and strict regulation on exhaust emission, the necessity of alternative fuel as a substitution of fossil fuel is felt (Parajuli, 2009). So, in order to improve energy security, reduce oil import bills, and greenhouse gas emission, and to generate income and also to reduce rural poverty, many countries are driven to identify and commercialize alternatives to petroleum fuels that have recently dominated the world. And Nepal is also not an exception to this (Ahuja et al, 2009**;** Parajuli, 2009).

In context of Nepal, of the total energy consumed in 2005/06, share of traditional, commercial and renewable energy was 85.5, 13.5 and 0.62 respectively (Economic survey, 2007).There is no any proven fossil fuel reserves/resources in Nepal till date that can contribute to its economic exploitation due to which fossil fuel required to meet country’s demand is totally imported (Parajuli, 2009). It has been recorded that in the year 2008/2009, about 489,219 million liters of diesel was imported which accounts 55% of total petroleum product imports of that year (Bhattarai, n.d). Dependency in fossil fuel has led to the spending of national economy to large scale, green house gas emission wherever they are used (Parajuli, 2009).With the emerging concept of biofuel energy, Nepal is also planning to produce biodiesel from *Jatropha curcas*, one of the important biofuel feedstock which is expected to have good potential in Nepal (Bhattarai, n.d).

Jatropha curcas at present is found widely in semi domesticated condition in different parts of the country (Bhattarai, n.d). Studies have found that about 30% of total area of the country climatically favors Jatropha cultivation. Also, there are lots of waste uncultivated lands in the country. So, utilizing even 6 percent of unused land, the total biofuel produced will be adequate to meet the current biodiesel demand of the country, if we assume yield of 5 tonn/ ha (Sharma and Baskota, 2006). More than 489 million liters of biodiesel will be needed to replace total dependency on petroleum diesel. So, Government of Nepal is in its way to develop Energy Sector Strategy to promote Jatropha biodiesel (Bhattarai, n.d).

1.2 Statement of the problem

Like many other fossil fuel dependent countries, Nepal also wants to decrease the fossil fuel imports and reduce its energy crisis. Government of Nepal sees Jatropha biodiesel as potential replacement for fossil fuel due to which it is in course of developing the Energy Sector Strategy in the country. They along with other national and international organizations are in process of promoting cultivation of *Jatropha curcas,* biodiesel feedstock in Nepal (Bhattarai, n.d). *Jatropha curcas* is non edible and can be grown in marginal land with little management practices. Besides, climatically, Nepal is suitable for Jatropha plantation and also there are large amount of waste uncultivated land in Nepal. Utilizing even little amount of such land can reduce import of the oil to large extent by meeting the present demand of biodiesel of the country (Bhattarai, n.d).

However, this information is not sufficient to determine potential of Jatropha in any area. Bio-physical, social, economic and environmental aspects should be considered for its sustainable cultivation. There is no any energy policy in Nepal and land evaluation is hardly done even for agricultural crops. At present, Jatropha plantation is carried out haphazardly without any thoughtful planning and technical examination. Though this might not result in immediate problems but in the long term, this may worsen the condition of land, farmers and country as a whole. It can lead to many environmental problems like erosion, soil fertility loss, biodiversity loss etc (Menichetti, 2009). Besides, it can invite problem of food security if farmer start to show more interest in Jatropha than on food crops as biofuel crops directly compete for land, water and labor with food crops (OECD/FAO, 2008). Furthermore, in a country with high rate of poverty, biofuel may or may not be economically sustainable. There are still controversies regarding its impact in future. So, it is important to evaluate a land suitable for Jatropha cultivation and socio economic and environmental prospects of Jatropha cultivation so that necessary decision could be taken whether to use a particular piece of land for that specific purpose or not. Moreover, very few researches have been done on Jatropha and there is no any land use policy and criteria set for planting Jatropha in Nepal. Also, there is no any scientific basis for determining where to plant Jatropha and where not to plant it. Evaluating a land before its use for Jatropha biodiesel indeed has good scope in Nepal. Realizing this problem and research gap, this study aims to fill the gap and prepare a scientific basis for determining potential of Jatropha cultivation in Palpa district of Nepal. The result obtained from the study would be useful at the local as well as at the national level land use planning.

1.3 Rationale of the study

Jatropha is recognized as biodiesel crop in Nepal to reduce dependency on import of fuel, concern for climate change and to raise income of rural and deprived farmers in Nepal. There is wide potential to establish biodiesel industry in Nepal while maintaining sustainable Jatropha cultivation. Since Jatropha has cultivation potential in Nepal, it has been promoted in different parts of the country and national Energy Sector Strategy is in its way to development. In order to develop the cultivation of this crop as a growing enterprise, the biofuel policy should be developed which would emphasize to expand its cultivation in different regions for the country, taking benefit of the location specificity and comparative advantage thereby maintaining social, economic and environmental sustainability of the area. There is an ardent need to have right biofuel policy directives and scientific basic for determining biophysical, social, economic and environmental potential of Jatropha in the Nepal.

Jatropha crop has been selected as the commodity in this study because Jatropha biodiesel is the only recognized biofuel in Nepal by the government at national as well as local level. Also, it has good potential to replace petro fuel and oil quality is good compared to other biodiesel crops. Jatropha cultivation is so far just at the initial level of production and social, economic and environmental sustainability is still to be explored as no such studies have attempted to address these aspects till date. Palpa district being one of the focus areas of government and nongovernmental organization for Jatropha cultivation is selected as the study site. This study will focus on the analyzing the rainfall, temperature, soil, slope and land use of Palpa district for supporting Jatropha cultivation to determine its biophysical suitability. Moreover, willingness of the farmers, their perception, cost and return from the crop and positive as well as negative environmental impacts of Jatropha cultivation will be analyzed critically to determine whether sustainable cultivation of Jatropha is possible in Palpa district of Nepal given the different characteristics of the area and the requirements of the Jatropha plant. Thus, the data on land potentiality will assist in selecting appropriate land for cultivation and determining viable technologies to be applied to specific conditions of the selected areas. This study further aims to make possible recommendations depending upon the findings of the study whether to undertake Jatropha cultivation or not. The information generated from this study will be useful in making policies for sustainable Jatropha cultivation and land use system in Nepal.

1.4 Research questions

- What is the level of biophysical suitability of Jatropha cultivation in Palpa?
- Is Jatropha cultivation socially suitable in Palpa?
- What is the level of social and environmental suitability of Jatropha cultivation in Palpa?
- What is the economic suitability level of Jatropha cultivation in Palpa?

1.5 Objective

The general objective of this study is to determine potential for sustainable cultivation of Jatropha in Palpa district of Nepal. The specific objectives are:

- To determine different levels of suitability for Jatropha cultivation in Palpa based on biophysical characteristics
- To assess social and environmental suitability of Jatropha cultivation in Palpa
- To analyze the economic suitability of Jatropha cultivation in Palpa
- To provide set of recommendations on sustainability of Jatropha cultivation

1.6 Scope and limitation of the study

- Study is helpful in evaluating potential of Jatropha cultivation in Palpa. The information obtained from the study is helpful in deciding whether or not to promote Jatropha cultivation in Palpa in order to maintain long term sustainability.

- Use of quantitative and qualitative method of data analysis.

- Methodology acquired in the study can be extended to other areas as well particularly in those areas of Nepal where land condition is similar to the study area. The similar approach can be applied in further studies.

- The result obtained from the study is not conclusive if applied all over the country given the limited samples taken, differences in geographic features and site specific problems.

- The study is not being able to cover all the factors of land suitability due to limitation in data availability.

- The responses in the survey have some biases regarding choosing respondents and interviewer and the data obtained is expected to have minimum error.

Chapter 2

Literature review

This chapter reviews the global overview of biofuel, *Jatropha curcas* as biodiesel feedstock, potential of Jatropha and challenges in Nepal, need of land evaluation and land suitability assessment.

2.1 Biofuel: definition and types

Fuel with minimum 80% of its content by volume derived from living organisms which is harvested within 10 years of its manufacture (Uhlenbrook ,2007) or solid, liquid or gas fuel which are derived from recently dead biological material is biofuel (Paudel et al, 2008).

Biofuels are basically derived from biological sources like grains, sugars, starch, oil crops, cellulose materials like grasses and trees and organic waste. Bioethanol and biodiesel are two main types of biofuel and together they account only for around 2% of the global annual consumption of 1200 billion liters of gasoline (in energy equivalent) (Fraiture et.al, 2007). Generally, bioethanol are derived from sugar crops, starchy crops and oil crops while biodiesels are derived from oil crops (FAO, 2008).These biofuel may be of first, second and third generation depending upon the source from which they are produced. First generation biofuel are mostly produced from sugar crops, starchy crops and oil crops while second generation from cellulosic material (UNCTAD, 2008; FAO, 2008).Since, high cost is required to break down lingo-cellulose, these second generation biofuel are not considered commercially viable. Third generation biofuel are based on algae and genetically modified plants and due to their high energy content and yield, these are issues for further research and investment (IUCN, 2008).

2.2 Biofuel in context of world

Biofuel is costly compared to fossil fuel (IEA, 2004a) but still it is gaining lot of attention these days. Many countries are in verge of promoting it even though subsidies are needed for its commercial viability mainly for energy security, concern for trade balance, climate change reduction and rural development and poverty reduction (Dufey, 2006; Fraiture et al., 2008). Though production and utilization of biofuel have grown significantly since early 2000, production of bioethanol increased three folds between 2000 and 2007 with US and Brazil accounting major share of this increment (Yang et al., 2009).Moreover, biodiesel expansion was even more pronounced with rise from less than 1 billion to almost 11 billion liters around the same time period. Many countries either initiated or flourished renewable energy production during the same time period (OEDC/FAO, 2008).

It is projected that global bioethanol production will reach 127 billion liters by 2017, with US and Brazil remaining the largest producers accounting for 41% and 31% of global bioethanol share. Other blooming regions are expected to be China and India which are estimated to increase their bioethanol production by two folds. Similarly, biodiesel production and use is projected to triple by 2017 globally as compared to the estimated production of 76 billion liters in 2005-2007(OEDC/FAO, 2008). The feedstock (a raw material required for industrial processing) used for bioethanol and biodiesel production are:

Bioethanol: Rye, wheat, sugar beet, Corn, sorghum, sugarcane, cassava, Molasses etc
Biodiesel: Rapeseed, Soya oil, Soybeans, Palm oil, castor oil, Jatropha, Straw, sunflower oil, coconut etc.

2.3 Energy demand, supply and fuel consumption in Nepal

Having no significant deposit of fossil fuel, Nepal relies heavily on traditional energy resources. Nepal still uses lowest commercial energy (around 500 kWh per capita per year) compared to all South Asian countries. The total energy consumption for the year 2003/2004 in Nepal was 363 million GJ (Gega Joule which is equal to 1 billion Joules) of which about 90 % was consumed by residential sector while only 1% is used by agriculture sector. On the basis of type of the fuel, biomass provided 86% of the total energy consumption, petroleum 9% (which is mainly consumed by urban area), electricity only 2% and renewable 1% of the total energy consumption. The various sources of energy in Nepal includes fuel wood, hydropower, petroleum fuel, solar energy, wind energy, bio-briquette etc (Upadhaya, 2008).

Talking about the case of petroleum fuel, privately owned large motor vehicles and unmonitored influx of mini vans and buses used for public transportation has shown unprecedented increase in last 5 years of time and this has highly accelerated the demand for petrol and diesel. On one hand demand of fossil fuel especially Motor Spirit (MS), High Speed Diesel (HSD) and Air Traffic Fuel (ATF) has been found increasing since 1993/94 NOC (2007/08) at national level while on the other hand price of petrol is increasing more than 30% in last 4 years along with the price of diesel and kerosene. Having no any fossil reserve or resource in the country, Nepal fulfills all its requirements through import from India. Nepal imported 489,219 kilo liters of diesel, which accounts for 55 % of total imports of petroleum products during the fiscal year 2008/2009.This indicate that to replace 100% petroleum diesel, Nepal needs more than 489 million liters of biodiesel. Through the proper planning, country can turn thousands of hectors of degraded land into greenery as well as could save billions of Nepali rupees going outside the country that could bring positive impact on its overall socioeconomic aspects (Bhattarai, n.d).

2.4 Overview of biofuel in Nepal

The first biofuel known to wider audience of the country is biodiesel. Since last few years, biodiesel is gaining lot of attention especially biodiesel from Jatropha as it can reduce amount of petroleum import and can also reduce carbon emission and pollute less (Karna, 2009).Government of Nepal is in process of bringing the Energy Sector Strategy which would give priority to promote Jatropha biodiesel in order to replace 5% petro diesel through biodiesel by 2020 (Bhattarai, 2009). Its local name is “Sajiwan”.

Being one of the food deficit countries in the world, Nepal has given priority for biodiesel production to non edible oil from *Jatropha curcas* as they are poisonous plants and do not compete with food web. Also, there are no any other sources of feedstocks identified till date to manufacture biodiesel in Nepal (Bhattarai, 2009). Though different varieties of feedstock is used for commercial production of biodiesel in various countries, *Jatropha curcas* is considered as a potential feedstock in many of the tropical and subtropical countries (Tiwari et al. 2007; Chhetri et al. 2008). In Nepal, there are more than 150

species of wild oil bearing plants however due to their low population in nature, low oil content and high free fatty acids (FFA) value, commercial production from all of them would not be feasible (Naik et al. 2008). There are more than 25 vernacular names of *Jatropha curcas* in different parts of Nepal (Bhattarai, 2008). It is found in semi-domesticated form in all tropical and subtropical districts of Nepal as hedge plant as well as in the sides of farmland (Bhattarai, 2009).

There are different species of Jatropha found in Nepal namely, *Jatropha curcas L.*, *Jatropha glandulifera Roxb* and *Jatropha gossypifolia* L. Of all these species, *Jatropha curcas* is only considered feasible for commercial production of biodiesel. To promote commercial production of Jatropha, some of the companies have been established in Nepal and they are Everest Biodiesel Company, Nepal Biodiesel Company Pvt Ltd, Future Energy International (FEI), Resunga Madane Jadibuti and Agriculture Product Processing Pvt Ltd, Himalayan Agro-Enterprise Center and Crystal Vision International Limited.

