# Characterization of Some Plants of Dhading District, Central Nepal to Harness the Bioenergy

A Dissertation Submitted for the Partial Fullfillment of the Requirement for the Master's Degree in Science, Central Department of Botany, Tribhuvan University


Submitted by

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Submitted to

**Central Department of Botany**

**Tribhuvan University**

**Kirtipur, Kathmandu, Nepal**

**February 12, 2017**

# TRIBHUVAN UNIVERSITY
INSTITUTE OF SCIENCE AND TECHNOLOGY
# CENTRAL DEPARTMENT OF BOTANY

Ref No:

KIRTIPUR, KATHMANDU
NEPAL

Tribhuvan University Central Department of Botany Kirtipur, Kathmandu

## Recommendation

This is to recommend that Mr. Bishnu Rijal has successfully completed his dissertation work entitled "Characterization of Some Plants of Dhading District, Central Nepal to Harness the Bioenergy" under our joint supervision. The work is mainly based on the data collected by the student himself and the result of this work have not yet been submitted for any other academic degree.

We, therefore, recommend his work for approval and acceptance for the partial fulfillment of Master's Degree in Botany from Tribhuvan University.

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Tribhuvan University
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### Letter of Approval

The M.Sc. dissertation entitled "Characterization of Some Plants of Dhading District, Central Nepal to Harness the Bioenergy" submitted at the Central Department of Botany, Tribhuvan University by Mr. Bishnu Rijal for the partial fulfillment of his Master Degree in Botany, has been accepted.

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Bishnu Rijal

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## Abstract

Exploration of potential bioenergy sources, mainly fuelwood and oil yielding species, in six Village Development Committees (VDCs) of Dhading district: Aaginchowk, Baseri, Budhathum, Mulpaani, Phulkharka and Salyantaar, revealed 220 species of potential bioenergy plants, out of which 140 species are trees, 44 shrubs, 11 climbers and 25 herbs. The list is based on formal and informal meetings, reconnaissance survey, focus group discussion, key informant interviews, audio visual records, field survey, herbarium analyses and photographs. Usually, the oil yielding plant resources are cultivated in every household (HH). Fuel wood species (99.16 % HH) is the most widely used source of energy followed by electricity, kerosene, solar, liquidfied petroleum gas (LPG) and bio gas. For the laboratory analysis, 10 species each from the general list of 54 fuelwood species and 37 oil yielding plants species widely used/known by 120 (40 in each VDCs namely Budhathum, Mulpaani and Phulkharka) household's (HH) respondents are selected on the basis of various potentiality measuring characteristics of plants. The governing characteristics are abundance, burning efficiency, degree of smoking, durability, use value, preference ranking, chorotype, stress tolerance, propagation, agronomical integration, edibility, harvest flexibility and oil content. In general, the proximate (moisture content, volatile matter, ash content and fixed carbon) analysis and the calorific value estimation supported the acuity of local people, accounting lesser amount of moisture and ash content and greater volatile matter and fixed carbon in the selected fuelwood species like *Rhododendron arboreum*, *Lyonia ovalifolia*, *Shorea robusta* and *Schima wallichii*. Additionally, the evaluation of oil content also supports the local people's perception to the greater extent with the depiction of higher percentage of oil content and the presence of neutral oil in the Fourier Transform Infrared (FTIR) spectrometry analysis of almost all oils from the selected oil yielding species: *Ricinus communis*, *Diploknema butyracea*, *Guizotia abyssinica*, *Brassica nigra*, *Camellia kissi* and *Jatropha curcas*.

**Keywords:** Energy sources, fuel wood, oil yielding plants, reconnaissance survey, proximate analysis, calorific value, oil content

# Abbreviations and Acronyms

| | |
|---|---|
| ESON | Ethnobotanical Society of Nepal |
| et al. | Et alii: and others |
| FTIR | Fourier Transform Infrared |
| GHG | Green House Gases |
| Gm | Gram |
| HH | House Hold |
| HoD | Head of Department |
| KATH | National Herbarium and Plant laboratories, Godavari, Lalitpur |
| Kcal | Kilo Calorie |
| Kg | Kilogram |
| LPG | Liquified Petroleum Gas |
| M | Metre |
| Ml | Mililitre |
| NARC | Nepal Agricultural Research Council |
| NAST | Nepal Academy of Science and Technology |
| STDEV | Standard Deviation |
| TUCH | Tribhuvan University Central Herbarium |
| VDC | Village Development Committee |
| wt. | Weight |

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# 1. Introduction

## 1.1 Background

Need of energy is inevitable for life. The Sun, being primary source of energy for all living components in earth, only photoautotrophs can harvest that energy for their usage (Ramachandra & Kamakshi 2005; Smith & Hughes 2009). And for the heterotrophs, secondary source of energy is crucial. However, human do search for technology in capturing solar energy but before the advancement of human civilization, people largely depend on easily available storage carbon as a source of their energy. Later on, various forms of energy are explored. Nowadays, diversification in energy usage is under promotion for sustainability in energy utilization (Chow *et al*. 2003). Rather than solely depending on fossil fuel, other categories of renewable and non-renewable energy are also under consumption (Lovins 2012), and biofuels are one among them (Russi 2007; Johansson *et al*. 2010).

It has been estimated that biofuels would provide almost 25% of the world's energy needs in few decades (UN Energy 2007). About 14% of the world energy and 38 % of energy in developing countries comes from the biomass. Now, 'bio energy is the second largest commercial renewable energy source' (cited in Patel & Gami 2012). Their availability in various forms – in solid (biochar, biobriquette, firewood etc.), liquid (ethanol, methanol, and diesel) and gaseous (methane, hydrogen) could be a probable substitution for coal, petroleum energy and natural gases to generate electricity, transport, run industries, heat the rooms etc. (Supply 2007; Jessup 2009). Instability in petroleum prices, climate change effects, heavily rely on fossils fuels and maximum harvest of petroleum products further corroborate need of significant change in energy use pattern (Campbell 2002; Barney & Ditomaso 2008; Bardi 2009; Jessup 2009; Lei *et al*. 2013).

Regarding Nepal, the dominant energy sources for cooking are traditional, like fuel wood and animal dung contributing to about 74.4% while commercial energy sources such as kerosene, LP gas and electricity shares about 22.1% of the national energy consumption. In totality, the firewood alone accounts for about 64% and the petroleum products contribute to about 22% (Bista 2014). As such, concern in bioenergy is increasing in developing countries like Nepal. Moreover, it seems essential in documenting the ethnic knowledge in utilization of various forms of biofuels.

Since time immemorial, denizens living in every part of the world were using fuelwood, oil plants and other bioenergy plants (Gerique 2006). They have their own scientific knowledge in their utilization. Selection for the plants that shows durability, abundance, easy burning and others plant related aspects for their usage as firewood or fuelwood are some of their scientific practices. Hence, it is essential to document this information about the bioenergy plants that are known and in use by the ethnic people. Meantime, in current scenario of energy crisis, use of bioenergy plants seem to be the ultimate, alternative, renewable, sustainable natural resource that can meet the present and future energy demands easily and cheaply providing quick, handy and multiple opportunities for the livelihood of rural communities (Supply 2007; Fletcher *et al.* 2011; Dipti & Priyanka 2013). As such, ethnobotanical survey would be most appropriate for the acquisition of such knowledge (Martin 1995; Alam 1998). Participatory approach of ethnobotanical studies makes it possible to gather such ethnic knowledge.

The leading nations in the world have set up the possible bio fuel plants that can hold the energy demand and are investing in the alternative sources of energy (Fletcher *et al.* 2011). The major potential bio fuel plants in the USA are *Populus* spp., *Salix* spp., switchgrass (*Panicum virgatum* L.), *Miscanthus* spp., sugarcane (*Saccharum* spp.), Jatropha (*Jatropha curcas* L.), corn (*Zea mays* L.), soyabean (*Glycine max* L.) and different types of algae (Jessup 2009; Bickham & Thomas 2010; Fletcher *et al.* 2011) where as in Brazil are sugarcane, rape seed, *Glycine max* L., and in European Union are Wheat, sugar beet, soyabean and rapeseed (Leal & Walter, 2014). Plant species like *Saccharum officinarum* L. and *Jatropha curcas* L. can be the potential species of Nepal which are abundantly found and are indigenous as well (Baral & Bhattacharya 2014).

However, the characteristics of plants that can disclose the potentiality can be governed with some of the characteristics as: easy propagation, seed bearing, higher growth rate, non-invasiveness, higher productivity, stand ability, stress tolerance, wildlife habitat, carbon sequestration, agronomical integration, highly abundant, maximum use value, regeneration, etc. (Jessup 2009). The development of bioenergy lasts long if the economic, social and environmental impacts are critically analyzed. Hence, especial attention should be made in selecting the species, sites, tools and techniques of production (UN Energy 2007). With these eco-physiological aspects, characteristics of bioenergy plants like its proximate values (moisture content, volatile matter, ash content nad fixed carbon) and energy content etc. for fuelwoods (Acda & Devera 2014) and percentage of oil content and types of triacylglycerides in oils further conveys the potentiality of bioenergy plants (Linder 2000; Moser 2009).

Moisture content of the fuel wood species – the amount of the water per unit mass of the solid (Khardiwar *et al*. 2013), affects the quality of the biomass. Higher the moisture content less potential the fuelwood. The moisture content also affects calorific value (the amount of energy per unit mass of the biomass) of the woody biomass. The moisture content reduces the calorific value of the wood as some part of the heat energy at the time of combustion is lost to evaporate moisture (Krajnc 2015). With higher amount of volatile matter, it is easier for burning the fuelwood which also measures it potentiality for fuelwood.