2.5 *Jatropha curas,* a biofuel crop

Jatropha curcas or Physic nut is a small tree up to the height of about 5m and belongs to the family Euphorbia. The name Jatropha derives from the two Greek words Jatros meaning doctor and Trophe meaning food or in other words it means medicinal uses. Similarly, Curcas is name commonly given for physic nut in Malbar, India. About 170 known species belongs to the genus Jatropha (Dovebiotech, n.d). It is a native plant of Tropical America, but thrives in many parts of the tropics and sub- tropics of Asia and Africa (Openshaw, 2000). It was believed to have been spread from South America and Africa to other parts of the world by Portuguese settlers (Gubitz et.al 1999). Also, it is a multipurpose tree with many attributes, multiple uses and considerable potential like its use to prevent or control erosion, to reclaim land, to be grown as live fences and also to be planted as a commercial crop (Openshaw, 2000).

Table 2. 1 Chemical composition of seed of *Jatropha curcas*

Chemicals	Chemical composition of Jatropha seed (%)
Carbohydrates	17.00
Protein	18.00
Fat	38.00
Fiber	15.50
Ash	5.30

Source: Lele, (n.d)

Jatropha seed contain 5-30% oil while kernel contains around 50-60% oil.21% of saturated fatty acids and 79 % of unsaturated fatty acid is present in Jatropha oil. These oils are not appropriate for human consumption since it contains chemical “Cursin” which is poisonous in nature (Lele, n.d).

2.5.1 Reasons to promote *Jatropha curcas*

There are various uses of *Jatropha curcas* and the major one is its use as biofuel crop. It is an impo

rtant source of biodiesel in different parts of the world mainly due to the following reasons (Jongschaap et. al, 2007):

- It has ability to grow on poor degraded soils and thus is able to ensure a reasonable production of seeds with very little inputs,
- It is resistant to pest and diseases as well as it has short gestation period,
- The chemical and physical properties of Jatropha biodiesel is similar to that of petro diesel,
- Jatropha biodiesel has high cetane number which indicates its potential for the higher engine performance,
- Jatropha biodiesel has superior lubricating properties besides its ability for better fuel consumption,
- There is no sulphur or aromatic substances in Jatropha biodiesel and has higher flash point for safer storage,
- Oxygen content in Jatropha biodiesel is relatively higher.

2.5.2 Biological characteristics of *Jatropha curcas*

These are the plants with thick glorious branchlets, straight tree trunk with grey or reddish bark and large white patches, green leaves with a length and width of 6 to 15 cm with 5 to 7 shallow lobes and with leaves arranged alternately. They are generally planted as hedge or living fences by farmers in different parts of the world since they are not browsed by animals. Talking about the root system, normally 5 roots are formed from each seeds out of which one is tap root and remaining 4 is lateral roots. Only lateral roots develop from cuttings of the plants. The plants are monoecious with unisexual flowers and inflorescences are formed terminally on branches. Moreover, process of pollination is assisted by insects and after pollination; a trilocular ellipsoidal fruits are formed with fleshy exocarp until the seeds mature. The seeds are generally blackish in color with an average size of 18mm long (11-30) and 10 mm wide (7-11) and weight around 727 gm per 1000 seeds i.e. 1375 seeds per kg in the average. *Jatropha curcas* has life span of more than 50 years (Dovebiotech, n.d). Fruits are generally produced in winter season and each inflorescence yields a bunch of around 10 or more ovoid fruits. The seeds get mature when the color of capsule changes from green to yellow which is normally after two to four months from fertilization. The bark of the plant extrudes white colored, watery latex when cut (Lele, n.d).

2.5.3 Various uses of *Jatropha curcas*

Beside its use as a biodiesel plant, it has several other uses as given below (Openshaw, 2000):

- Various parts of plants have medicinal value like bark contains tannin which attracts bees and thus is said to have potential for honey production.
- The seeds are used against constipation.
- Sap of the plant is used for wound healing.
- The leaves of the plant are used as tea to cure malaria.
- Fruit and seed have numerous uses. Having viscous oil, fruits of Jatropha are used for soap making, in cosmetic industries and also as kerosene or diesel substitute or

extender (useful when examining practical substitutes for fossil fuels in order to counteract the green house gas accumulation).

- After treatment the seed or seed cake of *Jatropha curcas* can be used as animal feed.
- It can store atmospheric carbon in its wood and help in building up of soil carbon.
- They are planted as hedges around the gardens and field in order to protect the crops against animals and also to demarcate the boundaries of fields and houses.
- They are also planted to reduce erosion caused by water and wind and also for the purpose of reclamation of soil.

2.4 Plantation and production potential of *Jatropha curcas* in Nepal

Basically, plantation and production potential of any crop depends on its natural, social and environmental conditions. The potentiality of Jatropha is determined in terms of available natural, environmental, social or economic condition which is explained in detail as follows:

2.4.1 Natural condition

Land availability, land quality, climatic condition, water requirements, available varieties etc are some of the natural conditions that need to be considered to determine the biophysical suitability.

- **Varieties**

There are large number of *Jatropha curcas* found growing wildly in different parts of the country and the yield (seed) ranges from 5 kg to 20 kg per tree, due to which it is possible to find the one with good agronomic traits (Bhattarai, n.d).With this high potential genotype of *Jatropha curcas*, good production of Jatropha can be expected in the country. It can also be grown as inter- cropping with other herbal (Lemon grass, Citronella, Pamarosa, Sepagandha etc) and spices crops (Termeric and Zinger) which can double the benefits which means it is not necessary to separately allocate the land for *Jatropha curcas* only (Bhattarai, n.d).

- **Land**

Studies have found that out of the total area of 14.7 million ha, 30% of it (4.41 million ha) has been found to be climatically favorable for Jatropha cultivation in Nepal. Even if we succeed in using only 10 % (0.44 million ha) of climatically favored land for Jatropha cultivation, about 1.1 million tones of biodiesel can be produced from it which is almost twice the amount of total petroleum fuel (0.67 million kiloliters) imported in the country (yield assumption taken as 10 ton/ha and 25 % oil content).Similarly, if we are able to use only 6 % of waste land (0.2645 million ha), with yield assumption of 5 ton/ha, the total biodiesel produced is sufficient to meet present level of biodiesel demand (Sharma et al ,2006).

2.4.2 Social conditions

The major social condition necessary for Jatropha cultivation and related issue are implication of Jatropha cultivation in food production, land conflict, gender issues,

indecent workers like low paid workers etc. Of all these impacts, food security and land conflict are the major one discussed below:

- **Jatropha cultivation and possible implications in food production**

Jatropha has particularly gained attention due to its ability to grow in marginal land and being non edible it does not compete directly with the food crops (Bhattarai, 2009). It can also be used as fence to protect food crops against animal incursions thereby reducing crop loss (Openshaw, 2000). It has been claimed by studies that Jatropha can avoid food versus fuel debate and thus negative implications on food security. However, if lands for food crops are used for its production, then it may lead to competition with food in terms of land, water, labor and other management practices. This could lead to rocketing of food prices and thereby affecting access to food (Tiwari et al, n.d).

Talking about the case of Nepal, biodiesel plantation means extra cost, extra labor and extra time (Parajuli, 2006). If the Jatropha plantation is carried out only in marginal land without any kind of competition with the food crops then it can reduce energy insecurity of the country without affecting food security, rather promotes rural development. Moreover, Jatropha has multi use like its use in soap making, and as fences etc. Farmers can get side by side economic benefit which helps them to uplift their living standard to some extent. Furthermore, farmers have to pay large amount of money to run the irrigation pump which can be diminished by the use of Jatropha oil which they produce and also these oils are comparatively cheaper. Thus, we can say that Jatropha strengthens food security in one or the other way (Tiwari et al, n.d). However, if in case farmers are lured by the profit from Jatropha cultivation, it may lead to tremendous effect on food security. And in this globalised world, harvesting Jatropha for fuel instead of harvesting food results in land being cleared somewhere else in the world to grow the missing food (Bhattarai, n.d).

- **Land conflict**

Jatropha curcas is basically gaining lot of attention due to the fact that it can grow well in marginal uncultivated waste lands. Even in Nepal this is one of the major reasons why this plant is under the priority of the government to generate biodiesel from it (Bhattarai, n.d). But, it is important to keep in mind that what actually is marginal waste land and where can we find such land. Studies have shown that these marginal, wasteland or idle lands are crucial for the livelihood of small-scale farmers, pastoralists, women and indigenous people. Many times, these lands are in fact lands that have been under traditional customary use for generations though not owned privately or under intensive agricultural production. The lives of the peoples living on these lands are all too often ignored. Banishing such people from their land with meager compensation is not justifiable as many of them may prefer to live on such lands as farmers, pastoralists or as hunters. Thus, it is important to identify the marginal land that does not violate the right of such people (Selvia, 2008).

2.4.3 Environmental condition

Planting Jatropha as living hedge protects the soil from wind erosion as its roots bind the topsoil and thus reduces problem of erosion. It also holds water thus allowing more absorption of water into the soil and less surface run off. The root system of Jatropha is tap

root and thus enables pumping of minerals from the depth to the surface of the soil (Beckerlegge et al, 2008). The root of the plant also breaks up the earth compacted during the dry period and allows more infiltration of water into the soil. Being non edible, Jatropha hedges protect fields and gardens from damage due to animals beside its contribution to fight against desertification. Importantly, Jatropha oil fuel creates closed C02 cycle as when oil is burned CO2 is given out but during the next crop season i.e. when the next crop grows, it takes the CO2 back out of the atmosphere. Compared to the fossil fuel, Jatropha reduces the net release of CO2 due to which Jatropha is considered to help in reducing the climate change (Malifolkecenter, n.d). Studies have reported that lack of proper management, high livestock population pressure and grazing, lands are susceptible to degradation (Baskota, 2000). Jatropha reduces problem of erosion (Beckerlegge et al, 2008) as this is one of the problem of hilly region of Nepal (Karkee, 2004).

2.4.4 Economic condition

Favorable economic condition is one of the most important conditions for determining the suitability of Jatropha, in fact of any crop or project. Determining the cost benefit analysis and comparing cost of Jatropha cultivation with other crops that grows in similar land condition is very important criteria for determining the suitability of Jatropha.

- **Cost and benefit of production analysis of Jatropha**

Potentiality of any crop or project depends up the analysis of its cost and benefit. We generally go for those projects or crops which gives us some benefit after recovering from the cost incurred. In case of Jatropha also, to determine the economics of Jatropha cultivation and employment generation, we need to estimate the cost of production analysis of the plant and possible benefit from its cultivation depending on which we can determine where it is potential for cultivation or not. To address this issue, following studies has been carried out.

(Pradhan, n.d) carried out a research to examine the case of biofuel in Nepal and to provide important recommendations on sustainable production of biofuel without affecting food security of country. This study shows that if Jatropha cultivation is carried out in a sustainable way without diverting land, food, water, and labor, then it secures energy access, provides employment generation, can reduce GHG emission and also reduce indoor pollution thereby improving the health condition. Similary, (Parajuli, 2009) also carried out his research to study the potentiality of *Jatropha curcas* in Nepal. He like (Pradhan, n.d), has estimated cost analysis of Jatropha production using the scenario: Cultivating Jatropha plant in at least 5% of the uncultivated area and 5% buffer area. This study shows that the total direct investment required for cultivating Jatropha plant over potential land estimated in this Scenario is tentatively 7167 million NRs which can create employment opportunity throughout the country mobilizing skilled and unskilled man power for different activities.

Chapter 3

Methodology

The main research question of the study is to evaluate potential of land based on biophysical, social, environmental and economic potentiality in Nepal. To achieve this objective, Palpa district was chosen as the study area. The research design, selection criteria for study area and study sites, data type, method and collection and data analysis followed in the study is discussed thoroughly as follows:

3.1 Research design

The study was conducted in Palpa district, western development region of Nepal. Based on selective sampling, four villages of Palpa district with Jatropha cultivation were selected after consultation with the local experts and officials from local NGOs and government offices. This study aimed to determine potential of land for Jatropha cultivation in the district through biophysical, social, environmental and economic suitability. The field study was conducted from July to September 2010. For the purpose of the research, data were collected from primary and secondary sources. Data analysis involves both qualitative and quantitative methods.

3.2 Selection criteria for study area

Since few years, Jatropha cultivation has been promoted in different districts of the country after the national recognition of biodiesel from *Jatropha curcas*. Terai being basket of food, western development region having highest amount of waste uncultivated lands (31.46%) and mountains having very high altitude for Jatropha cultivation, mid hills have been selected as the study region. The main criteria for choosing Palpa district include (ISRC, 2008; Pandit, n.d):

- Around 70% of the district is uncultivated grazing land.
- Degradation of natural resources is very high due to fragile agricultural slopes of Palpa.
- More than 50% of the population does not have enough food to survive.
- District has lots of naturally growing Jatropha as well as cultivation of *Jatropha curcas* has been started.

The study sites were selected after consulting with Jatropha specialists, local NGO Bhairav Darsan Sajiwan Urja Kendra which is the only organization working for Jatropha cultivation in Palpa district and District Forest Palpa.

3.3 Data types and collection

Primary and secondary types of data were used for the study to analyze the potential of Jatropha cultivation in Palpa district. The type of primary and secondary data used and method of its collection is explained thoroughly as follows:

3.3.1 Secondary data

The secondary data included climate data, land use data, altitude, demography data, topographic date and soil data. This information was collected from Department of Hydrology and Meteorology (DHM), Department of Survey (DOS), National Land Use Project (NLUP), Central Bureau of Statistics (CBS), District Agriculture Development Office (DADO), District Agriculture Development Office (DADO) and different journals, working papers, published and unpublished project reports, seminar/workshop papers and e-materials. Due to the lack of soil data researcher conducted soil sampling in the study sites and tested in soil testing lab of Soil Management Directorate, Nepal.

3.3.2 Primary data

Primary data was collected for information on social suitability, economic suitability and impact on environment like willingness to cultivate, people willing to use land for plantation, willingness to replace food crops, people willing to use maximum amount of land willing, labor availability, training, social accord, plantation support, support on household expenses, satisfaction from Jatropha cultivation, impact on environment, crop diversification loss, subsidy, producers share on market price, cost and return from Jatropha, Cinnamon and Broom grass and market satisfaction from Jatropha cultivation.

For collection of primary data, household questionnaire survey, key informant interviews, field visits and observations and group discussions were done. Both closed and open ended questions were used to collect information. The questionnaires were tested for 10 percent of sampling numbers of households. The purposive random sampling of suitable sampling intensity was carried out.

- **Household Questionnaire Survey**

For this survey, households from the study area were randomly selected. These people belonged to different ethnic groups and wealth ranks with appropriate sampling percentage. The close ended as well as open ended questions were employed for this purpose. Prior to the actual household survey, pre-testing of the questionnaire was done in order to determine if questionnaires were clear enough and focused to meet the objectives. Necessary modification and adjustments was made wherever necessary.

Sampling unit

The study was conducted in four villages with Jatropha cultivation. Based on selective sampling, four villages of Palpa district of Nepal were selected after consultation with the local experts and officials from local NGOs and government offices. And then, different households were selected through random sampling in order to avoid any kind of bias in the study. Individual household represents one sampling unit.

Simple random sampling was done for selection of households for questionnaire survey. For the purpose of conducting household survey and collecting primary data, following formula is used:

$$n = \frac{N}{1+ Ne2} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where**,** n= Sample size
N= Number of households
e= error limit (10%)

Using equation 1, the expected sample size was 65 in Madanpokhara, 66 in Telgha, 69 in Tansen and 64 in Masyam however the study was possible to take only 64, 60, 46 and 56 sample size (households) in Madanpokhara, Telgha, Tansen and Masyam respectively due to very low variation in the respondents responses.

- **Key Informant Interviews**

The key informant's interviews were carried out to get in depth information from the key people and also to cross check the information obtained from the household survey. There were 9 key informants in the study and they were chairperson of Bhairav Darsan Sajiwan Urja Kendra (Local NGO), key Jatropha promoters, District Forest Officer (DFO), chairperson of Deurali Ban community forest user groups, officer of Alternative Energy Promotion Center (AEPC), Jatropha specialist and chairperson of Everest biodiesel Ltd.

- **Focus group discussion**

The group discussion of appropriate size was held to gather the information that was not obtained from the household survey. It acted as gap filler to household survey. The information generated from group discussion were on labor availability, social accord, trainings on Jatropha cultivation, cropping system followed and cost and return from Jatropha, Cinnamon and Broom grass. It was basically conducted in two villages i.e. Madanpokhara and Tansen.

- **Field/direct observation**

The field observation was done to observe the Jatropha fields and gather relevant information's for the study. This also helped to verify the information collected through household questionnaire survey, key informant interviews and group discussion. It was basically conducted to determine the cropping system followed and type of land used by the farmers.

3.4 Method and techniques of data analysis

There are different methods and techniques of data analysis used for this study depending up on each objective which is presented as follows:

3.4.1 Land suitability

For land suitability, 10 indicators namely rainfall, temperature, slope, land use, soil texture, soil organic matter, soil drainage, soil PH, soil depth and soil nutrient were used (Chalatlon, 2008; WeiGuang, 2010). These data's were obtained from Department of Survey (DOS), Department of Hydrology and Meteorology (DHM) and National Land Use Project (NLUP).

For data analysis, FAO based land suitability framework was used for this study in order to determine potential of Jatropha cultivation in Palpa district. For determining the weight

of each factor, Analytical Hierarchical Processing (AHP) was employed and linear combination method was used to determine score of land suitability.

3.4.2 Social suitability and impact on environment

For social suitability and impact on environment, 12 factors were taken. The factors taken for this objective were willingness to plant/extend, land willing to use for plantation, willingness to replace food crops, maximum land willing to use, social accord, labor availability, trainings, plantation support, support on household expenses, satisfaction from Jatropha cultivation, impact on environment and loss of crop diversification (Gamboa 2006; Tiwari, 1999). These data were obtained from the household survey, key informants interview, direct observation and focus group discussion.

For data analysis, descriptive statistics such as frequency, percentage and AHP were used. The data were processed, tabulated and analyzed using Statistical Package for Social Sciences (SPSS) ver. 16 and Microsoft Excel-2007. The findings of the study were presented in tables, bar diagrams and pie charts.

a. Satisfaction index

Satisfaction index determines the level of satisfaction of the respondents. A three point scale of satisfaction including satisfaction, dissatisfaction and neutral was used. Satisfaction index is calculated as:

$$SI= Fs-Fd/N$$

Where, SI= Satisfaction index
Fs= Frequency of respondents responding satisfaction
Fd= Frequency of respondent responding dissatisfaction
N= Total number of observation

The value of the index ranged from +1 to -1 indicating 1 as satisfied, 0 as neutral and -1 as dissatisfied.

3.4.3 Economic suitability

For economic suitability, 4 factors were considered for the study like subsidy, producers share on market price, cost and return from Jatropha and market satisfaction from Jatropha cultivation (Tiwari, 1999; Rossiter, 1995).

For data analysis, qualitative analysis, descriptive statistics like percentages and frequency, producers share, Net Present Value (NPV), Benefit Cost Ratio (BCR), Internal Rate of Return (IRR), Satisfaction Index (SI) and AHP were used. The data were processed, tabulated and analyzed using Statistical Package for Social Sciences (SPSS) ver. 16 and Microsoft Excel-2007. The findings of the study were presented in tables, bar diagrams and pie charts.

3.5 Research Methodology

The research focused on studying biophysical, social, environmental and economic suitability of Jatropha cultivation in Palpa district. This study started with thorough literature review and then research gap was determined. The objectives were set and to achieve them research was designed and study area was selected. The types of data to be collected were first determined and then were collected accordingly. Primary data were collected using household survey, key informant interview, group discussion and field observation. Secondary data were collected from Department of Survey (DOS), Department of Hydrology and Meteorology (DHM), Central Bureau of Statistics (CBS), National Land Use Project (NLUP) and District Agriculture Development Office (DADO), Palpa. The collected data were then analyzed separately for each objective followed by conclusion and recommendation of the study. The detail of research methodology is discussed thoroughly in chapter 3 and is also presented in form of flow chart as shown in Figure 3.1.

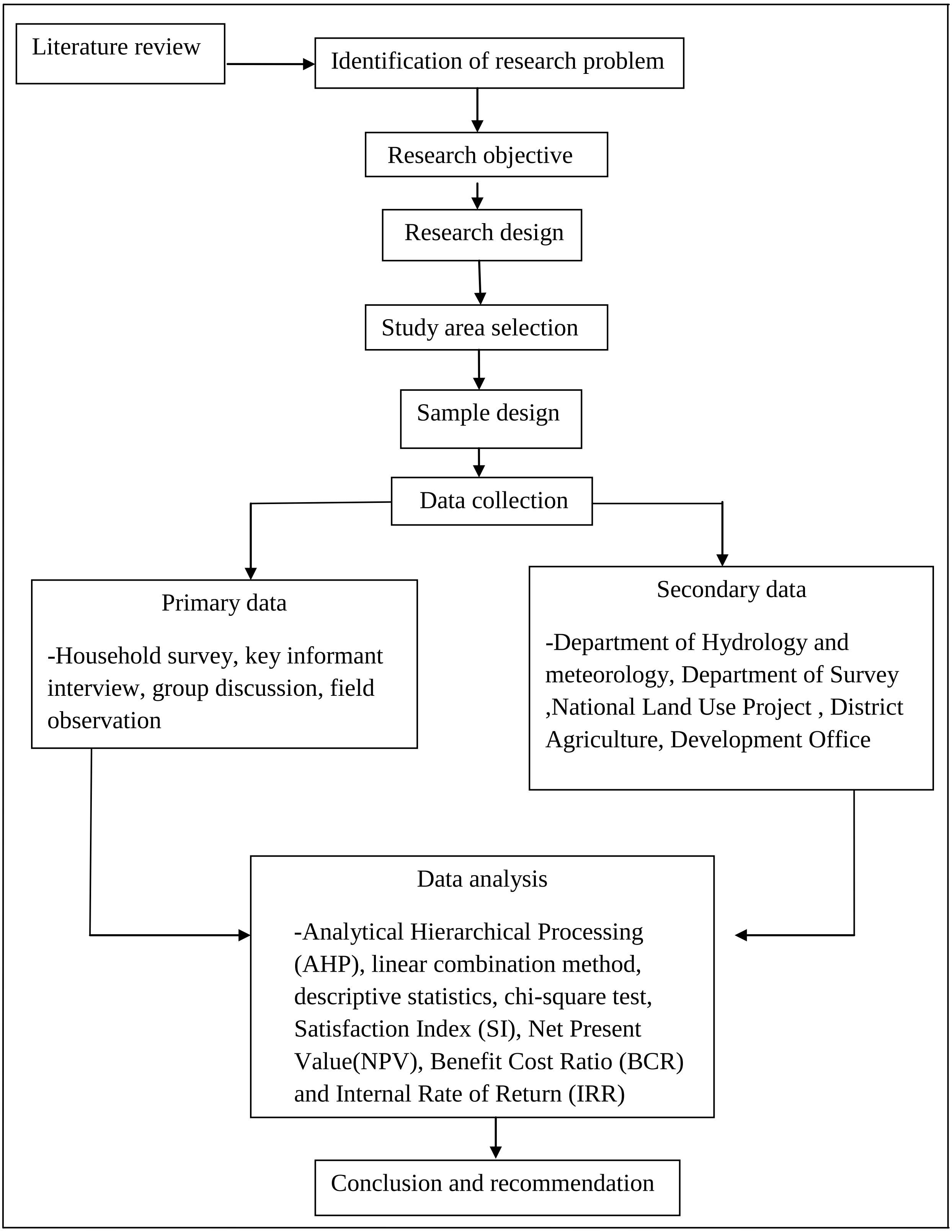

Figure 3. 1 Flow chart of research methodology

Chapter 4

Study area profile

This chapter describes the general overview which includes environmental, social and economic context of the study area. It also clearly describes the background information and present overview of Jatropha cultivation in four study sites of Palpa district that is directly related to the objective of the study.

4.1 Description of Palpa district

Nepal is divided into fourteen zones and seventy-five districts administratively of which sixteen districts lies in the mountain region, thirty nine in the middle hilly region and remaining twenty in the Terai region. All these districts are put together to form five development regions based on the location of the districts. There are sixteen districts in the east which fall under Eastern development region, nineteen in the Central, sixteen in the Western, fifteen in the Mid-western and nine in the Far-eastern development region. The districts are further divided into number of municipalities and Village Development Committees (VDC's). In Nepal, there are 9 wards in each VDC and number of wards in a municipality may vary from 9 to 35 (Statistical Year Book, 2007).

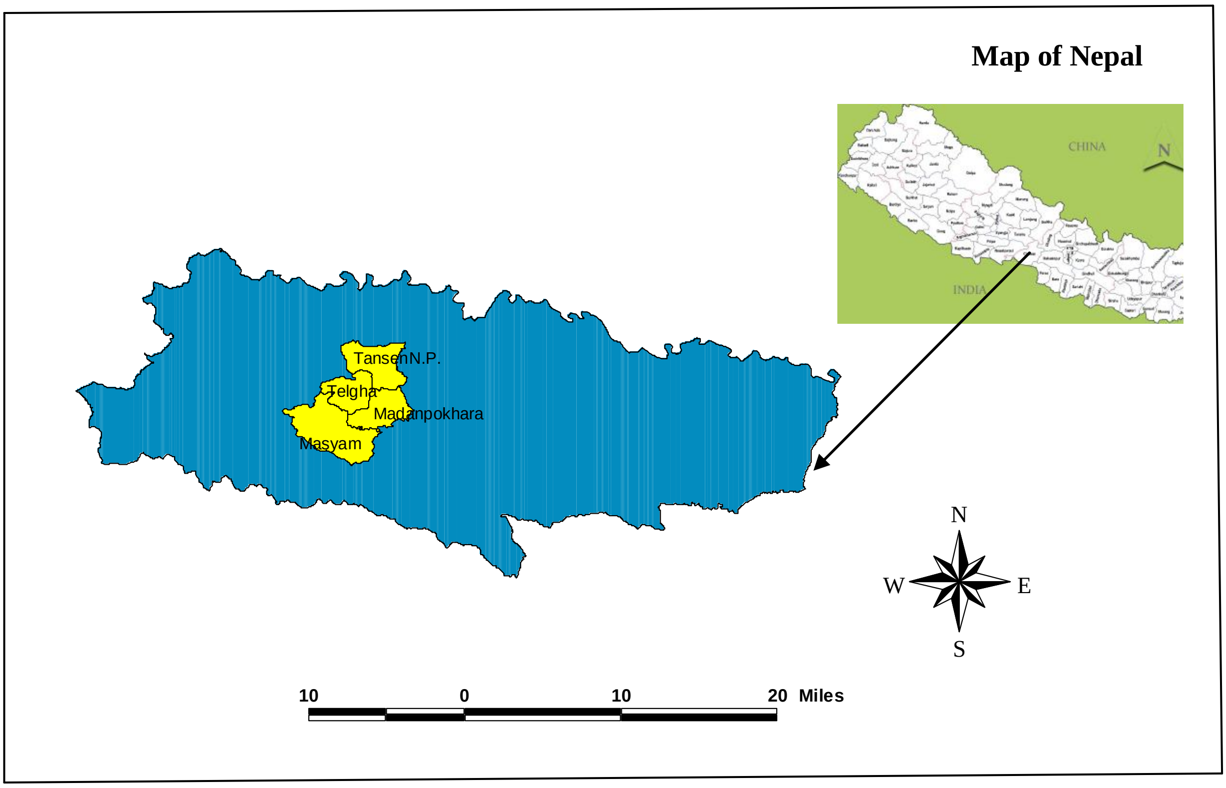

Figure 4. 1 Map of Palpa district

Palpa district is one of the sixteen districts of Western Development Region of Nepal and is situated in hilly region of Lumbini zone. It ranges from Middle mountain to Terai region and geographically extends from the latitude of 27°34' to 27°57' North and 83°15' to 84°22' East longitude. Nawalparasi district in the east, Syanga, Tanahun and Gulmi district

in the north, Arghakhanchi in the west and Rupandehi and Nawalparasi in the south are the surrounding boundaries. The district has length of 75 km in the east west direction and breadth of 26 km in the north south, covering total area of 1,365.95 sq kms. Politically, the district is divided into 65 VDCs and 1 municipality within the broad divisions of 3 electoral constituencies and 13 Ilakas. The district headquarters is located at Tansen municipality with an elevation of 1,311 meters.