Likewise, the nonvolatile mineral matter remaining even after the release of volatile matter is the fixed carbon, the presence of which indicates the easier burning and high energy content in the wood sample (Kharidwar *et al*. 2013). Ash content – the inorganic matter left out after the total combustion of the biomass, affects the ash fusion and hence is the indicator of the potential biomass for energy. The total ash content and the chemical composition direct the energy release from the biomass. The sticky ash may cause problems in the combustion and the gasification reactors. Similarly, the calorific value- the amount of energy released during the complete ignition of the unit mass of biomass is most important feature of the fuel. It reveals the total amount of heat energy developed during ignition of the sample in presence of oxygen in standard calorimeter. Higher the calorific value, higher will be the preference of the fuelwood species (Moka 2011).

Plant oil is inevitable component in the human societies these days, as it is most widely used for various purposes and is composed of triglycerides, which are esters formed by the reaction between three fatty acids and trihydric alcohol. The plant oil is now not only used for the household purposes but also for running the vehicles, industries and generators. The oil is treated with the short chain low molecular weight alcohols (methanol or ethanol) in presence of base or acid as catalyst, at the time of biodiesel production. Ethanol is preferred due to its low cost, where as Methanol is more efficient. Most often, base catalyze technique is used for the production of biodiesel which is supposed to be faster and cost efficient than the acid catalyze technique (Anastopoulos *et al*. 2009). Higher the oil content in the plant seeds higher is the preference of the plant for biodiesel production.

### 1.1 Research questions

The research questions are as follows:

1. What are the most preferred bioenergy plants by the local people for their livelihood?
2. Is there any difference between peoples' perception and laboratory characterization of bioenergy plants?

### 1.2 Objectives

The overall aim of this research work is to assess availability and the potentiality of bio energy (fuelwood and oil yielding) plants of Dhading district, to address the dependency of people in the biomass based energy.

**Specific Objectives**

1. Enumerate the bioenergy plants preferred by the people for their livelihood.
2. Measure the proximate values and evaluate the calorific value of the selected fuel wood species.
3. Determine the oil content and its constituents in the selected oil yielding plants.

### 1.4 Justification

A huge number of residents in Nepal are using bioenergy plants in their daily life to run their livelihood since ages especially for cooking, warming, and lighting purposes. However, their documentation about the knowledge of using those plants is rarely done. Not only for the household usage but also to run the industries, are the bioenergy plants being used due to their great benefits at present days especially in comparison to other energy sources.

Moreover, the bioenergy from bioenergy plants is ultimate, alternative, renewable, sustainable and natural energy source that can meet both present and future energy demands. Bioenergy is the easier and cheaper means of energy, used since the evolution of human civilization. Besides these, bio-energy provides quick, handy and multiple opportunities for the livelihood of rural communities. Hence, the exploration and scientific use of the bioenergy plants is crucial at present days to substitute the conventional fossil fuel and to reduce the global climate change effects (Kayo *et al.* 2015).

Not only for the rural communities, the biomass of plants (pellets and coal) being used in the urban communities for household and industrial purposes. Environment friendly biodiesel obtained from the biomass of plants is only a potential solution to the problems of fluctuating fossil fuel prices and desired energy security. However the characterization of such plants is rarely done.

With all these premises, the study was designed to explore the dependency of local inhabitants in bioenergy plants at the six VDCs of Dhading district, Central Nepal, followed by enumeration of such plants and finally measuring the potentiality of bioenergy plants via ethnobotanical data which was accompanied by the laboratory analysis for the selected species. The study can be a good reference for the depth study of the plants in future. Therefore, the chosen dissertation topic is expected to be justifiable.

### 1.5 Limitation

Although an exhaustive field survey and laboratory work wasdone, there were few limitations in obtaining the required data. Some of them are listed as follows:

1. Plant seeds were collected in different seasons.
2. The oil content of the seeds was excluded in triplicate due to the limiting facility of the laboratory.
3. The study covers six out of fifty two village development committees of Dhading district.

# 2. Literature review

## 2.1 Dependency of people in differenct energy sources

According to Bhatt & Todaria (1992), the fuelwood species like *Ilex dipyreana*, *Viburnum grandiflorum*, *V. cotinifolium*, *Betula utilis*, *Rhododendron campanulatum* and *Juniperus wallichiana* in Garhwal Himalaya have better firewood properties. Quantitative analysis of 32 indegenous mountain fuelwood species was performed which revealed that the temperate species are best for firewood due to high calorific values, low ash and water content, high density and high biomass to ash ratio.

Abbasi *et al*. (2011) reported that the oldest fuel which is used since the immemorial time is fuelwood. Based on ethnobotanical studies in lesser Himalayas-Pakistan, the species like *Melia azedarach, Morus* spp., *Pinus roxburghii, Woodfordia fruticosa*, *Quercus* spp., *Prunus* spp., etc. were depicted as the widely used species for fuelwood. Almost 90% people depend on fuelwood and remaining 5% depend on kerosene and gas cylinders in the Himalayas. KC *et al*. (2015) reported the higher value of benefit due to the dependency of the people in the firewood and fodder of community forest.

With the application of household survey method in Dolakha district, Kandel *et al*. (2016) reported that biomass energy especially fuelwood is the major source of energy in developing countries like Nepal. The main aim of the research was to explain about the consumption trend of the fuelwood and to investigate the role of community forest and private farmland in biomass supply to rural households. Most of the households were found dependending on the community forest and private farmland for the energy.

## 2.2 Laboratory analysis of fuelwood species

Bhatt & Todaria (1992) reported that *Pinus roxburghii* has the calorific value of as 17.8 KJ/gm (4254.30 Kcal/kg) on dry weight basis, moisture content as 40.2% and ash content to be 1.5%. Moisture content was obtained after drying the wood sample at 100±5°C for 48 hours and energy was estimated burning the sample in an oxygen bomb calorimeter and ash content was estimated using 2 gm sample burning in a muffle furnace at 600°C.

On the basis of local people's preference scores using participatory rural appraisal, Chettri & Sharma (2007), comparethe firewood value with constituent wood properties from trekking corridor, Sikkim India. They evaluated seventeen widely used fuelwood species of local people's preference scores against constituent wood properties using Pearson correlation and multiple regressions. They found that the *Quercus* spp. and *Rhododendron* spp. were the most preferred species on the basis of local preference scores and Firewood Value Index (FVI). They reported that the moisture content of *Alnus nepalensis*, *Castanopsis indica*, *Schima wallichi* and *Rhododendron arboreum*was 66, 38, 59 and 25 on percentage basis respectively. Similarly, ash content and calorific value was 1.6%, 0.38%, 0.22%, 0.24% and 16.25 KJ/g (3883.84 Kcal/Kg), 18.84 KJ/g (4502.87 Kcal/Kg), 19.41 KJ/g (4639.10 Kcal/Kg) and 19.72 KJ/g (4713.19 Kcal/Kg) respectively for *Alnus nepalensis*, *Castanopsis indica*, *Schima wallichi* and *Rhododendron arboreum*.

Sharma *et al*. (2014) studied the trend of fuelwood collection of tribal pockets of villages in Kanker forest division of Chhattisgarh state and recorded the information with the people of age between 16 and 50 years. They also revealed the higher dependency of people in the fuelwood and estimated the calorific value of the major fuelwood species. The calorific value of *Shorea robusta* wood was recorded 4400 Kcal/KG and also less smoky.

### 2.3 Laboratory analysis of oil yielding speceis

Hurburgh *et al*. (1990) received the soyabean seeds at 12 central Iowa elevators in 1985 – 1987 and analyzed the protein and the oil content. They found the standard deviation of the protein and oil content in the samples as 1 and 0.5 percentage points. The oil content of the species ranged from 18.1 to 20.2%. Aldalin *et al*. (2012) studied the seed protein and oil content of the soyabean cultivars (*Glycine max* (L.) Merr.) grown in the field condition in the experimental plots. The seeds were sown brought from different countries. The oil content was estimated using a standard Rushkovsky gravimetric method with the help of soxhlet apparatus and sulphur ethyl ether. The variation in the oil level ranged from 19 to 27% on the basis of dry weight seeds. Jokic *et al*. (2013) measured the oil content by traditional laboratory soxhlet-extraction with n-hexane. The apparatus was run for 16 hours until totally depletion of the oil in the sample and the average oil content was calculated to be 20.08 ± 0.14%.

Dutta *et al*. (1994) found 29 – 39% oil content in *Guizotia abyssinica* seeds collected from different regions of Ethiopia and also estimated the fatty acid, tocopherol and sterol content in the oilseeds by gas-liquid chromatography and high performance liquid chromatography methods. They also compared the results with the known data from safflower and sunflower. Kandel and Porter (2002) studied the distribution, uses, chemical composition, crop management, harvesting and storage methods, yields and economics, market facilities, pests and diseases of Niger in Northwest Minnesota and also reported the percentage of oil content to be 30 – 35% in Niger seeds. Ramadan & Morsel (2002) also estimated the percentage of lipid recovered from Niger seed to be 29.6% and 49.9% by seed weight from the solvents Hexane and Chloform/Methanol (CM) (2:1, v/v) respectively. Fatty acid composition, triacylglycerol molecular species and sterol contents were also estimated.