- **Physiographic regions**

Palpa district is divided broadly into three physiographic regions namely Middle mountain, Siwalik and Terai. Middle mountain covers around 1120.08 sq km area which is 82% of the total area, Siwalik around 233.57 sq km areas which is 17.1% and Terai around 12.29 sq km which is 0.9% of the total area.

- **Slopes and elevation**

Land slope directly affects the agricultural production. Land above 30^0 slopes is not suitable for the crop production. Crops can be grown up to 30^0 slopes with terracing. Merely 5.9 % of Palpa district area lies in the flat and nearly flat areas having slopes less than 5 degrees. Nearly 27.6% of the total area of the district is situated on the land having slopes between 5^0-30^0. More than 63 % of the district total surface lies in the slopes greater than 30^{0}. The elevation in the district ranges from 200 m to 2,000 m from the mean sea level.

- **Climate**

The district has sub tropical to warm temperate climatic zones. The overall average temperature in the district is about 23 degree celsius. The minimum temperature recorded in the district is about 3.7 degree while the maximum recorded is 35 degree celsius. The annual precipitation in the district is 1,913.7 mm while the average relative humidity is 58%.

- **Soil type**

There are six major dominant soil textures recorded in Palpa district. 92.3% of the district areas have loamy skeletal soil, 3.9% have loamy soils, 1.9% have loamy/boulder, 1.6% have fragmental sandy, 0.2% have variable soil, and 0.04% of the district have sandy/cobbly soils.

- **Land types and use**

Of the total of 1,365.95sq km areas, agricultural land covers 571.72 sq km (365.67 sq km cultivated and 206.05 sq km uncultivated land), forest covers 711.79 sq km, grazing land 699.8 sq km and remaining other types of land 125.3 sq km (Table 4.1).

Table 4. 1 Distribution of land in different sectors

S.N	Land type	Area (sq km)
1	Agricultural land - Cultivated - Uncultivated	571.72 365.67 206.05
2	Forest land	711.79
3	Grazing land	699.8
4	Others (including landslides, river, sand/gravels/boulders and urban area)	125.3

Source: Nepal District Profile, (2002)

- **Demographic description**

The total population of the district is 268,558 and constitutes of 49,942 households. The population comprises of 125, 068 males (46.5%) and 1, 43,490 females (53.4%) with average household size 5.4 (Source: CBS, (2001); DDC, (2010). The overall literacy rate of the district is 66.2 %. However, there is high disparity between male and female literacy rate which is 76.2% for male and 57.8% for female. The total number of population falling under age group <15 years of age is 109,941, age group (15-64) is 1, 41,589 and ≥65 is 14,015. Similarly, Magar are the dominant ethnic group/caste in Palpa followed by Brahmins, Chettri, Kami and Newar. Agriculture is the main occupation of the people of the district with 63.17% and other than agriculture with 36.83% (CBS, 2001; DDC, 2010).

4.2 Description of the study sites

The study was conducted at household level of three village development committee namely Madanpokhara, Telgha, Masyam and a municipality Tansen. Selection of the study site was done with the consultation with local NGO Bhairav Darsan Sajiwan Urja Kendra, district forest officer, chairperson of community forest user group, promoters and farmers involved in Jatropha promotion and cultivation.

- **Tansen**

Tansen municipality is the district headquarters of Palpa with an area of 19.91sq.km. Climatically, the region has warm temperate zone. The mean annual temperature is about 19.8 degree celsius and absolute maximum and minimum temperatures are respectively 34.7 to 4.2 degree celsius. The total number of household in Tansen is 4,813 and population size 20,431 with male 10,205 and female 10,226. Dalit and Janajati are the major ethnic group of this region with total size of 2,196 and 7,957 respectively. Besides, total number of people falling under other ethnic groups is 10,278. Maize, rice, wheat, barley, buckwheat, mustard and zinger are the major crops grown in this region. It has loamy sand to sandy loam to stony sand type of the soil with acidic condition. The organic matter content is medium to low in the soil of this region.

- **Madanpokhara**

Madanpokhara is one of the 65 VDC's of Palpa district with an area of 16.56 sq.km. It has warm temperate climatic condition. The total number of household is 1,235 with female 3,357 and male 2,865 and total population of 6,222. The total number of Dalit is 1,047 and

Janajati 2,409 and others 2,766. Maize, rice, wheat, mustard and vegetable production are the major crops grown in this region. The VDC has sandy loam to stony sand type of soil with acidic condition. The organic matter content ranges from low to medium level.

- **Telgha**

Telgha VDC (Village Development Committee) also has warm temperate climatic condition. The total number of household is 667 with female 1,843 and male 1,493 and total population of 3,336. Number of Dalit in this region is 729, Janajati 1,286 and others 1,321. The total area of the VDC is 14.37Sq.km. This VDC has sandy clay, loamy clay and clay sandy type of soil with acidic condition. The organic matter content ranges from low to medium.

- **Masyam**

Masyam VDC (Village Development Committee) has moderate type of climatic with warm temperate condition. It is largest (32.89Sq.km) in area of all other study sites taken. The total number of household is Masyam 884 with female 2,650 and male 2,419 and total population of 5,069. Number of Dalit in this region is 590, Janajati 3,480 and 999. The soil type ranges from loamy sand to silty loamy sand to stony sand with slightly acidic condition. The organic matter content is medium to low.

Chapter 5

Socioeconomic situation of the study area

This chapter discusses socio economic profile of the respondents and their household. The information presented in this chapter aids in understanding the respondents, background of the study and in meeting the objectives of the study.

5.1 .Sex of the respondents

In order to reduce the bias in the study, attempt was made to include both male and female groups in the survey to understand their perception and roles in Jatropha cultivation. Figure 5.1 shows that 59.4% of the respondents were male and 40.6% of them were female. Household survey conducted during the morning and evening time included more males while during the day time the main respondents were female. This is because women were busy with their household chores in the morning and evening time while during the day time men were found going out for some work or to meet their friends. In the household where both male and female were available, even if attempt was made in women participation, male were found more dominant.

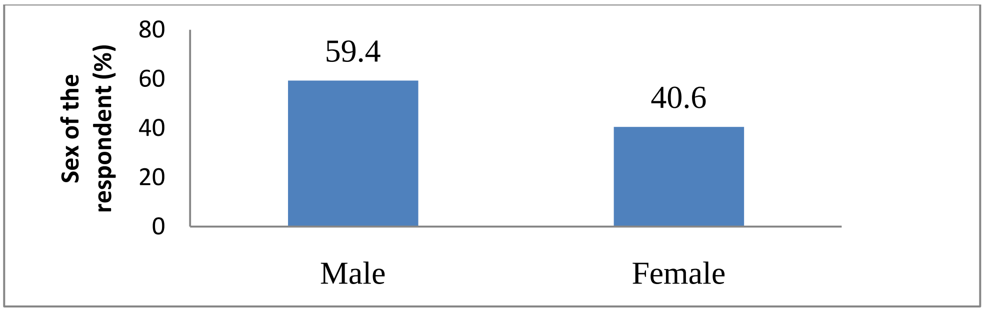

Figure 5. 1 Sex of the respondents

5.2 Ethnicity/Caste

Dalit, Chettri, Brahmin and Janajati are the major ethnic groups/caste in the study area. Of the total of 229 sampled household, 34.5% were Chettri, 31.4% Dalit, 18.8% Brahmin and 15.3% Janajati as shown in Table 5.1.

Table 5. 1 Ethnicity/Caste of the sampled household

Dalit (%)	Chettri (%)	Brahmin (%)	Janajati (%)	Total respondents
31.4	34.5	18.8	15.3	229

Field survey, (2010)

5.3 Education status

The education levels of the sampled farmers were categorized into four groups' i.e. illiterate, primary education, secondary education and higher secondary education.

Illiterate refers to those who cannot read or write, primary with education level less than class 5, secondary class 5 to 10 and higher secondary from 10 to higher. Figure 5.2 shows that highest percentages of respondents were in the primary education category (42.4%) followed by secondary (22.3%), illiterate (20.9%) and >secondary (14.4%).

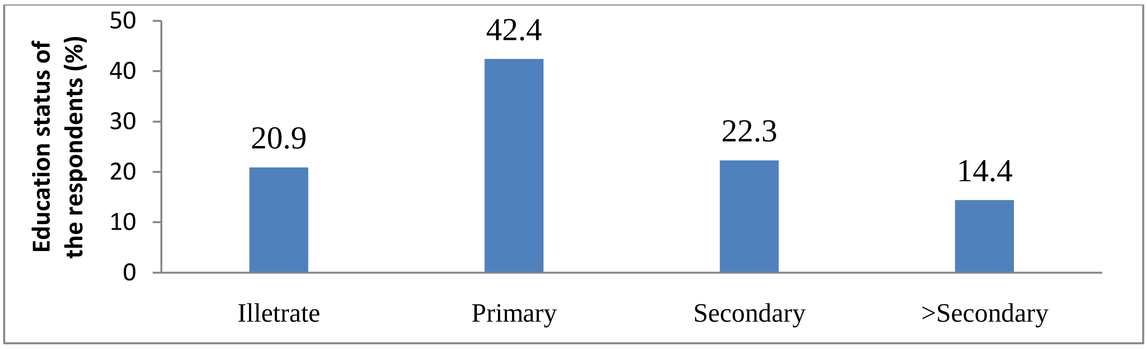

Figure 5. 2 Education status of the respondents

5.4 Family size and household head

The family size is an important variable in order to determine the supply of family labor to the Jatropha cultivation. The average household size was found to be 5.1 in the study area. The participation of both men and women were actively seen as the family labor while men were the major decision makers. Household head of the respondents family was found to be male (89.1%) in most of the cases while few of them were female (10.9%).

5.5 Age group

The age groups of the respondents were divided into three category i.e below 19 years, 20-60 years and above 60 years. Of the total respondents of 229, highest percentage of them belonged to age group 20-59 (48.4%) followed by below 19 years (36.6%) and above 60 years age group (14.8%) as shown in Table 5.2.

Table 5. 2 Age groups of the respondents

Age groups	Family members (%)
Below 19 years	36.6
20-59 years	48.4
Above 60 years	14.8
Total	229

Source: Field survey, (2010)

5.6 Land ownership

Table 5.3 represents land ownership of the respondents in the study area. Self owned land ownership (96.17%) was found to be highest in the study area. Respondents with sharecropping and landless were each 1.32% of the total 229 respondents.

Table 5. 3 Land ownership of the sampled household

Self (%)	Sharecropping (%)	Landless (%)	Total respondents
96.17	1.32	1.32	229

Source: Field survey, (2010)

5.7 Food security

With regard to the level of food security of the respondent's household in the study area, Table 5.4 shows that in majority of household, food was found to be secure for >12 months (34.6%). Similarly, in 31% of household food was found to be secure for 3-6 months, 19.65% of household for < 3 months and 15.2% of household for 9-12 months. Attempt was made to include farmers of all groups to understand their perception and expectation from Jatropha cultivation.

Table 5. 4 Status of food security of the sampled household

Duration of food secure	Household (%)
<3months	19.65
3-6months	31
9-12months	15.2
>12months	34.6

Source: Field survey, (2010)

Chapter 6

Biophysical suitability of land

This chapter analyzes the biophysical characteristics of land by using multiple criteria decision making analysis in order to determine suitability level of land in Palpa for Jatropha cultivation.

6.1 GIS based multiple criteria decision making analysis

The multi factor evaluation was used in GIS for identifying suitable land and Analytical Hierarchical Processing (AHP) was used for computing weight of the factors. The factors used for identifying suitable land for Jatropha cultivation in this study are rainfall, temperature, land use, slope, soil texture, soil depth, soil PH, soil nutrient, soil organic matter and soil drainage.

Table 6. 1 Rating score for classifying Jatropha cultivation in Nepal

S.N	Factors	Suitability			
		High (4)	Moderate (3)	Marginal (2)	Not suitable (1)
1	Rainfall	900-1200	600-900mm or 1200-1400mm	<600->300mm or 1400-1500mm	>1500 or <300
2	Land use	Degraded lands of farms, road sides, community forests	Good lands of community forest	Agriculture lands and housing areas	Water resource and boulders
3	Temperature	25-30	18-25	10-18	<10 or >35
4	Slope	0-3	3-5	5-30	>30
5	Soil Texture	Sandy, loamy sand	Sandy clay loam, sandy loam, clay loam silty clay loam	Stony soil	Clay, clay sandy, clay silty
6	Soil PH	6-6.8	5-6	4-5 or 7-8	<4 or >8
7	Soil Organic matter	High OM	Medium	Medium-Low	Very low
8	Soil Nutrients N:P:K (kg/ha)	48;46;24	-	-	Very high NPK
9	Soil Drainage	Well drained and good aeration	Low drainage and medium aeration	Prone to water logging	Water logged
10	Soil Depth	>100-<150	>150	>50-<100	<50

Sources: Chalatlon, (2008); WeiGuang, (2010); expert judgment

Table 6.1 represents factors considered in the study and their rating score to determine suitable land for sustainable cultivation of *Jatropha curcas.* Selection of the factors and its ranking were done based on literature review (Chalatlon, 2008; WeiGuang, 2010) and from research survey with 5 experts which includes 2 Jatropha specialists, two organization officers working for Jatropha promotion and 1 farmer from the study area (Detail in Appendix 2).