Srinivasan (2005) studied the impact on consumers and producers of the liberalization on the oilseed and edible oils of India. In doing so, the author reported the amount of production and the oil content of different oil yielding species from different parts of the country and hence evaluated the oil content of mustard to be about 33%, ground nuts 40% and soyabean 18%. Jham *et al*. (2009) assessed the oil of mustard (*Brassica juncea* L.) for biodiesel production and obtained 94% wt.% yield by standard transesterification process using methanol catalyzing by sodium methoxide. They harvested the wild mustard seeds from mature plants growing on fallow land on campus of Universidade Federal de Vicosa, Vicosa, MG, Brazil and estimated the oil content as 37.9 wt.% using hexane as solvent, soxhlet apparatus and rotary evaporator. Hence, they summarized the mustard oil is possible feedstock for biodiesel production. Abul-Fadl *et al*. (2011) determined the physic-chemical properties of yellow and brown mustard seeds and the functional properties of prepared mustard meals. They found that the both seeds comprised higher amounts of protein (32.48 – 36.37%) and oil contents (31.78 – 36.32%). In addition to this, they also reported that four major unsaturated fatty acids: oleic, linoleic, linolenic and gadoleic acids were present in the descending order of the amount.

Villancio (2007) reported that *Jatropha curcas* seeds can produce 0.75 – 2 tons biodiesel/hectare with 0.3 – 0.9 kg/tree seeds production estimating the crude non-edible oil content of about 30 – 40%. Nzikou *et al*. (2009) reported the oil content to be 50% and 47% by soxhlet and Blye & Dyer method for *Jatropha curcas* oils, variety Congo-Brazzaville whereas the oil content of *Jatropha curcas* L. collected from Dehradun, India was estimated to be 46.27% (dry basis) using soxhlet extraction method and gas chromatography by Joshi *et al*. (2011). They also studied the physicochemical properties like acid value (36.46), iodine value (106 mg/g), and saponification value (194.7 mg/g).

Chhetri *et al*. (2008) revealed that *Sapindus mukorossi* Gaertn. and *Jatropha curcas* L. seed oils have huge potential for biodiesel production. The conclusion was drawn on the basis of the experiment performed and the results obtained. They found that the oil content in the soap nut kernel collected from Nepal was about 30% and that of jatropha seeds was reported to be 27.8%. The oil was extracted by the cold press method. In the soap nut kernel oil they found 9.1% free FA, 84.43% triglycerides, 4.88% sterol and 1.5% others on an average whereas the jatropha seed oil contained about 14% free FA. More than 97% conversion of soapnut and jatropha oil to FAME was obtained. Huang *et al*. (2009)b studied the major physicochemical properties and fatty acid composition of *Sapindus mukorossi* Gaertn. seed oil. The study concluded that the oil content in the seed was 42.7%. The soapnut oil was recommended to be a possible source for the production of biodiesel due to its higher oil content and the greater composition of unsaturated fatty acids (86.63%) in which oleic acid was 55.68%. Ariharan and Parameswaran (2015) estimated the oil content of the seeds of *Sapindus trifoliatus* thought to be closely related to *Sapindus mukorossi* Gaertn. and found 30% oil on dry weight basis by running the soxhlet apparatus for 48 hours using petroleum ether as solvent. They also estimated the acid value, iodine value, and saponification value of the 10% blended 20% blended biodiesel. They also compared the values of the parameters with the ASTM standards of biodiesel and concluded that the biodiesel blend B20 was within the ASTM standards which can serve as a potential source of biodiesel.

Cisse *et al*. (2013) were influenced by the two hybrids of classic maize (*Zea mays* L.): white and yellow quality protein maize quality protein maize during the process of searching new sources of oil. To analyze the physicochemical parameters (like refractive index, free fatty acids, peroxide value, iodine value and saponification value) of the oil obtained from the both quality protein maize, they collected the seeds in June 2012 from the experimental plot of land owned by national program of rice growing in Yamoussoukro city (Cote d'lvoire). Oils were extracted from 50 grams crushed seeds with 300 ml of n-hexane (40 - 60°C) using soxhlet extractor. Thus the oil content of white and yellow quality protein maize was recorded 5.36 ± 0.02% and 5.44 ± 0.04% respectively.

Based upon analyzing the properties like oil content, pH, fatty acid, cloud point, flash point, pour point, specific gravity, viscosity, refractive index, colour, acid value iodine value, saponification value, peroxide value of oil of *Ricinus communis*, Okechukwu *et al.* (2015) reported that the biodiesel produced from the castor oil can be one of the options in substituting the diesel fuel. They also reported the oil content ofthe seeds of *Ricinus communis* collected from an open market, Onitsha, Anambra state, Nigeria to be 28.48% by solvent extraction method whereas, Yusuf *et al.* (2015), extracted the castor oil by mechanical cold pressing (<45°C) of the castor seed found in Katsina, Nigeria and found the percentage of oil content to be 39.43%. They also characterized the seed oil on the properties like oil content, specific gravity, acid value, iodine value, saponification value, peroxide value and found it meeting the ASTM standards. The presense of functional groups like hydroxyl, carbonyl, olefinic and methylenic was confirmed by Fourier transform infra-red spectroscopic analysis.

While assessing the regeneration status of multipurpose species *Diploknema butyracea*, Tewari *et al.* (2015) also estimated fruit and seed yield and identified the high oil yielding sites in central Himalayan region. For the evaluation of the oil content they collected the kernel of ripe fruits from different places and estimated the oil content by soxhlet apparatus using petroleum ether as the solvent. The apparatus was run for 8 hours and hence the percentage of oil content was reported to be ranging from 38.8 ± 1.12% to 60.6 ± 0.75% on dry wet basis.

Lad *et al.* (2016) studied the chemical properties of marking nut (*Semecarpus anacardium*) shell liquid. They extracted the oil in terms of shell and kernel and found to be ranged between 21.4 to 21.88% and 30.22 to 34.15% respectively using soxhlet apparatus. They also studied the acid value, saponification value, free fatty acid, iodine value, specific gravity, pH, refractive index and viscosity.

# 3. Materials and methods

## 3.1 An overview of study area

The study was carried out in Dhading district which is located at 27°40' N to 28°17' N Latitude and 84°17' E to 84° 35' E longitude in central Nepal. The altitudinal gradients vary from 488 m to 7500 m above mean sea level. The district covering an area of 1,926 $km^2$ along a wide range of geographical ascents lies in the Bagmati zone. The military boot shaped district is bordered by Tibet autonomous region of the People's Republic of China and Rasuwa district in the north, Gorkha district in the west, Chitwan and Makawanpur districts in south, Kathmandu, Rasuwa and Nuwakot districts in the east (GoN 2012).

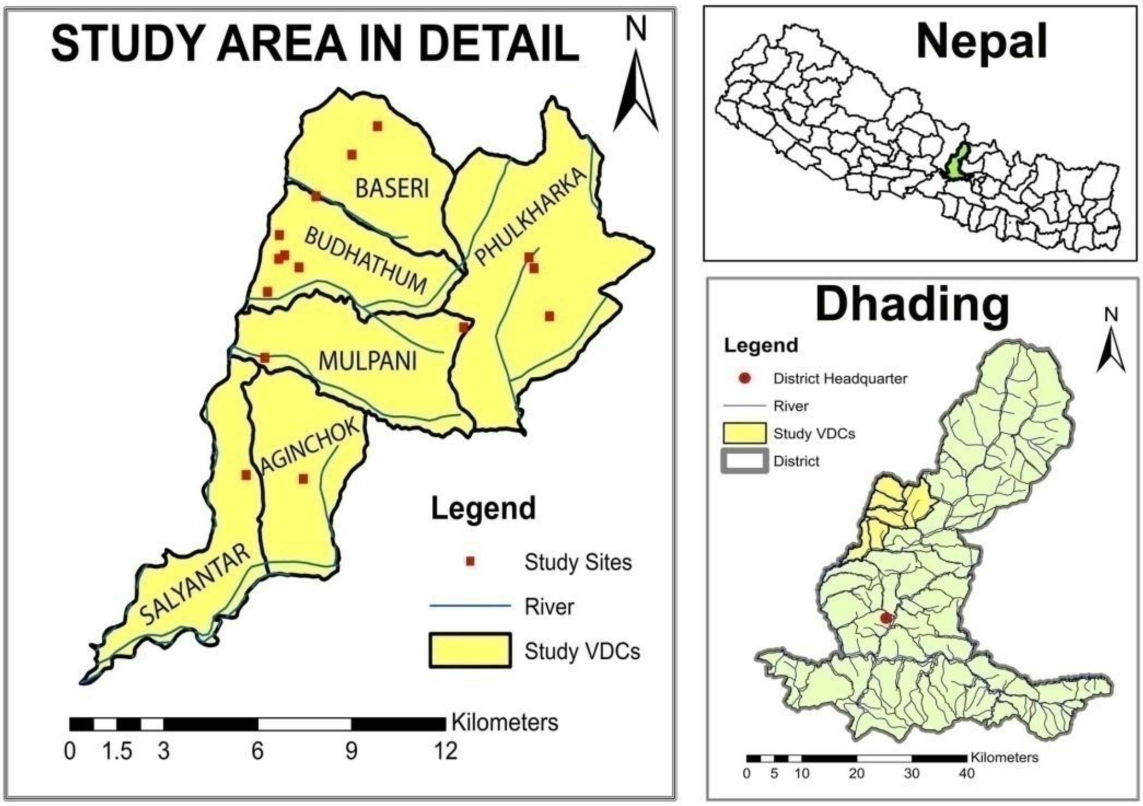



Figure 1: Study area

The six VDCs namely Budhathum, Mulpaani, Phulkharka, Salyantar, Baseri and Aaginchok were selected as the study sites which covers diverse geographical and environmental conditions. The altitude ranges from 500 m to 2920 m within these VDCs. The extreme climatic conditions from the hot tropical region to the cold upper temperate region comprise a varied elevation, topography, temperature and precipitation. The tropical region below 1000 m altitude is characterized by vegetation like *Shorea robusta*, *Acacia catechu*, *Lagerstroemia parviflora*, etc. The major part of the mid hills from 1000 m altitude to 2920 m is covered by subtropical and temperate regions. The major species in the subtropical region were *Schima wallichii*, *Castanopsis indica*, *Pinus roxburghii*, *Alnus nepalensis*, etc. Similarly the temperate region holds the dominant species like *Rhododendron arboreum*, *Symplocos theifolia*, *Pieris formosa*, etc.