Suitability level in Palpa district

The biophysical characteristics of land in Palpa district possess different level of suitability from highly suitable to moderate, marginal and not suitable. The different level of suitability and score given to each of the factors is clearly presented in the Table 6.2.

Table 6. 2 Suitability level of biophysical factors in Palpa district

S.N	Factors	Suitability level	Score of the factors
1	Land use	High (S1)	4
2	Soil Texture	Moderate (S3)	3
3	Soil organic matter	Marginal	2
4	Soil nutrient	Marginal	2
5	Rainfall	Marginal	2
6	Soil drainage	M, T, Ms= High and Tel= Moderate	M, T, Ms=4 and Tel=3
7	Temperature	Moderate	3
8	Slope	M, Ms, Tel= Marginal, T= Moderate	M, Ms, Tel=2 and T=3
9	Soil PH	Moderate	3
10	Soil depth	Marginal	2

*M= Madanpokhara, T= Tansen, Ms= Masyam and Tel= Telgha

Source: Field survey, (2010)

6.2 Analytical Hierarchical Processing

Satty's Analytical Hierarchical Processing model (AHP) was applied to weigh factors such as land use, slope, soil texture, soil nutrient, soil depth, soil organic matter, soil drainage, soil PH, rainfall and temperature in order to identify land suitability. The objective of AHP is to define relationship between each factor (independence factors on dependence factors) such as crop yield and growth rate. Satty (1990) also developed the pair wise comparison matrix for reducing bias in weighting factors. The three main steps in AHP are

1) Development of pair wise comparison matrix,
2) Computation of factor weights and
3) Estimation of consistency ratio.

6.2.1 Development of the pair wise comparison matrix

According to Satty (1990), this process starts by ranking the factors in their order of value assigning value 1 to the first factor and values to the other factor in suitable form. After that it compares the most important factor with the combination of all the others with

values from 1 to 9 to rate the relative preference between two factors using fundamental scale for pair wise comparisons.

In this study, the pair wise comparison matrix was constructed through literature review and also by asking 5 experts during the survey which includes 2 Jatropha specialists, 2 organizations and 1 farmer working for Jatropha promotion and extension. Then the values were computed into the matrix as shown in Table 6.3 which consisted of rainfall (R), temperature (T), land use (LU), slope (SL), soil texture (ST), soil depth (SD), soil organic matter (SOM), soil PH (SPH), soil nutrient (SN) and soil drainage.

Table 6. 3 Pair wise comparison of the evaluation factor

	R	SD	ST	LU	SOM	SPH	SDP	SN	T	SL
R	1	1	2	3	3	3	3	3	4	5
SD	1	1	2	3	3	3	3	3	4	5
ST	1/2	1/2	1	2	2	2	2	2	3	4
LU	1/3	1/3	2/3	1	1	1	1	1	2	3
SOM	1/3	1/3	2/3	1	1	1	1	1	2	3
SPH	1/3	1/3	2/3	1	1	1	1	1	2	3
SDP	1/3	1/3	2/3	1	1	1	1	1	2	3
SN	1/3	1/3	2/3	1	1	1	1	1	2	3
T	1/4	1/4	2/4	3/4	3/4	¾	3/4	3/4	1	2
SL	1/5	1/5	2/5	3/5	3/5	3/5	3/5	3/5	4/5	1
Sum	4.61	4.61	9.23	14.35	14.35	14.35	14.35	14.35	22.8	32

Sources: Expert Judgment and literature review

6.2.2 Determining factor weights

Priority weighting of alternatives for each criterion is done in the following ways:

- Summation of value of each column of the pair wise matrix.
- Division of each element by column total and the resulting matrix is referred to as the normalized pair wise comparison matrix.
- Computation of average of element in each row for the normalized matrix. These averages provide an estimate of the relative weights of the criteria being compared as shown in Table 6.4.

Table 6.4 Determining the relation factor weight

Factors	R	SD	ST	LU	SOM	SPH	SDP	SN	T	SL
weights	0.2	0.2	0.12	0.07	0.07	0.07	0.07	0.07	0.05	0.04

6.2.3 Estimation of the consistency ratio

In this step, all values were determined in order to verify that the comparisons were consistent. Weighted sum vector was determined by multiplying the weight for the first criteria timed the first column of the original pair wise comparison matrix, then multiplying the second weight timed by the second column of the original pair wise comparison matrix until n criteria and then the addition of values along the rows was

carried out. Then after, consistency vector was determined by dividing the weighted sum vector by the factor weights determined previously. The average value of consistency vector was then computed which is lambda value (λ). Consistency index (CI) was then determined by using the formula (CI= λ-n/n-1). Finally Consistency ratio (CR= CI/RI where RI= 1.49 for 10 factors considered) was computed. If the value of consistency ratio is ≤0.1 then pair wise comparison matrix is considered to be consistent. The weight of the factors and consistency ratio of the pair wise comparison matrix is presented in Table 6.5.

Table 6. 5 Weights and consistency ratio (CR) of the factors

Factors	Weight (Wn)	Consistency Ratio (CR)
Land use	0.07	CR= CI/RI = 0.09/1.49 = 0.06 CR≤ 0.1 so consistency in pair wise comparison matrix
Soil Texture	0.12	
Soil organic matter	0.07	
Soil nutrient	0.07	
Rainfall	0.20	
Soil drainage	0.20	
Temperature	0.05	
Slope	0.04	
Soil PH	0.07	
Soil depth	0.07	

Table 6.5 shows the result obtained by weighing the evaluation factors based on their impact on Jatropha production shows that soil drainage and rainfall has highest weights followed by soil texture, land use, soil organic matter, soil nutrient, soil PH, soil depth, temperature and slope with the least value. Same weight of land use, soil organic matter, soil nutrient, soil PH and soil depth shows similar level of importance in Jatropha cultivation.

6.3 Linear combination method

Linear combination method is the procedure best suited for suitability assessment. It employs equal or unequal weights based on the importance considered for each criterion. The final suitability is given by the weighted sum of several factors (Hopkins, 1997). As the rating and weighting scores are identified, Jatropha suitability scores are calculated by the linear combination method which is defined as follows:

Mathematically,

Land suitability (Rs) = ∑ (W1*S1+ W2*S2……WnSn)

Where, Rs= Score of land suitability; Wn=Weight of the parameters; Sn=Score of the parameters
and n=number of parameters

The suitability score obtained from linear combination method and different levels of suitability for 4 study sites namely Madanpokhara, Telgha, Tansen and Masyam is given in Table 6.6.

Table 6. 6 Land suitability for Jatropha cultivation in the study sites

Study sites	Suitability score	Jatropha suitability
Madanpokhara	0.68	Moderate
Telgha	0.63	Moderate
Tansen	0.71	Moderate
Masyam	0.68	Moderate

As shown in Table 6.6 Madanpokhara, and Masyam has similar land use, slope, climate and soil condition so has same land suitability score. Telgha has all other properties similar except the soil property. The soil drainage is medium level in Telgha. Similarly, unlike in all other VDC's Tansen has moderate level of slope while others have marginal. However, all the values obtained from the analysis fall under moderately suitable range i.e. (0.4-0.8). Thus, we can say that biophysically Palpa district is moderately suitable for Jatropha cultivation.

Chapter 7

Social and environmental suitability

This chapter analyzes social and environmental suitability of Jatropha cultivation in Palpa. It determines whether the intended study area is socially and environmentally suitable for Jatropha cultivation. The social and environmental factors considered in the study are famer's willingness to plant/extend, farmers willing to use land for plantation, farmers willing to replace food crops, farmers willing to use maximum amount of land, social accord, labor availability, training, plantation support, support on household expenses, satisfaction from Jatropha plantation, impaction on environment and crop diversification loss (Gamboa 2006; Tiwari, 1999).

7.1 Farmers willingness to plant/extend

Farmer's willingness to plant or extend is one of the most important criteria for determining suitable land for cultivation of Jatropha. Even if the land is biophysically, environmentally and economically suitable but people do not want to grow them then it cannot be considered to be the suitable site for plantation. Thus, in order to determine willingness of farmers to cultivate Jatropha in their farms, household survey was conducted in four study sites. Analyzing this parameter gives the clear picture of farmer's willingness. Under this parameter, farmers not growing Jatropha at present were asked if they wish to cultivate in future and those already growing Jatropha were asked if they would like to extend further or continue with the Jatropha plantation.

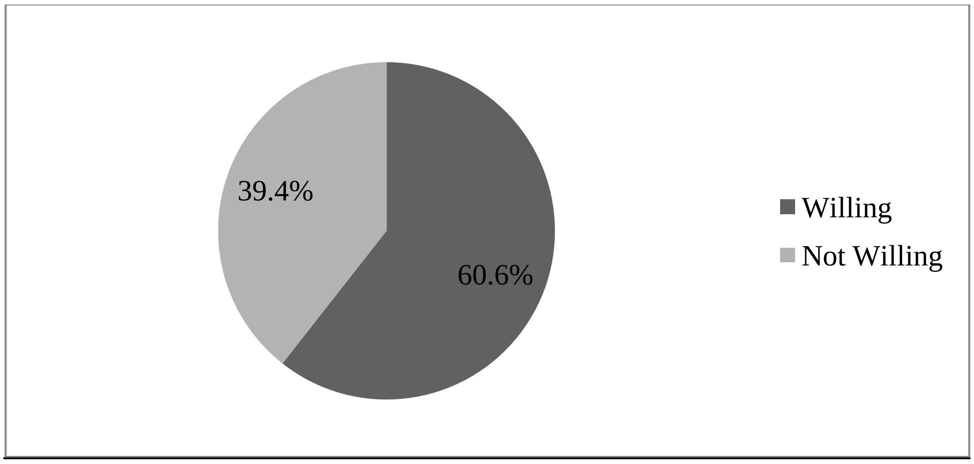

Figure 7. 1 Willingness to plant/extend

Figure 7.1 shows that majority (60.6%) of the farmers are willing to undergo Jatropha cultivation. Land availability, market condition and active working members in the family for Jatropha cultivation are the basis of farmer's willingness. Current market condition (51.1%) is the most influencing criteria determining farmer's interest followed by active working members (31.8%) in the family and finally land availability (17.1%) as shown in Figure 7.2. This shows that willingness to grow Jatropha depends upon the reasonable market price, market assurance, availability of active working members in the family and land availability.

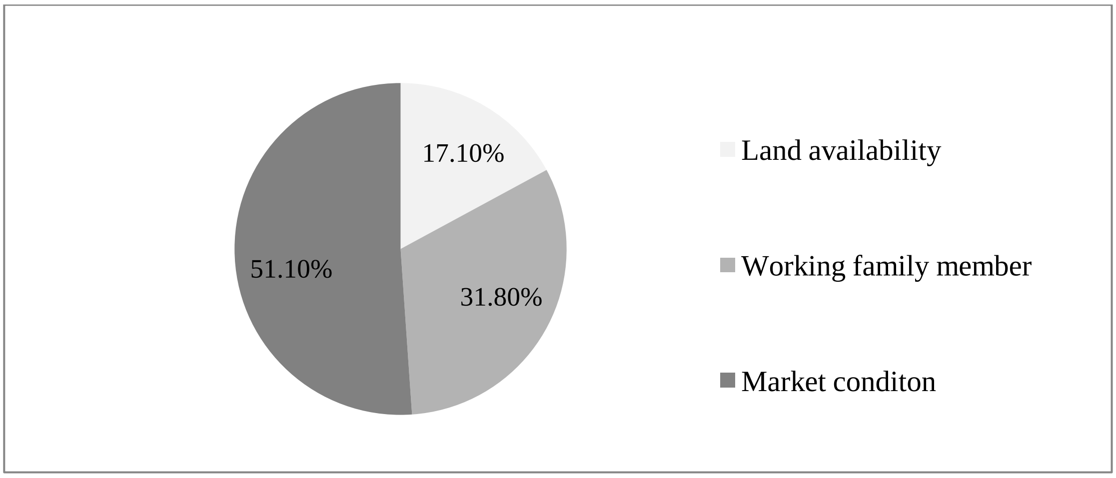

Figure 7. 2 Basis of willingness to plant/extend

7.2 Farmers willing to use land for plantation

Like willingness to plant or extend, the land farmers are willing to use for plantation is equally important to access. What the farmers desire and how they want to achieve them is very crucial. For an instance, farmers might be willing to grow Jatropha but if they wish to use the land suitable for food crops then this might create the problem of food security (Jongschaap, 2007). To analyze this, the farmers were asked about the land they are willing to use for plantation of Jatropha and they shared different views in this regard.

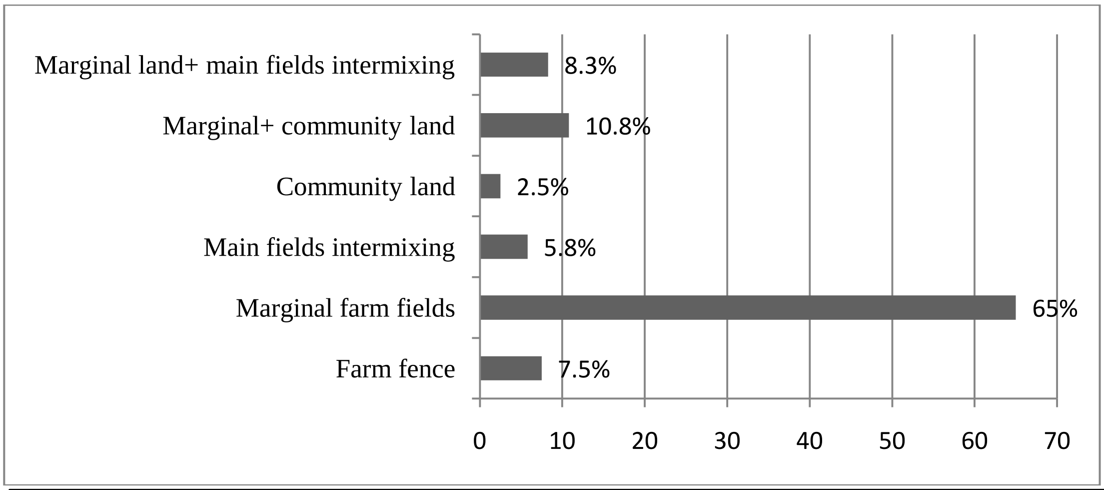

Figure 7. 3 People willing to use land for Jatropha plantation

Figure 7.3 shows that 65.0% of farmers are willing to use marginal lands of their farm fields, 10.8% marginal land of their farms and community lands, 8.3% marginal lands of their farms as well as in the main field intermixing with food crops. Similarly, 7.5% of farmers are willing to use their farm fence for cultivation, 5.8% in main fields intermixing and 2.5% in marginal community lands. In overall, 85.8% of farmers are willing to only marginal land whether of their farm or community land except some (14.2%) interested in intermixing Jatropha in the main farm fields (arable lands) with food crops like ginger and maize. This clearly shows farmers intent to use mainly wasted marginal lands. This is not

just because farmers are aware that Jatropha can and should be planted in marginal lands but also because the farmers in an average account very small land holding and they do not have enough land to allocate for Jatropha which is non edible (Bhattarai, 2008).

7.3 Farmers willingness to replace food crops

Farmer's willingness to replace food crops with Jatropha is very important issue of concern at present (Jongschaap, 2007). Attempt was made to determine whether farmers are willing to replace food crops with Jatropha or use land suitable for growing food crop for Jatropha cultivation in case they get more profit from it compared to any other crops. The result shows that no farmers of any of the study sites are willing to replace food crops with Jatropha no matter how much benefit they get. The main reason for this is small land holding size of the farmers, food insufficiency and their inability to depend on buying food from market which is expensive as well as its availability is uncertain.

7.4 Farmers willing to use maximum land for Jatropha plantation

Desire to use maximum amount and quality of land determines the scope of Jatropha cultivation. The farmers with the desire to utilize maximum amount of unused marginal can be beneficial for Jatropha cultivation. Farmers of 4 study sites were asked maximum amount of land they would like to devote in growing Jatropha to analyze their intensity of desire.

Table 7. 1 Maximum land willing to use for Jatropha plantation

Maximum amount of land willing to use	Total respondents (%)
All land except land for food crops	19.4
Half of the marginal land	22.7
Partial land	32.2
Only in presently used land	25.5
Total respondents	180

Source: Field survey, (2010)

From the analysis it was found that no farmer in the study area wants to grow Jatropha in land suitable for food crops. As shown in Table 7.1, about 32.2% of the farmers are willing to use partial amount of marginal land, 25.5% wants to continue with the present amount of marginal land being used, 22.7% half of the marginal land and 19.4% in all marginal lands except those for food crops. This means that willingness to devote different amount of land is more or less similar except that majority of them wants to use partial amount of marginal land of their farms In terms of amount of land willing to allocate for Jatropha cultivation, there is moderate to high level of willingness.

7.5 Social accord

Social accord in a society refers to the harmony of people's opinions or actions (Wordnet, 2006). During the social discord and dissatisfaction among people, the working environment is not favorable enough for cultivation and even if they undergo cultivation such production which creates discord cannot be considered as sustainable. Also, social concord among people makes the working environment more favorable.

To achieve this objective, farmers along with key informants were asked whether they have observed any kind of discord related or not related to Jatropha cultivation hampering its cultivation. Also, through group's discussion, the level of support they provide to each other at the times of difficulty or during cultivation was analyzed. It was found from the study that
there is no any kind of serious conflicting situation or discord in the study area except some minor timely misunderstandings which is common to occur everywhere. Majority (75.7%) of farmers has not observed any such discords however 24.2% of them have noted its occasional existence. Misunderstandings take place while deciding which commodity to grow and also while determining boundary line of community land though this problem is not typically of Jatropha only rather can take place while group of people use community land for any purpose. Farmers revealed observing minor disagreement while using community forest land for Jatropha cultivation in Tansen and Madanpokhara. Some of the farmers showed willingness to grow Jatropha while others Cinnamon, Broom grass or any other crops. Jatropha being non edible and not suitable for feeding livestock (Beckerlegge et al, 2008; Baskota, 2000) disagreement was found even within the family members regarding whether to grow it or not.

However, at the same time there is also social accord among farmers. They help each other in times of need whether in form of financial support or help each other during cultivation in form of manpower. Farmers do not need to hire labor as they support each other at the time of cultivation. So, in terms of social accord, study area is suitable for plantation of Jatropha.

7.6 Labor availability

Labor availability makes work easy in any situation. Jatropha requires large number of labors for pit digging, applying fertilizers, planting, irrigating, trimming, harvesting etc (Jongschaap,2007). The easy availability of labor at reasonable price helps growers to hire them for plantation.

The result from the analysis shows that there is medium level of difficulty in labor availability (43.4%) followed by easy (37.1%) and difficult (19.4%). Using labor for working in the farm in a paid basis by farmers is not common in Palpa. Generally, farmers help each other in preparing field, in planting and in harvesting. This is common among the farmers sharing harmonious relation. However, this situation poses difficulty in labor availability in case farmers wish to hire them. For an instance, hiring labor not being common in the study area, farmers not sharing mutual relation with their neighbors and not having any one to help him might have problem in labor availability which thereby affects Jatropha cultivation.

7.7 Training on Jatropha plantation

Right kind of training at right time encourages as well as sharpens the skills of the farmers to undergo plantation. This also teaches them to plant in the right and sustainable way. In case of Jatropha cultivation in Palpa, training is important especially because this plant is very new and in many cases it is totally new to the farmers so it is efficient to give them production and management related trainings. This enhances Jatropha cultivation and level of Jatropha production.

Figure 7.4 shows that majority of farmers (81.7%) have not received any kind of trainings while few percentage (18.3%) of them have received some trainings on nursery establishment and plantation of seedlings and its management practices. Farmers are highly expecting trainings that would help them in Jatropha cultivation and they are also hopeful that the trainings would cover all the level of farmers of different villages.

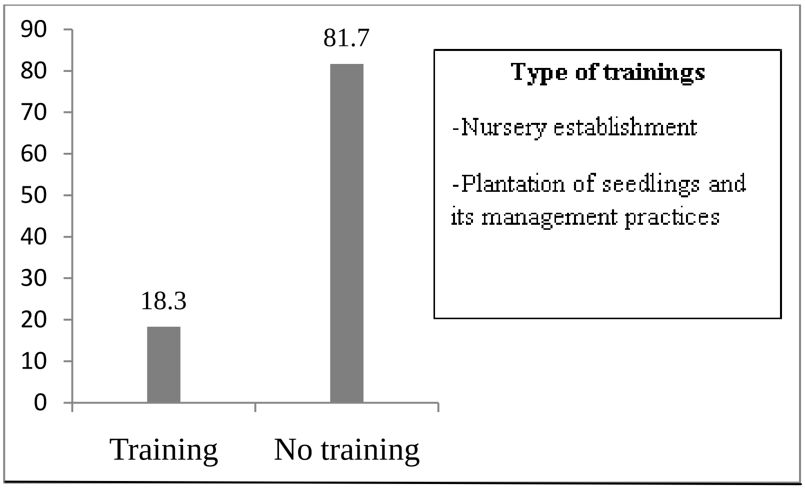

Figure 7. 4 Training on Jatropha cultivation

Training programs have been arranged in Palpa district 2 to 3 times for making farmers aware and more efficient in Jatropha plantation and management but the effort has been very limited. Jatropha plantation still being new area of interest, conducting training programs in large scale in an efficient way has not been possible. Government of Nepal has been making effort through local NGO's in this regard. Bhairav Darsan Sajiwan Urja Kendra, only NGO of Palpa working for Jatropha promotion and cultivation is actively taking part in such activities. They have been giving trainings to the farmers of Parasi and Palpa since last 2 to 3 years. In Palpa itself, different training programs have been organized by the support of District Forest and Department of Soil Conservation and Watershed Management. In their request, about 50 farmers which include community forest user groups and general farmers of Palpa were given training. The type of training includes training on nursery establishment and plantation.

7.8 Plantation support and rating of support

Along with the desire for plantation and favorable working environment, plantation support is also crucial especially when the commodity is in its initial stage of development. Jatropha cultivation has just been started with the farmers understanding its importance as fence and in generating fuel, income and environmental benefits since last 4 to 5 years. In such situation, encouraging them is very important to provide different plantation support and the quality of service they provide is equally important. Farmers are getting plantation support or not and if yes then who is supporting them and how they rate the performance of the supporters is an important criteria to decide potential of Jatropha cultivation in an area.

With regard to plantation support, 71.2% of farmers are getting support (43.4% from Local NGO and 27.8% from local community groups) while 28.8% are not getting any support as shown in Table 7.2.The support local NGO is providing includes creating

awareness through demonstrations, trainings, information on plantation, providing seedlings and buying their seeds or visiting them to collect seeds. Similarly, the support of local community forest user groups is in form of providing land, providing manpower, seedling availability and necessary information on Jatropha cultivation and marketing.

Table 7. 2 Plantation support to the growers

Plantation support	Total respondents (%)
Local NGO	43.4
Local community groups	27.8
No support	28.8

Source: Field survey, (2010)

Similarly, with regard to rating of support, 45.5% grade them as good while 36% poor and 18.5% neutral as shown in Figure 7.5. Those rating the support as good do not think they can expect more from them as it has only been around 3-4 years that Jatropha plantation has started in the country and within this short time NGO have demonstrated the use of Jatropha in order to generate information among them, provide trainings, necessary information's and buy their seeds. Farmers are hopeful that as Jatropha plantation extends in Palpa, number of supporters and level of support will definitely increase. Similarly, those rating poor are dissatisfied that supporters are not able to reach them all especially during the training programs and even are not providing sufficient information about Jatropha right from its production to marketing.

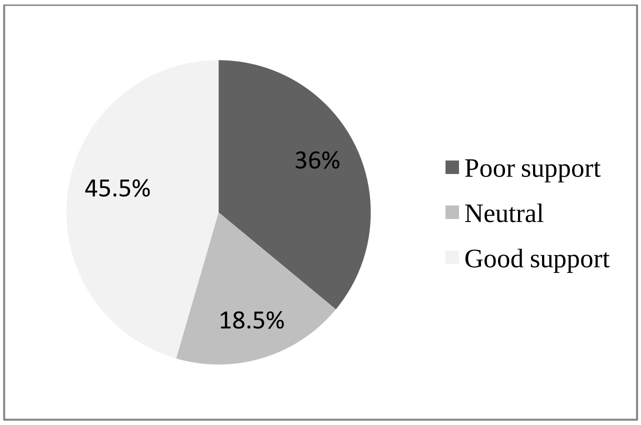

Figure 7. 5 Rating plantation support

7.9 Support on household expenses

Plantation of any crop is done with some profit motive and this motive might be in form of monetary value or indirect benefits like food value, religious value, use value or environmental value. Similarly, planting of Jatropha is also carried with some motives like fuel value, economic value and environmental value (Bhattarai, 2008). Farmers expect some level of support on their day to day household expenses from growing a commodity.

Support on household expenses of the farmer due to the benefit especially economic can encourage farmers to undergo Jatropha cultivation widely.

The result from the analysis shows that 38.6% of the household have received support but 61.3% have not received any support. Those getting support are mainly nursery owners and large scale producers. The reason for not receiving support is that in majority of cases (77.7%) planted Jatropha are small enough to obtain economic return to support household expenses of farmers. The planted Jatropha are around 3-4 years old and optimum return from Jatropha can be obtained only after 4 to 5 years of plantation (Bhattarai, 2008). Some of the farmers (22.2%) are not even selling their produce in market due to lack of information on market value of Jatropha.

It is important to wait for few more years so that the planted Jatropha gets matured enough to give return and it's possible to observe real effect of Jatropha plantation though majority of growers are expecting some good benefit from it.

7.10 Satisfaction from Jatropha plantation

Level of satisfaction is also an important criterion to determine further the willingness of the farmers to undergo plantation or extension. As the farmers get satisfaction from growing Jatropha, they tend to devote themselves more to it.

Table 7.3 shows that 40.4% of the farmers are satisfied, 35.5% are neural and 23.9% are dissatisfied. Farmers sharing neutral level of satisfaction were those still waiting to see the return from Jatropha. In most of the cases, plants are small enough to produce seed. Jatropha takes 5 years to give optimum level of return due to which farmers are still waiting to reach any judgment level.

Farmers showing dissatisfaction were those affected by high mortality and sterility rate of the planted Jatropha. As shared by farmers, plant take long time to give seed and is not even useful as livestock feed. This result is supported by (Lele, n.d; Openshaw, 2000; Bhattarai, 2008). Due to this some of farmers have to go to the longer distance in search of feed for their livestock. The level of uncertainty regarding market assurance of Jatropha is also very high.

The satisfaction seen among some of the growers is not only because of economic benefit but due to the benefits like maintaining greenery of their farms, acting as good fence thereby protecting their farms against livestock destruction (Beckerlegge et al, 2008). Farmers do not even need to take any care of Jatropha due to its ability to grow well even without management practices and separate productive land for its plantation (Bhattarai, 2008).

Table 7. 3 Satisfaction from Jatropha plantation

Satisfaction from Jatropha plantation	Total respondents (%)
Satisfied	40.4
Neutral	35.5
Dissatisfied	23.9

Source: Field survey, (2010)

7.11 Impact on environment

Impact on environment is one of the major factors to decide whether to plant Jatropha or not. These issues are not directly observed many times and are often neglected but in the long run this might result in serious problems associated with the environment like degradation of land, soil erosion, loss of genetic variability etc (Beckerlegge et al, 2008).