Unity in diversity is the beauty of the society in the district. Three major castes/tribal groups have been settling in the VDCs as Brahman/Chhetri, Janajati (Gurung, Sherpa, Magar, and Newar) and Dalit, etc. The major inhabitants in the study area are Janajaati (gurung, sherpa, magar, newar etc) with 45% followed by Brahman/Chhetri 29.17% and Dalit 25.83%. Janajaati and Dalit are considered as the less privileged ethnic groups as compared to the Brahmans/Chhetris. The people in the study area have different religious beliefs with the greater extent of religious tolerance. The major religions followed by the local people are Hinduism 70%, Buddhism 17.5% and Christianity 12.5%.The major occupation of the study area is agriculture with 86.67%. Besides agriculture, service 7.5%, business 5%, and others 6.46% (wage labours, students, foreign employment, etc.) are the major occupations found in the VDCs. Some people are multiprofessional as well.

### 3.2 Research design

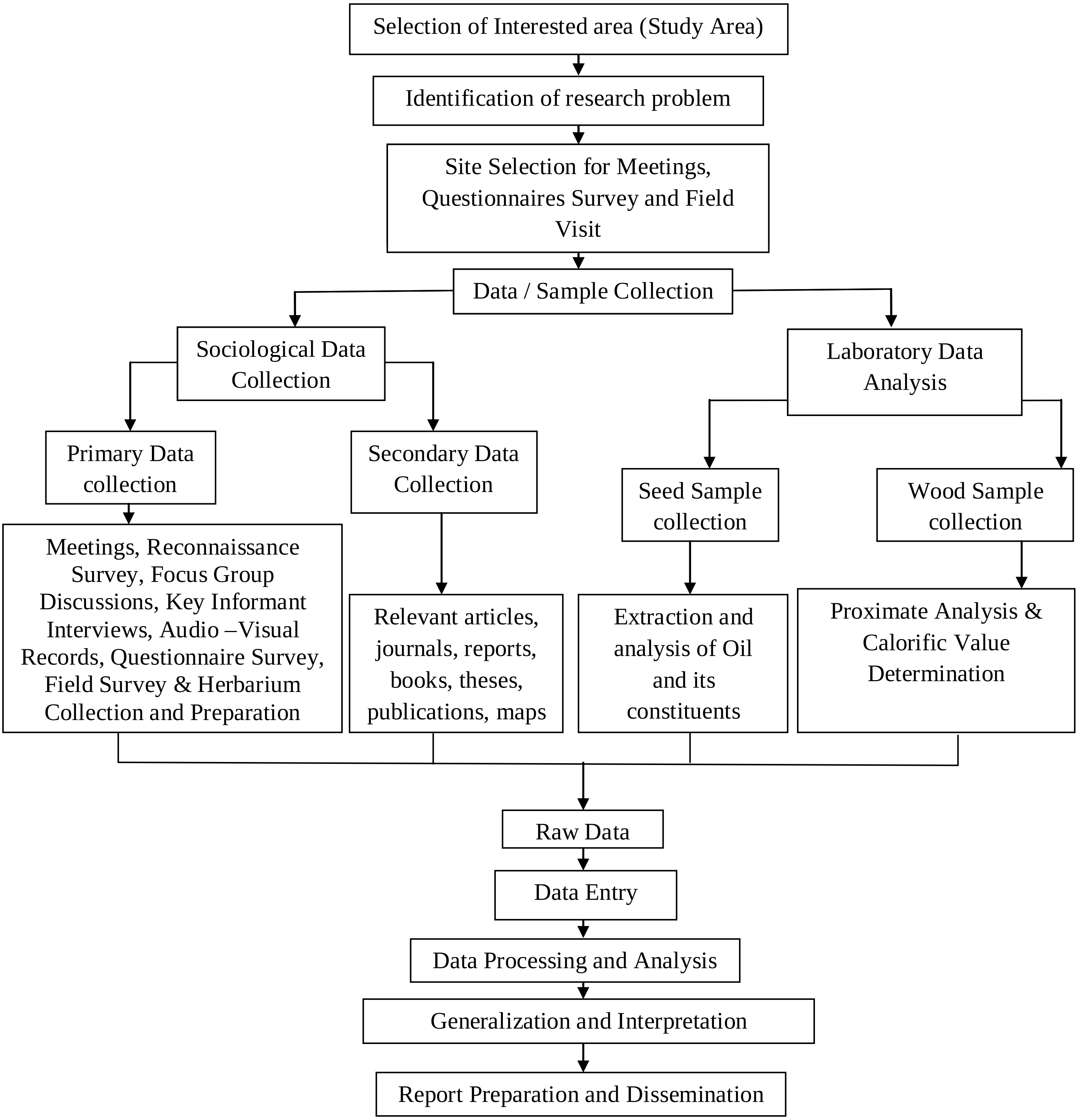



Figure 2: Flow chart showing the research plan

### 3.3 Enumeration of bioenergy plants

The enumeration of bioenergy plants was done on the basis of household surveys, field visits, meetings, case studies, etc.

#### 3.3.1 Field visit records

All together six field visits for forty days were done from May 8, 2014 to November 8, 2014 with a varied number of household surveys, meetings, case studies, herbarium and sample collections, etc. (Appendix I).

#### 3.3.2 Data collection on bio-energy plants:

- Formal and informal meetings: Altogether seven formal and informal meetings with the local people of study area were conducted. The meetings were organized especially in the schools, and colleges. The beneficial aspects of doing that were: information transmitting to maximum households, multi professional tendency of the teacher in remote areas (as a same person is teacher, social worker, politician, traditional healer, businessman, etc.), easy access to the study area, helpful nature of academic person to the researcher, capacity building of the students, etc.
- Reconnaissance survey: The most important weapon for the study was considered as "The Local Map of the Study Area". The study area was quite new and therefore the local people were requested to prepare the local map. The important plant areas with the important religious, academic, tourist areas with developmental projects, roadways, rivers etc were marked in the map. Hence, thirteen local maps were prepared in the study area during meetings and focus group discussions.
- Focus group discussions (Appendix II): From the meetings and reconnaissance survey; the focal person in the research area who knows more about the use of the plants in the field of energy were identified and six (two each) focus group discussion in Budhathum, Mulpaani and Phulkharka VDCs were conducted. Similarly one each focus group discussion in Baseri, Aaginchowk and Salyantar VDCs were also conducted.
- Key informant interviews: Throughout the study, a number of key informant interviews were also taken if some especial cases were identified in the field of harvesting energy from the plants.

- Questionnaire survey: Prior information written consent, including the consent for the publication was taken with each respondent before taking the knowledge of the respondents. The aims and the impacts of the study were also clearly informed to the respondents. The most important part of data collection was the questionnaire surveys. The respondents were asked the use, conservation measures, expectations and the possibilities of bio energy (see Annex XI).
- Audio visual records: A number of recordings during the meetings, reconnaissance surveys, focus group discussions, key informant interviews, questionnaire surveys and field surveys were also recorded.
- Photographs: The photographs were also taken during every aspect of primary data collection and especially in field surveys, and herbarium collection and preparation to identify the plants correctly.
- Herbarium specimens' collection and preparation: Triplicate specimens of each species were collected. Voucher specimens were tagged in the field during collection with appropriate field note. The specimens were dried, mounted on herbarium sheet and were deposited at Tribhuvan University Central Herbarium (TUCH). The identification was done using standard literatures: (Grierson & Long 1993-2000), (Polunin & Stainton 1984; Stainton 1988) and consulting the plant experts. The specimens were finally confirmed by cross comparing with the specimens deposited at National Herbarium and Plant Laboratories (KATH). The nomenclature and the author citations were based on the 'Catologue of life' (www.catalogueoflife.org) and 'The plant list' (www.theplantlist.org).

### 3.3.3 Categorization of bio-energy plants into fuel wood and oil yielding species

The plants were classified into two categories as Fuel wood plants (plants burnt for livelihood including herbs and climbers) and the oil yielding plants. The major bio energy plants used for potential fuel wood and oil yielding purposes were recorded that are most frequently used by the respondents. Finally the major ten species of both the categories were selected as the most potential bio energy plants in the study area. Ten basic features to categorize the plants as most potential fuel wood plants and oil yielding plants are:

I. For Fuel wood plants: Abundance, Burning, Smoking, Durability, Use value, Preference ranking, Chorotype, Stress tolerance, Propagation and Agronomical integration.

II. For oil yielding plants (plants used for oil extracting): Preference ranking, Chorotype, Abundance, Edibility, Stress tolerance, Agronomical integration, Use value, Harvest flexibility, Propagation and Oil content

Each of the features in both categories is given full marks as 3 and hence a total full mark is 30 for each species in the list. The marks for each features are categorized as 1(least importance), 2(moderate importance) and 3(highest importance). The plant species that secures highest marks are selected as the most potential bio energy plants (Pretty *et al*. 1995).

### 3.4 Laboratory analysis

Ten most potential fuel wood plants (Appendix III) and the oil yielding plants (Appendix IV) each were characterized in the laboratory to confirm their potential as the bioenergy plants.

#### 3.4.1 Laboratory characterization of the fuel wood samples

The laboratory analysis of the fuelwood samples followed the following procedures.

##### 3.4.1.1 Sample collection and processing:

- The stem (primary branch) of the fuel wood species was collected, cleaned. Dust particles, mosses, lichens and fungi were removed and brought to the laboratory of Nepal Academy of Science and Technology. The samples were air dried for about one month.
- The dried plant samples were grinded to make fine particles in the crushing mill (ISO 9001: 2008; WHO – GMP). After grinding, the crushed samples were packed and sealed in transparent polythene plastic bag with labeling.

##### 3.4.1.2 Proximate analysis:

The proximate analysis of the woody biomass was done following procedure of the ASTM D1762 – 84 (2007). Initially the crucible was heated at 750 ºC (cooled down in desiccators for 1 hr) in the muffle furnace. The sample was then taken in the crucible to analyze the moisture content, volatile matter content, ash content and fixed carbon content as mentioned below:

- Moisture content: The moisture content of the biomass was determined by the oven dry method. First of all, 1gm sample was taken in a crucible using a balance (ML104 /01; Metller Toledo) and dried in the muffle furnace (DMF – 05) at 105 ºC for two hours. The crucible was transferred to the desiccators for 1 hour and the weight of the crucible and sample was noted with the help of balance and the percentage of moisture content was calculated by using the following formula:

$$\text{Moisture content, \%} = \frac{\text{W1} - \text{W2}}{\text{W1}} \text{ X } 100$$

Where,

W1 = grams of air-dry sample used, 1gm and

W2 = grams of sample after drying at 105 ºC.

- Volatile matter: The same sample from the earlier calculation of moisture content is used to find out the percentage of the volatile matter. The sample in the covered crucible is then heated to 950 ºC in the muffle furnace for 6 minutes. The crucible was taken out and kept down to the iron plate quickly and then transferred to the desiccators to cool down into room temperature for 1 hour. Final weight of the crucible and the samples were taken. The percentage of the volatile matter of the sample is calculated using following formula:

$$\text{Volatile matter, \%} = \frac{\text{b} - \text{c}}{\text{b}} \text{ X } 100$$

Where,

b = grams of sample after drying at 105 ºC.

c = grams of sample after drying at 950 ºC.

- Ash content: The same sample from the earlier calculation of volatile matter is used to find out the percentage of the ash content. The sample in the uncovered crucible is then heated to 750 ºC in the muffle furnace for 6 hours. The crucible was transferred to the desiccators for 1 hour and the weight of the crucible and sample was noted. The ash content in the sample is calculated by using following formula:

$$\text{Ash content, \%} = \frac{d}{b} X\, 100$$

Where,

d = grams of residue and

b = grams of sample after drying at 105 ºC

- Fixed carbon: The residue from expel of the volatile matter contains some amount of non volatile or fixed carbon. The fixed carbon in the woody biomass sample is calculated using following formula (Kharidwar *et al*. 2013):

$$\text{Fixed carbon (\%)} = 100 - (\text{\%moisture content} + \text{\%volatile matter} + \text{\%ash content})$$

### 3.4.1.3 Calorific value determination

The calorific value of the wood samples was determined using Oxygen Bomb Calorimeter (1341EE BOMB CALORI PLAIN). First of all 1 gram samples were taken in the crucibles and left for 24 hours in the oven to calculate the dry matter present in the samples. Similarly, 1 gram sample was taken in the iron crucible and was bombed in presence of Oxygen at (30 - 35) atmospheric pressure. Two kg water was weighed, and kept in the water cane which was fitted in the calorie meter. The water stirrer was fitted and the electric current was supplied. The temperature was noted as it stops rising in the thermometer. Then, the sample was bombed and the final temperature in the thermometer was noted again as the mercury level stops rising. The difference in the temperature was calculated and noted to find the calorific value of the samples. The calorific value was calculated using the following formula (Dara 1999 & Kharidwar *et al*. 2013).

$$\text{Calorific value (kcal/kg)} = \frac{(W + w) \times (T1 - T2)}{X}$$

Where,

W = weight of water in calorimeter (Kg),

w = water equivalent of apparatus,

T1 = initial temperature of water (°C),

T2 = final temperature of water (°C),

X = weight of sample (dry) taken (Kg).

### 3.4.2 Laboratory characterization of the oil yielding samples

The laboratory analysis of the oil yielding samples followed the following procedures.

#### 3.4.2.1 Sample collection and processing

- The seeds of the selected plant species were collected, cleaned and the dust particles were removed and brought to the laboratory of Nepal Academy of Science and Technology. The samples were air dried for more than a month.
- The air dried seed samples were grinded to make fine powder in a grinder (MGSTSL 6020 - 449). After grinding, the powdered samples were packed and sealed in transparent polythene plastic bag with labeling.

#### 3.4.2.2 Estimation of oil content

For the estimation of the oil content in the samples, 40 gram grinded sample of each species was taken in the thimble and kept in the soxlets apparatus. The soxlets apparatus was maintained and oil was extracted using hexane as the solvent. The extraction was done for 24 hours. The extracted solution of the oil and hexane was separated using rotatory evaporator (RE 210). The mass of the pure oil of the sample was measured in balance. The percentage of the oil content was calculated using the following formula.

$$\text{Oil content, \%} = \frac{\text{Mass of the oil extracted}}{\text{Mass of the sample taken}} \times 100\%$$

#### 3.4.2.3 Analysis of oil constituents

Fourier Transform Infrared (FTIR) spectrometry technique was used to determine the presence of different functional groups in the oil samples. FTIR can obtain the infrared spectrum of absorption or emission of solid, liquid or gaseous samples. Initially, the background screening of Potassium Bromide (KBr) was done. Then, a few drops of oil were dropped on the KBR and was scanned again. The spectra showed different frequencies and hence different functional groups at different frequencies were analyzed using infrared and Raman spectroscopy table (Larkin 2011). The higher peaks were considered as the indicator of the presence of the particular functional group at particular range of the spectral peak.

### 3.5 Statistical analysis and interpretation

The raw data were tabulated. Figures and analysis were made and mean and standard deviation of the data were calculated in the Microsoft Excel 2007. The dissertation report was prepared using Microsoft word 2007.

# 4. Results

## 4.1. Livelihood and bioenergy plants

To run the livelihood, people were using different sources of energy on the basis of their access, economic condition, and knowledge about the plants. Besides oil, people were found depending on fuelwood which was the locally available, cheap source of energy and found abundantly.

### 4.1.1 Dependency of people in different sources of energy

High variation of energy sources were used in the study area. Fuelwood was used as the most important source of energy. It is noted that 119 households use fuelwood as the major source of energy for cooking, heating, lighting, business and other purposes, and 77 households use electricity in their houses for lighting, heating, business, cooking, etc. Similarly, 64 households use kerosene, 28 use solar, 24 use LPG, 10 use biogas, 7 use candle and 2 households use charcoal for various purposes (Fig.3). This shows that the people are highly dependent on fuelwood to run their livelihood.

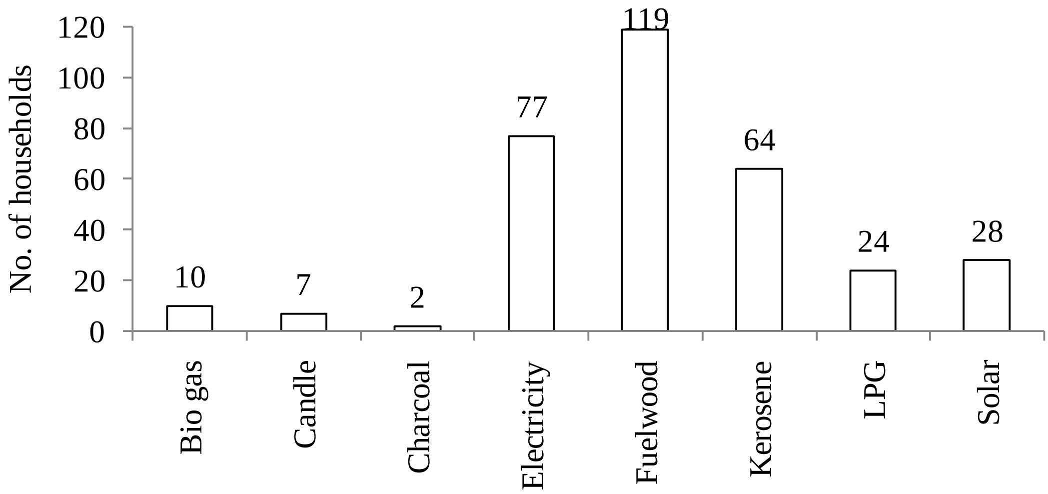



Figure 3: Dependency of people in different energy sources

### 4.1.2 Collection of firewood

Most of the households collect firewood from the community forests (93 households) managed by them. In addition to this, people are significantly dependent on field bunds, hedge and barren lands of their own (56 households) for the firewood. Government managed forest (1 household) is almost untouched and few people collect from other (13 households) areas like riverside and roadside as well (Fig.4).