During the survey, farmers as well as the key informants were asked the impact of Jatropha plantation on environment that they have perceived after the plantation of Jatropha. This question was asked to both Jatropha growers as well as non growers.

The result shows that 53.1% of farmers have observed positive impact while remaining 46.9% have neither noticed positive impact nor any negative impacts. This means that there is no any observed negative environmental impact rather there are positive impacts of Jatropha cultivation in the study area. Jatropha maintains greenery in the unused marginal land, check landslides and erosion effect and can also protect crops from being eaten by the animals due to its use as fence which is non edible. However, no significant effect has been observed till date as planted Jatropha is still small enough to show any immediate effect. This result is supported by the study (Beckerlegge et al, 2008; Baskota, 2000) which further stress on its ability to hold water, pump minerals from the depth to the surface of the soil and allow more infiltration of water into the soil thereby breaking up of the compacted earth by the root of the plant.

Similarly, as documented from key informants, District Forest and Department of Soil Conservation and Watershed Management have planted around 22,000 Jatropha seedling in Bahadurpur and 10,000 in a place called Kachal due to its ability in maintaining soil conservation. Areas with severe landslide problem and sides of newly constructed roads have been selected for cultivation in order to reduce erosion and landslides and help land in reclamation. This planting was done just around 1 and half years ago and the real environmental impact is yet to be observed however both Department of Soil Conservation and Watershed Management and District Forest are very positive in this regard. Literatures show that Jatropha has tap root system and is deep rooted. It can hold water and soil with it tightly and as a result such places have lower problem of landslide, erosion and drought (Beckerlegge et al, 2008; Baskota, 2000). Also, the trimmed parts of the plants especially small branches and leaves are used for mulching as it has high nutrient values especially urea (Lele, n.d; Openshaw, 2000).

7.12 Crop diversification loss

The study shows that mono cropping is the most common cropping system practiced (54.2%) followed by mixed cropping (20.6%), mixed as well as mono cropping (16.8%) and intercropping (8.4%) as shown in Figure 7.6. In case of plantation in community land, mixed cropping is more common while in case of planting in the individual farm, mono cropping is widely practiced.

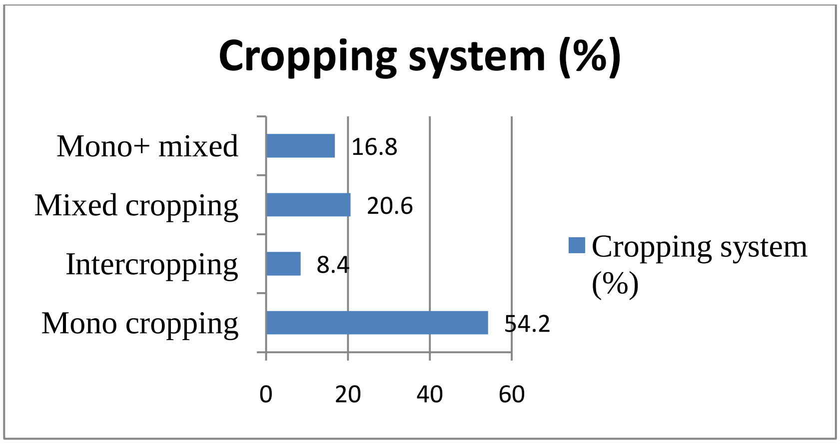

Figure 7. 6 Cropping system followed by the farmers

Literatures show that marginal lands often have high biodiversity value since such lands are the last remnants of ecosystem so using such land might affect biodiversity. Also, growing of Jatropha as mono crop can lead to loss of genetic diversity (EPFDL, 2008 - 2009). That is mono cropping can lead to loss of crop diversification which could invite several associated problems like risk of crop failure, genetic variability loss. In case of Palpa, mono cropping is widely practiced and cropping system to be followed is not taken as serious issue. At present, plantation is in very initial stage and it is done in only small scale due to which this is not seen as the problem but if the same condition persists in the coming days as well then there is no doubt that loss of crop diversification will be one of the serious problem. There is immense need of encouraging mixed or intercropping rather than mono cropping in Palpa.

Determining social and environmental suitability

AHP enables relative ranking between factors through pair-wise comparison on basis of pre-defined criterion and weights. The scale of weights varies from 1 to 9 which correspond to equally important to extreme important of one variable to other (Satty, 1990). AHP was used for ranking different factors of social and environmental suitability of Jatropha and for assigning weight to these factors. Pair wise comparison matrix was done assuming each factor to be equally important. The weights assigned to the factors were normalized in order to have sum of variables for each category equaling to 1. Later, the sum of each factor was averaged so that the value of factors equaled to 1. For examining, the consistency of judgments consistency ratio was calculated. Consistency ratio less than 0.10 are accepted (Eakin et al., 2008), if not pair wise comparison have to be reviewed again and again. The obtained factor weight is then multiplied with the ranking value until n number of factors using linear combination method to give suitability score. The criteria for determining level of social and environmental suitability are explained as follows:

>80%-Highly suitable

40-80%- Moderately suitable

20-40%- Marginally suitable

<20%- Not suitable

4,3,2,1 are the ranking given to each level of suitability i.e S1, S2, S3 and N respectively. The factor weight of social and environmental suitability is clearly presented in Table 7.4.

Table 7. 4 Social and environmental suitability of Jatropha

S.N	Factors	Value obtained (%)	Factor score	Factor weight	Suitability score
1	Willingness to plant/extend	60.2	3	0.083	0.70
2	People willing to use only marginal land	85.8	4		
3	Not willing to replace food crops	100	4		
4	People willing to use maximum amount of land	32.2	2		
5	Social accord	76	3		
6	Labor availability	43.4	3		
7	Trainings given	18.3	1		
8	Plantation support	71.2	3		
9	Support in household expenses	38.6	2		
10	Satisfaction from Jatropha plantation	40.5	3		
11	Positive environmental impact	53.1	3		
12	Crop diversification	29	2		

0.70 falls within the moderately suitable range (0.4-0.8), social and environmental suitability of Jatropha can be considered to be moderate in Palpa.

Chapter 8

Economic suitability

This chapter analyzes the economic suitability of Jatropha cultivation in Palpa district. Madanpokhara, Tansen, Masyam and Telgha are taken as the study sites. The parameters taken for the study are subsidy on production inputs, producers share on market price, cost and return from Jatropha, Broom grass and Cinnamon and market satisfaction from Jatropha cultivation (Tiwari, 1999; Rossiter, 1995).

Marketing of Jatropha

The field survey revealed that Jatropha is in its initial stage of production and marketing but still its demand and scope is in increasing rate. This is due to the increasing level of awareness regarding production of biodiesel from Jatropha, interest, encouragement and support of government and non-governmental organizations and also growing interest and awareness among farmers. There are still many marketing constraints and in fact no market assurance which creates the boundary line of risk for the growers and they are not certain whether they should go with its production and if yes then to what scale. Being non perishable, Jatropha seed does not need to be sold immediately though it might require care and storage if delayed for considerably long period of time. After 6 months of harvesting, Jatropha seed loses its germinating capacity so it needs to be sold in time. Marketing of produce is equally important to its production. Failure to get appropriate market price discourages farmers while good market price and favorable marketing condition lures farmers towards cultivation. Same case is true for Jatropha. Getting subsidy on inputs, appropriate market and market price, accessibility to market, efficient marketing channel, higher net present value, internal rate of return and benefit cost ratio is very important in fact they are the deciding factors for the farmers to be interested in its business. The detail of these aspects is discussed as follows:

8.1 Subsidy

Subsidy, an important incentive to encourage or support farmers in crop production was analyzed for Jatropha cultivation in Palpa. Group discussion along with key informant interview was carried out to determine whether there is any provision of subsidy in any form to the farmers growing or willing to grow Jatropha. From the survey, it was found that they were not even getting subsidy in fertilizer which they were getting since a long time. After almost a decade, government has reintroduced subsidy on fertilizer from the year 2009/10. For the fiscal year 2010/11, government is coming up with the package of doubling the subsidy in fertilizer and also subsidizing shallow tube wells. This attempt of government is to provide relief to the farmers facing rocketing farming cost which is reducing their competitive power compared to those farmers in other countries (Xinhuanews, 2010). A survey in Palpa further revealed that chemical fertilizers, compost manure, seedlings, irrigation and equipments are the major inputs required for Jatropha cultivation. However, there is provision of subsidy only on fertilizers and irrigation pump. Having no any subsidy on Jatropha seeds/seedlings, farmers are finding it quite costly. Farmers are expecting government to provide subsidy in seed/seedling of Jatropha along with the fertilizer and irrigation tube wells.

This study shows that farmers will have reduced cost in fertilizer and irrigation but still they have to bear the full cost of the current price of seeding/seeds and equipments. Interesting, for the initial plantation in community forest, district forest distributed 5,000 Jatropha seedlings free of cost to Deurali community forest user groups. The subsidy on fertilizer is not specifically for Jatropha promotion rather for general crop production but still this proves to be of great relief to the farmers growing Jatropha. Based on the information generated from the farmers, many of them will undergo Jatropha plantation if they get support in buying seedlings/seeds though the reduced cost in fertilizer and irrigation can be taken as positive step towards it.

8.2 Producers share in market price

To determine the market price of Jatropha at farmer's level and to compare it with that of retailers and collectors share, farmers, collectors and retailers interview was conducted. It was revealed that market price of Jatropha seeds has been fixed by biofuel personnel's from different sectors like AEPC, private NGO's and key personnel involved in Jatropha cultivation and promotion in and outside the district. Demand and volume of seed arriving in the market is one of the major factors they considered while pricing the seed as reflected from the study. The price charged by the retailers and collectors is little higher compared to their buying price from the farmer. Farm gate price of Jatropha seed is NRs.15-18/kg if they sell to the retailers or collectors but if they sell directly to the consumer then the price is NRs. 20/kg. Similarly, if the retailers and collectors are involved then collector's price is NRs17-19/kg and retailer's price is NRs 18-20/kg. Thus, the study indicates that there is small price difference between farmer's and retailer's price. The detail information regarding farm gate price, collector's price, market margin and producer's share in market price of Jatropha seed are presented in the Table 8.1.

Marketing margin is the difference between farm gate price received by the farmers and the price paid by the consumers. Similarly, producer's share is the amount received by the farmers compared to that of retailers (Pariyar, 2008). The formula used for calculation of marketing margin and producer's shares is given below:

Marketing margin= Retailers price (Pr)-Farm gate price (Pf)…………1

Producers share= Farm gate price (Pf)/Retailer price (Pr)*100………..2

Table 8. 1 Market price and producers share from Jatropha cultivation

Farm gate price (NRs/kg)	Retailers price (NRs/kg)	Market margin (NRs/kg)	Producers share (%)
16.5	20	3.5	82.5

Field survey, 2011 (1USD= 72.3NRs)

The result in Table 8.1 depicts that average market margin received by retailers is 3.5 and producers share in the market price of the seed is 82.5%. The profit share of the producers is very high compared to that of retailers. The difference between the price received by farmers and retailer is quite low i.e there is only some price gap between farmer and the retailer's price. This price difference between farmer and retailer is reasonable one. Jatropha cultivation being in initial stage and Jatropha market newly formed, there is no monopoly in both producers and retailers side. The producers are getting relatively higher

share in market price compared to that of retailers and also price difference between retailer's price and farmer's gate price is quite low. This can be taken as an encouraging factor to the farmer's. However, the situation might change if the market structure becomes stabilized, volume of the produce and consumers increases.

8.3 Cost of production and return from Jatropha and other marginal land crops

Cost and return from production strongly determines cultivation potential of Jatropha to the farmers. Based on the cost and return they get from Jatropha in a particular site, their willingness to grow is highly dependent. In order to determine whether Jatropha cultivation is economically sustainable in the study sites, average cost and return from it in 4 different study sites were analyzed. Additionally, to determine whether planting Jatropha is more beneficial compared to other plants that require similar kind of land as Jatropha, the cost and return analysis of Broom grass and Cinnamon plant has been done individually. Ten years period has been considered for the analysis as Jatropha gives maximum return until 10 years and then it has to be trimmed to the height of 2m and again it grows slowly and gives similar level of optimum return (Bhattarai, 2008). In order to determine economic feasibility of Jatropha, Net Present Value (NPV), Benefit Cost ratio (BCR) and Internal Rate of Return (IRR) has been calculated.

The cost of production is the sum of operating cost (variable cost), fixed cost, labor cost and marketing cost. Generally, labor cost is included in the operating cost but in this chapter it has been presented separately as labor cost is one of the most important cost to be observed closely in case of Jatropha cultivation. Cost of Jatropha grass has been computed on the basis of cost incurred in growing them in 1 hectare of land. The prevailing rates of inputs, labor, fixed assets and marketing of different plants were obtained interviewing farmers and key informants. The total cost of production is calculated from the sum of operating, fixed, labor and marketing cost. Net profit is calculated by deducting total cost from gross income. Similarly, NPV, BCR and IRR were calculated for Jatropha which is shown in Table 8.2 and 8.3.