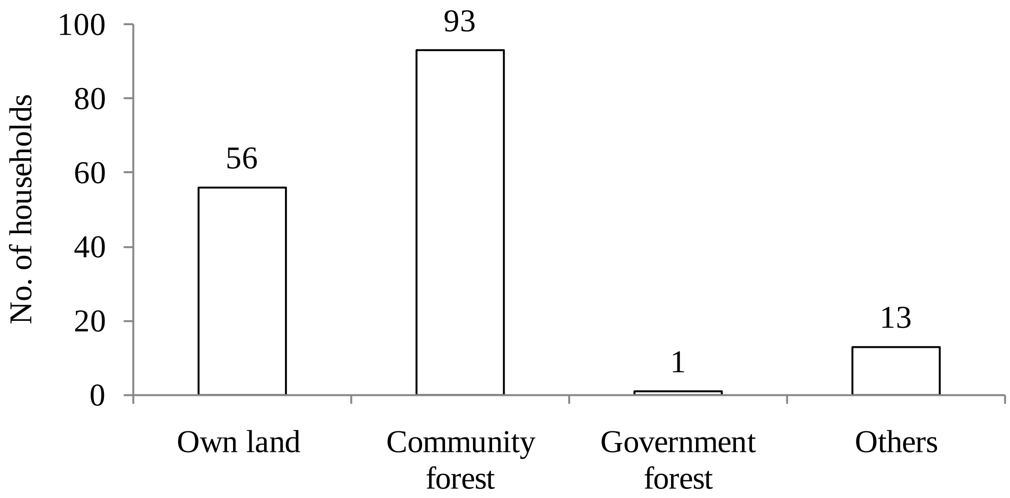



Figure 4: Sources of collecting firewood

**4.1.3 Cultivation and benefits analysis**

Knowingly or unknowingly most of the people are self dependent on firewood of which 96 households are cultivating the firewood whereas 24 households are depending of community forest and others. Majority of them (96%) of the cultivating households reported that they are having benefits whereas only 4% reported to have loss (Fig. 5).

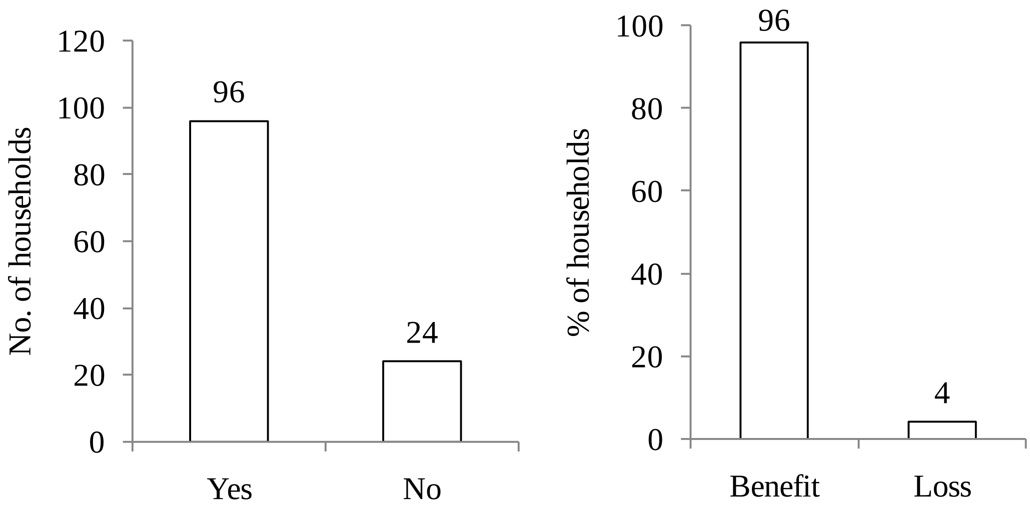



Figure 5: Cultivation of firewood and benefit/loss analysis

**4.1.4 Enumeration of bioenergy plants**

Two different types of enumeration of plants were done to find out the availability of maximum number of bioenergy plants and the most widely used bioenergy plants. The detail results are as follows:

### 4.1.5 Total enumerated bioenergy plants

Initially, 211 plant species were recorded as the general list of bioenergy plants from the questionnaire surveys, field visits, key informant interviews, focus group discussions and different formal and informal meetings was prepared (Appendix I). The greatest number of the plants were recorded from the family Fabaceae (25 species), followed by Moraceae (16 species), Rosaceae (9 species), Asteraceae (7 species), Rutaceae (7 species), (Fig.6) where as the highest number of species were reported from the genus *Ficus* (11 species) followed by *Brassica* (5 species) (Appendix III).

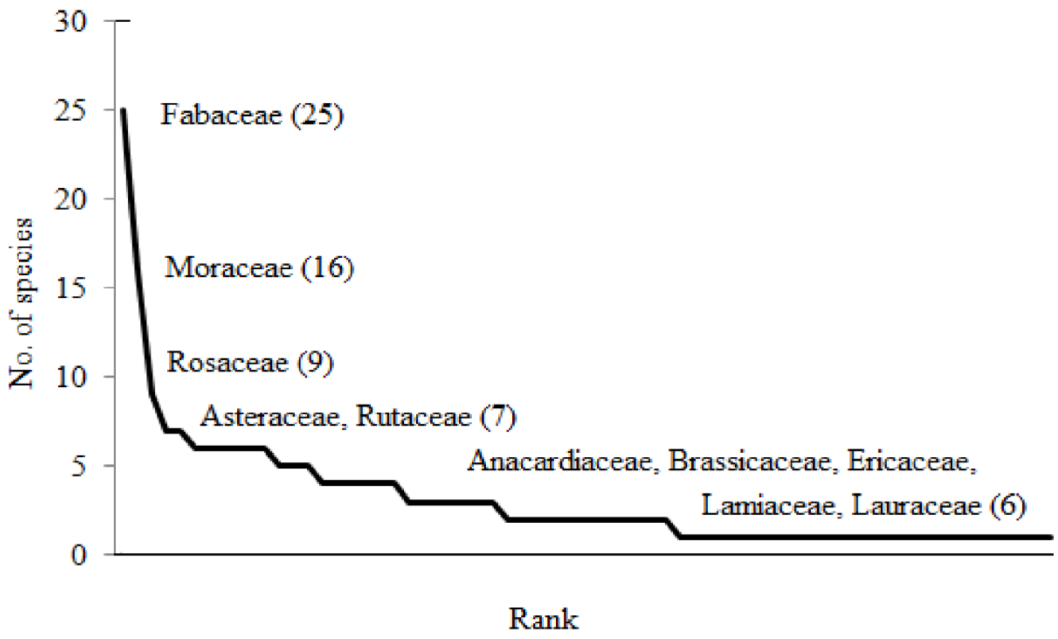



Figure 6: Rank curve of different families of bio-energy plants

### 4.1.6. Proportion of fuel wood and oil yielding species

In total, 182 were fuel wood species and 76 were oil yielding species have been reported in the present study, whereas, 47 species were listed as both fuel wood and oil yielding species (Fig.7).

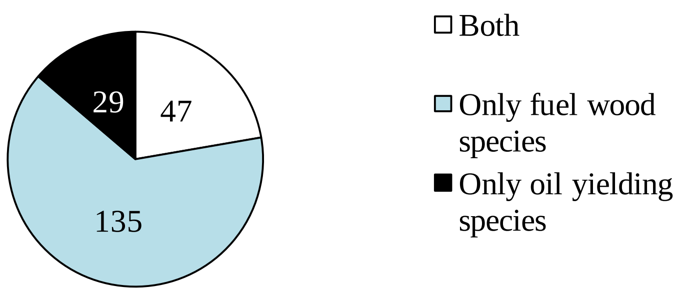



Figure 7: Number of plants of different categories

**4.1.7. Life form of bio energy plants**

Regarding the life form of the species, 73.08% of the total fuel wood species were recorded as the tree species followed by shrubs (24.18%). The herbs and the climbers are negligible as compared to trees and shrubs. However, in case of oil yielding species, trees (42.11%) are comparatively less than that reported in fuel wood species. The herbs and the climbers were significant with 27.63% and 6.58% respectively while shrubs were comparable to that reported in fuelwood species (Fig.8). Hence, most of the fuel wood species were trees and shrubs while oil yielding species comprised significant numbers of all the life forms. Among 76 oil yielding species 71.05% were recorded as the edible oil, whereas 28.95% species were recorded as non-edible oil.

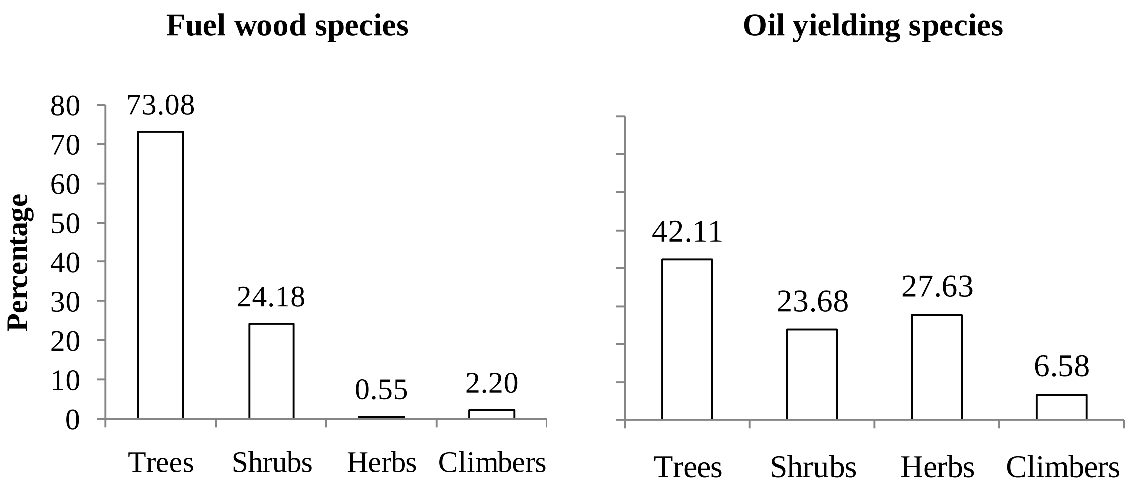



Figure 8: Life forms of bio-energy plants

### 4.1.8. Potentiality of the bio energy plants

To find out the potential bio energy plants, a more precise list of bio energy plants was prepared on the basis of questionnaire survey. Hence, 91 most widely known plants were recorded, of which 54 were fuelwood (Appendix IV) and 37 were oil yielding species (Appendix V).