Table 8. 2 Cost and return from Jatropha

Area (ha) = 1 hectare
Spacing= 2m*2m
Number of seedlings= 2500
Life span = (50-60) years
Maturity/ gestation period = 5 years
Estimated years for the analysis = 10
By products = - Leaf (bio-fertilizer); cake (biogas, fertilizer (NPK is high i.e. does the work of urea); glycerol (gives glycerin after purification that can be used for the production of soap, cosmetics etc)

S.N	Cost	Unit	Required amount (10 years)	Average rate (NRs)	Average cost in10 year (NRs)
1	**Variable**				
	Seedling	No	2,500	5	12,500
	Compost	Kg	3,7500	4	20,0051.9
	Irrigation		-	-	26,673.59
	Total variable cost				239,225.49
2	**Fixed**				
	Land tax	NRs	-	450	4,500
	Kodalo	No	20	46	920
	Shovel	No	20	120	2400
	Secateur	No	20	1085	18,852
	Total fixed cost				28,173.55
3	**Labor**				
	Site preparation, pit digging	No	-	240	28,800
	Compost mixing, sowing	No	-	240	192,049.8
	Weeding and trimming	No	-	240	128,033.2
	Harvesting of seed	No	-	240	62,921.56
4	**Marketing**		-		
	Jute bag	No	1,055	50	30,285.43
	Transportation		-	-	29,980.02
	Total marketing cost				60,265.45

1(USD= 72.3 NRs)

Return from Jatropha

S.N	Item	Quantity (In 10yrs)	Average market price (NRs)	Return in 10 years (NRs)
1.	Seed	52,500 kg/ha	16.5	124957.8

(1USD= 72.3 NRs)

A project or any investment is said to be profitable if NPV is positive, BCR is greater than 1 and IRR is greater than that of interest rate. Jatropha satisfies these criteria. The analysis shows that investment in Jatropha is profitable.

Table 8. 3 Economic analysis of Jatropha

S.N	Plants	NPV(NRs)	IRR (%)	BCR
1	Jatropha	108,736.54	30	1.68

Source: Field survey, (2010) (1USD= 72.3NRs)

8.4 Satisfaction from market

Every commodity is grown by farmers with some profit motive and income. No matter what the fuel value of Jatropha is to the country but farmers undergo its plantation only if they get enough income from it. No subsidy or no support can lure them if they are not satisfied with the market price and if market condition is not stable. This makes market satisfaction an important parameter of evaluation.

The level of market satisfaction of the Jatropha growers was calculated in order to test satisfaction index of the growers regarding existing price of the seed and market mobilization. The basis of satisfaction was subsidy on production inputs, market price, cost and return from Jatropha cultivation, mode of transportation, marketing channel, market centers and market stability.

During the interview, respondents were given three options assigning scores like satisfied (+1), neutral (0) and dissatisfied (-1). A three point scale of satisfaction used in the study was satisfied, dissatisfied and neutral. Satisfaction index is calculated as:

$SI= Fs-Fd/N$

Where, SI= Satisfaction index

Fs= Frequency of farmers responding satisfaction

Fd= Frequency of farmers responding dissatisfaction

N= Total number of observation

The value of the index ranged from +1 to -1 indicating 1 as satisfied, 0 as neutral and -1 as dissatisfied.

Table 8. 4 Satisfaction from market and government roles and rules

	Dissatisfied	Neutral	Satisfied	Satisfaction Index (SI)
Market	33	95	42	0.05

Source: Field survey, (2010) n (No. of respondents) =170

The result presented in Table 8.4 shows that satisfaction level of farmers from exiting market condition is nearly neutral. There were number of farmers showing dissatisfaction (33), satisfaction (42) and those with neutral (95) level of satisfaction.

Farmers sharing neutral level of satisfaction were those not aware of overall return they can generate from Jatropha business basically because Jatropha planted are still small and optimum yield from Jatropha can be obtained only after the 5th year of plantation. Optimum return from Jatropha is yet to be observed.

Similarly, dissatisfaction seen among farmers is due to lack of market stability. This has created uncertainty among farmers whether or not to cultivate Jatropha. The local NGO's, promoter and demonstrators are the major buyers of seed at present in Palpa. Farmers shared their uncertainty whether they will be able to get same level of market as they are getting now if volume of the produce increases and their present buyers (local NGO's and promoters and demonstrators) stops buying their produce. The prevailing unstable market condition, comparatively low market price and unobserved optimum return from the Jatropha are major causes of dissatisfaction.

Determining economic suitability

Analytical Hierarchical Processing (AHP) enables relative ranking between variables through pair-wise comparison matrix on the basis of predefined criterion and ranking. The scale of weights varies from 1 to 9 which correspond from equally important to extreme importance of one variable over other. AHP was used for ranking different factors of economic suitability of Jatropha and for assigning weight to these factors. Pair wise comparison matrix was done assuming each factor to be equally important. The weights assigned to the factors were normalized in order to have sum of variables for each category equaling to 1. Later, the sum of each factor was averaged so that the value of factors equaled to 1. For examining the consistency of judgments, consistency ratio was calculated. Consistency ratio less than 0.10 are accepted (Eakins et al., 2008), if not pair wise comparison have to be reviewed again and again.

Moreover, after obtaining factor weight using AHP method, suitability score is determined by using linear combination method. Different factors have different criteria for determining level of economic suitability. 4,3,2,1 are the ranking given to each level of suitability i.e S1, S2, S3 and N respectively. In case of subsidy, producers share on market price and market satisfaction, criteria is almost similar which is

>80%-Highly suitable
40-80%- Moderately suitable
20-40%- Marginally suitable
<20%- Not suitable

Chemical fertilizers, compost manure, seedlings, irrigation and equipments are the major inputs required for Jatropha cultivation however, there is provision of subsidy only on

fertilizer and government is planning to provide it in irrigation pump so is considered be marginally suitable.

Similarly, NPV positive, BCR >1 and IRR>interest rate then the commodity is profitable. In this case, all three values satisfy the criteria of positive investment and also the value obtained is very high so these factors are given high factor score.

The detail of factors, factor values obtained from the study, factor score, weights and suitability score is given in Table 8.5.

Table 8. 5 Economic suitability of Jatropha

Factors	Values obtained	Factor score	Factor weight	Suitability score
Subsidy	Only on fertilizer and irrigation pumps	2	0.16	0.8
Producers share	82.5%	4		
Net Present Value (NPV)	108,736.54	4		
Benefit Cost Ratio (BCR)	1.68	4		
Internal Rate of Return (IRR)	30%	4		
Market satisfaction	24.7%	2		

The Table 8.5 shows that suitability score of Jatropha is 0.8. This value falls within the moderately suitable range (0.4-0.8) so the economic suitability of Jatropha can be considered to be moderate in Palpa.

Chapter 9

Conclusion and Recommendation

9.1 Conclusion

The study on potential for sustainable cultivation of *Jatropha curcas* determines the biophysical, social, environmental and economic suitability at different level in Palpa district. The conclusion of the study is divided objective wise and discussed under separate headings as given below:

9.1.1 Biophysical suitability of the land for Jatropha cultivation

Jatropha cultivation is moderately suitable in Palpa district based on biophysical characteristics. Tansen has the highest suitability score of 0.71 followed by Madanpokhara and Masyam with 0.68 score each and then Telgha with the least score of 0.63. However, suitability level of most of the biophysical factors in all study sites was similar in most of the cases. This is because the area considered for the study share boundary with each other and is very small in area to show variation in factors of land suitability.

There is limitation in some of the biophysical factors like low rainfall, low soil organic matter and soil nutrient, steep slopes and medium level soil drainage. To minimize these limitations in order to improve yield of the plant and main sustainability of the resources, external inputs such as irrigation, fertilizers and compost manure can be added and drainage system can be constructed to reduce water logging. Also, 27.6% of total district area is situated on the land having slopes between 5-30 degrees and >63.0% of district total area in slopes >30 degrees. So, there is need to follow the land capability guidelines of the country according to which plantation should be limited to the land belonging to the class I (<1degree slope), II (1-5degree slope) and III (5-30 degree slope). Class III used only after terracing.

The study was able to integrate rainfall, temperature, slope, land use and soil properties however there were number of other factors that could have been looked at but due to data unavailability the study could not include them all. The map generated from the study would have been complete had the study been able to integrate all the factors determining suitability of Jatropha in the study area

9.1.2 Social and environmental suitability for Jatropha cultivation

There were 12 factors considered in the study to determine social and environmental suitability. The basis of evaluation were willingness to plant/extend, farmers willing to use land for plantation, willingness to replace food crops, farmers willing to use maximum amount of land, social accord, labor availability, training on Jatropha cultivation, plantation support to the growers, support in household expenses, satisfaction from Jatropha plantation, impact on environment and crop diversification loss.

The result from the analysis shows that there is moderate level of social and environmental suitability of Jatropha cultivation in Palpa. The suitability score obtained from the analysis was 0.70.

There is limitation in some of the social and environmental factors like not enough support from local organizations and government, not enough training programs organized and even the organized trainings is able to reach very few numbers of farmers only, lack of awareness on importance of Jatropha due to which many farmers are not selling their produce and mono cropping has been followed widely in all study sites. To resolve these limitations, there is need of generating awareness and providing information among farmers regarding importance of Jatropha, its production and marketing. Effective plantation support from the organizations especially by providing seedlings of good yielding varieties and organizing training programs that is able to meet the need of large group of farmers need to be done. Similarly, the recently ignored mono cropping of Jatropha must be discouraged and strict rules and serious steps should be made at the national level.

9.1.3 Economic suitability for Jatropha cultivation

Subsidy on production inputs of Jatropha, producers share on market price of Jatropha, cost and return from Jatropha (NPV, IRR and BCR) and market satisfaction from Jatropha cultivation were the factors used in the study to evaluate economic suitability of Jatropha cultivation in Palpa. The result shows that economically, Jatropha cultivation is moderately suitable in Palpa with suitability score 0.8. Jatropha has high economic benefit since their NPV, IRR and BCR value is very high (NPV: 108,736.54 NRs, BCR: 1.68 and IRR 30%).

Having no provision of subsidy in seedlings, there is need of providing incentive in form of subsidy in production inputs to encourage the farmers. There is lack of information among farmers regarding production and marketing of Jatropha cultivation due to which it is important to generate awareness effectively among the farmers. Also, farmers claimed to have no market assurance so for long term social and economic sustainability, market assurance and stability is the key step to be taken before encouraging farmers to undergo cultivation.

The result obtained from the study is useful in determining level of Jatropha suitability and the potential area for its cultivation in Palpa. It also highlights external inputs to be added and management practices to be carried out to obtain optimum level of production. The information generated from this study is useful in making policies for sustainable Jatropha cultivation and land use system in Nepal. The general methodology acquired in the research can be extended to other areas as well as to the different parts of the country where land conditions is similar to study area. However, the result obtained may not be conclusive if applied all over the country given limited samples taken, differences in geographic features and site specific different scopes and problems. Also, the study is not being able to cover all the factors of biophysical, social, economic and environmental suitability due to the limitation of data availability.

The main strength of the study is inclusion of sustainability dimension in land evaluation i.e. the evaluation is based on thorough analysis of biophysical, social, economic and environmental aspects. The similar approach can be applied for further studies of Jatropha or any other commodity whether food crops, cash crops or any ornamental plants in different parts of the world. Evaluation of land before its use maintains long term sustainability of land, its resources and people. This study highlights the need of inclusion of all three sustainability dimension in land evaluation for overall sustainability.

9.2 Recommendation

The findings of the study indicate that Tansen municipality and Madanpokhara, Telgha and Masyam VDC's of Palpa exhibit moderate level of potentiality for Jatropha cultivation. There is need of serious steps to be taken for its sustainable cultivation in the study area. The capacity and role of different sectors varies in improving Jatropha cultivation in Palpa in a sustainable way. Therefore, on the basis of the research findings, recommendations have been made targeting local people, government and non-governmental organizations and for other keen researcher in different areas.

9.2.1 Recommendation at local and national level

- Plantation of Jatropha should be limited to marginal lands of farms and community lands. Erosion prone areas that need reclamation and newly constructed road side areas should be used.

- Guidelines of land capability assessment should be followed. Plantation should be limited to the land belonging to class I (<1degree slope), II (1-5degree slope) and III (5-30 degree slope). Class III used only after terracing.

- To reduction limitations of biophysical factors like low rainfall, low soil organic matter and soil nutrient, steep slopes and medium level soil drainage, external inputs (irrigation, fertilizers, FYM, construct drainage system to reduce water logging) should be added.

- There is need to encourage plantation support at private and government level through subsidy on seedlings, creation of awareness, providing good yielding varieties of seeds, trainings and market information.

- Assurance of market and its stability should be done before encouraging farmers to cultivate Jatropha.

9.2.2 Recommendation for future research

- This study used rainfall, temperature, slope, land use, soil texture, soil drainage, soil organic matter, soil PH, soil nutrient and soil depth to analyze biophysical potential of Jatropha in 4 study sites which were close to each other and had similar biophysical characteristics but detailed study may be done in wider area i.e. in different physiographic region of the district using more number of parameters such as erosion hazard, altitude, irrigation, watershed, river, access to road, distance from market etc.

- The impact on environment is based on farmer's observation and perception but further research could analyze environmental impact thoroughly through quantification method. In order words, land use impact assessment on soil and biodiversity may be assessed in the future.

- Potential area at different level of suitability for Jatropha cultivation may be determined.

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Appendix 1Weighing score for Identification of suitable land for Jatropha cultivation in Palpa

The weighing score taken was from 1 to 5 and their meanings are as follows:

5 means the most important factor
4 means important factor
3 means moderately important factor
2 means marginally important factor
1 means slightly important factor

Factors that has influence to Jatropha yield (weighting score)

S.N	Factors	Weighting score (1-5)
1.	Land use	
2.	Rainfall	
3.	Temperature	
4.	Slope	
5.	Soil texture	
6.	Soil drainage	
7.	Soil organic matter	
8.	Soil nutrient	
9.	Soil depth	
10.	Soil PH	

Appendix 2: Temperature, rainfall and soil data

Table A21 Average temperature of 22 years (degree celsius) at Tansen station

Maximum Temperature	Minimum Temperature	Average Temperature
27.12	13.21	20.17

Source**:** DHM, (2010)

Table A22 Monthly average rainfall of 22 years (mm) at Tansen station

JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
35.3	43.3	35.9	37.9	89.2	260.6	468.6	376.5	169.4	53.9	29.3	24.9
Average rainfall 135.438											

Source: DHM, (2010)

Appendix 3: Photos relevant to the study

Jatropha plant

Jatropha nursery

Oil from Jatropha

Broom grass

Cinnamon leaves

Cinnamon bark

Researcher interviewing DFO | **Researcher conducting household survey**

Researcher interviewing local NGO officer | **Researcher labeling sampled soil**