### 4.1.9. Fuel wood plants

On the basis of the scores provided for each 10 characters of the plants, the most potential species were sorted out. Finally, *Shorea robusta* Gaertn.(Saal), *Rhododendron arboreum*Sm. (Lali gurans), *Lyonia ovalifolia* (Wall.) Drude (Angeri), *Alnus nepalensis* D.Don (Uttis), *Schima wallichii*Choisy (Chilaaune), *Pinus roxburghii* Sarg.(Khote salla), *Ficus semicordata* Buch.ex J.E. Smith (Khanayo), *Castanopsis indica* (Roxb. ex Lindl.) A.DC. (Katush) and *Myrica esculenta* Buch.-Ham.ex D.Don (Kaafal) were recorded as the most potential fuel wood species (Fig.9).

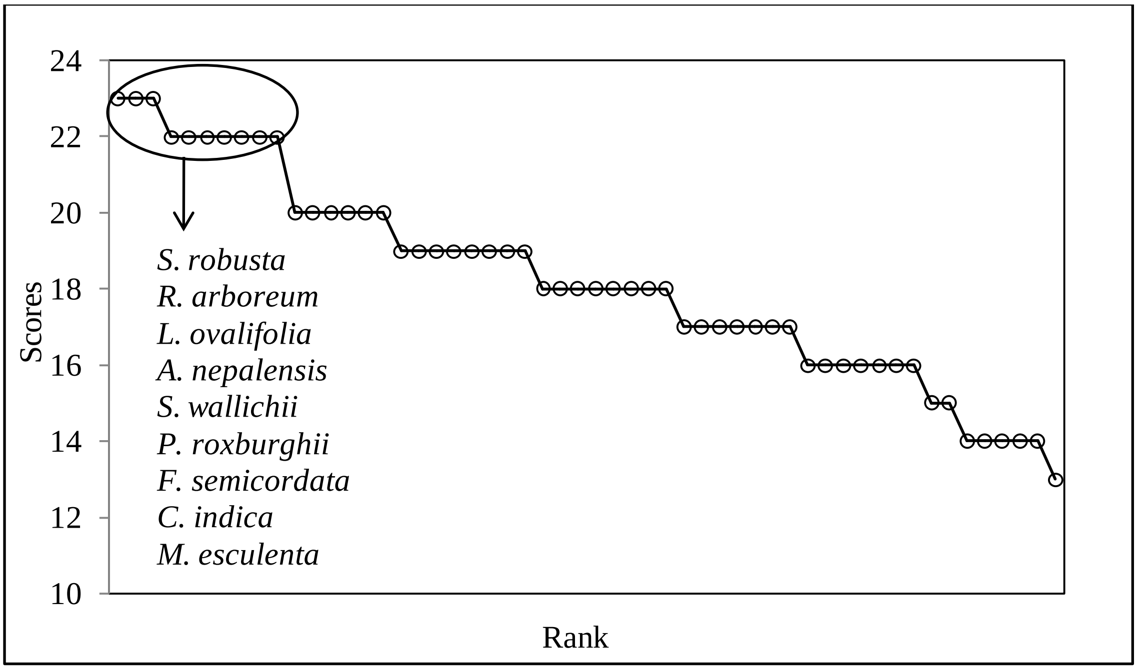



Figure 9: Rank curve of fuel wood species

### 4.1.10 Oil yielding plants

Similarly, the most potential oil yielding species were recorded as: *Guizotia abyssinica* (L.f.) Cass. (Jhuse til), *Jatropha curcas* L. (Sajiwan), *Camellia kissi* var. *confusa* (Craib)T.L.Ming (Goldhari), *Zea mays* L. (Makai), *Glycine max* (L.)

Merr. (Bhatmass), *Ricinus communis* L. (Ander), *Diploknema butyracea* (Roxb.)H.J.Lam (Chiuri), *Semecarpus anacardium* L.f. (Bhalaayo), *Brassica nigra* (L.)W.D.J.Koch (Kaalo tori) and *Sapindus mukorossi* Gaertn. (Riththaa) were selected (Fig. 10). Among *Raphanus sativus*, *Helianthus annuus*, *Brassica junceae* and *Sapindus mukorossi* with equal rank score (22), *Sapindus mukorossi* was selected for laboratory analysis because the other species are the valuable cultivated species whereas *Sapindus mukorossi* is not cultivated.

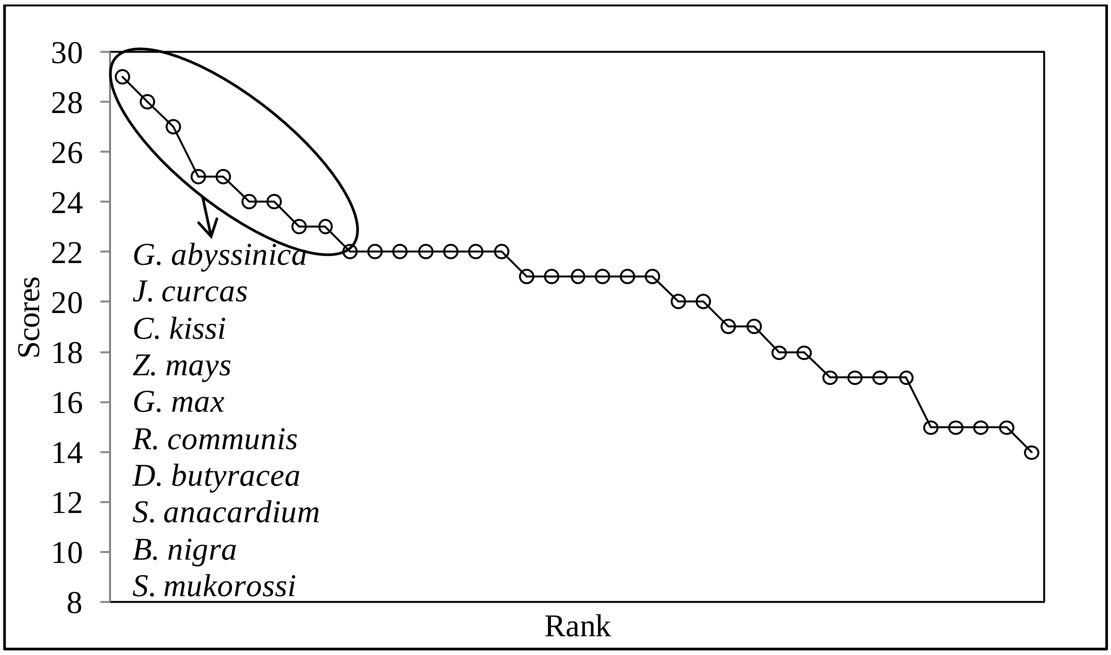



Figure 10: Rank curve of oil yielding species

### 4.2. Proximate analysis and the calorific value

Proximate analysis and the calorific value estimation were the major laboratory analysis made to find the potentiality of the selected fuelwood species.

#### 4.2. 1. Proximate value of the selected fuel wood species

Since the species selected were the most potential species on the basis of the ethno-botanical survey, the proximate values i.e. moisture content, volatile matter, ash content and fixed carbon do not vary to some large extent within the selected species. In addition to this, the moisture content and the ash content of the fuel wood species are lesser where as the volatile matter and the fixed carbon of the species are greater as required for the potential fuel wood biomass. Therefore, the proximate analysis of the fuel wood species supports the result of ethno botanical survey. However, there are some variations within the species in proximate values to fewer extents. The proximate analysis is presented as below:

### 4.2.2. Moisture content

The moisture content of the species varied to the lesser amount. The highest percentage of moisture content (11.76 ± 0.53%) was noted in the species *Pinus roxburghii* and the lowest (8.16 ± 0.17%) was found in *Rhododendron arboreum*. The percentage of moisture content of *Schima wallichii* and *Alnus nepalensis* were found comparable with *Pinus roxburghii,* and that of *Lyonia ovalifolia* was found closer to *Rhododendron arboreum*. Other species were moderately valued regarding the moisture content as shown in the bar diagram below (Fig. 11).

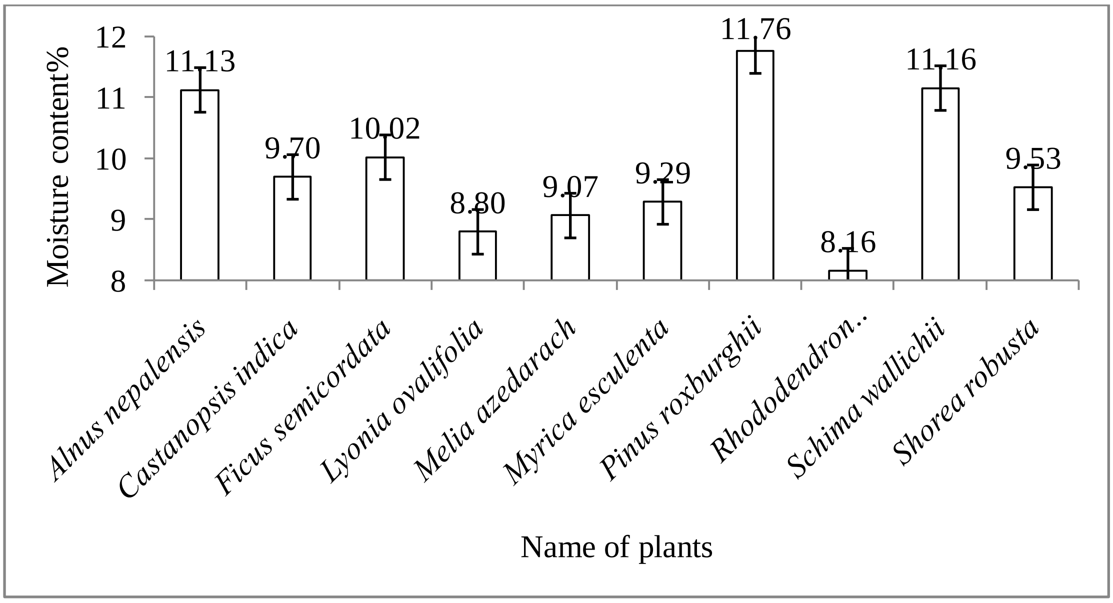



Figure 11: Percentage of moisture contant of selected fuelwood species

### 4.2.3. Volatile matter

The volatile matter of all the species was found to be in greatest amount than moisture, ash and fixed carbon content. The highest percentage (88.22 ± 0.5%) of the volatile matter was revealed by *Shorea robusta* followed by *Melia azedarach* and *Castanopsis indica.* In contrast, the lowest percentage (82.46 ± 0.06%) of the volatile matter was found in *Myrica esculenta*. The other species stored moderate percentage of the volatile matter as shown in bar diagram below (Fig. 12).

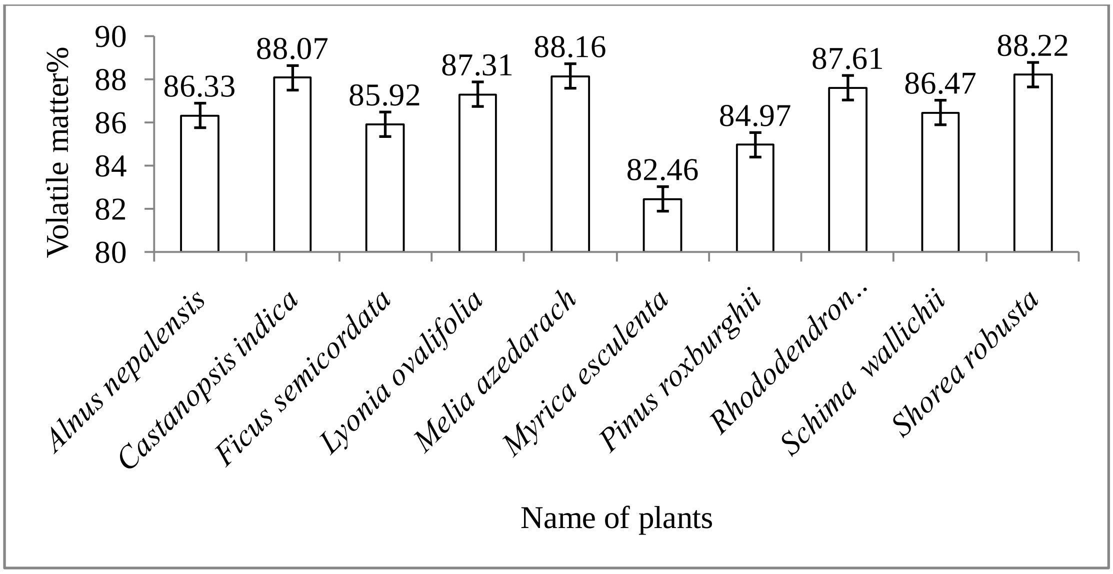



Figure 12: Percentage of volatile matter of selected fuelwood species

### 4.2.4. Ash content

The ash content of the species was found quite less. Among the selected species, the highest percentage (1.83 ± 0.09%) of the ash content was found in *Ficus semicordata* followed by *Schima wallichii*, *Castanopsis indica* and *Alnus nepalensis*. However, the lowest percentage (0.37 ± 0.03%) of the ash content was reported in *Lyonia* ovalifolia. Comparable percentage (0.4 ± 0.03%) of ash content was found in *Pinus roxburghii* (Fig. 13).

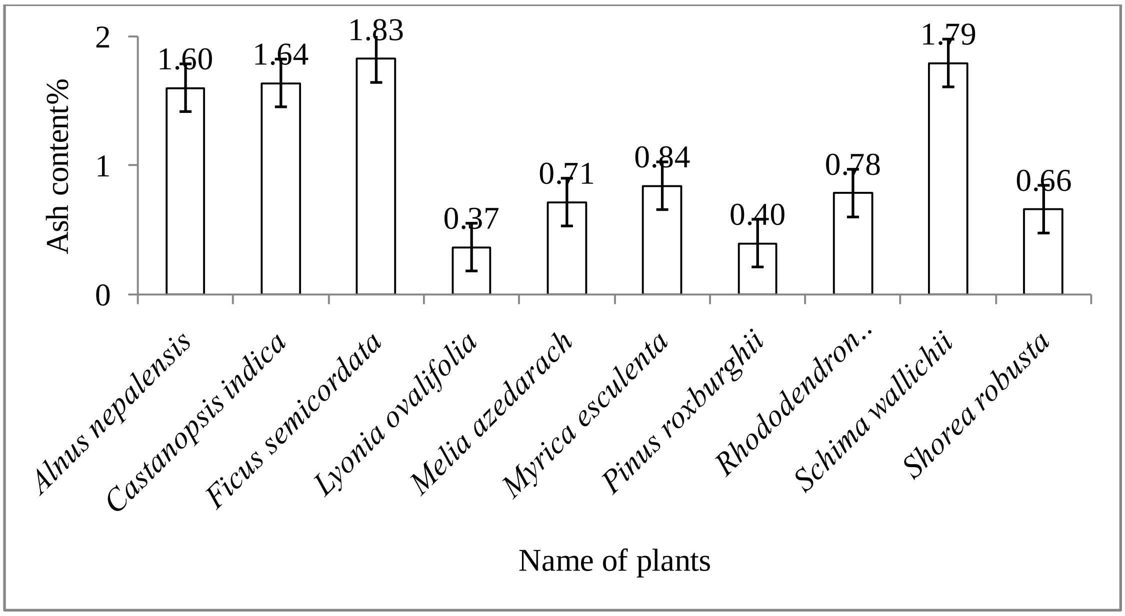



Figure 13: Percentage of ash content of selected fuelwood species

### 4.2.5. Fixed carbon

The highest percentage (16.7 ± 0.07%) of the fixed carbon was recorded in *Myrica esculenta* which was followed by *Pinus roxburghii* (14.44 ± 1.05%). In converse to this, *Castanopsis indica* was found to be reserving the lesser percentage (10.48 ± 0.87%) of the fixed carbon. While other species were between *Myrica esculenta* and *Castanopsis indica* (Fig. 14).

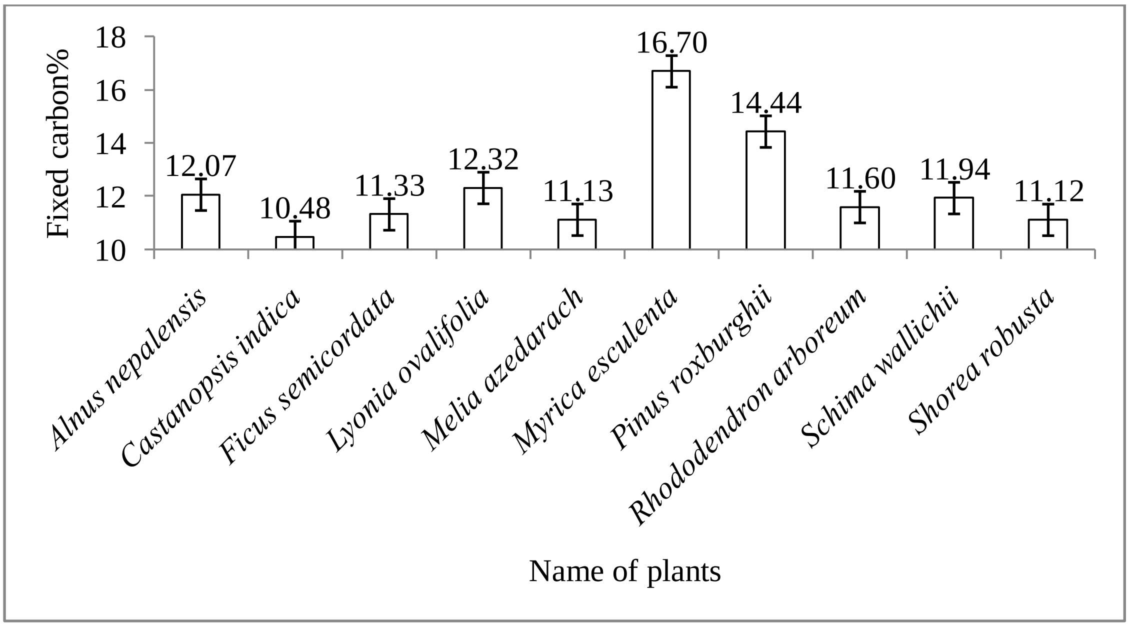



Figure 14: Percentage of fixed carbon of selected fuelwood species

### 4.2.6. Calorific value estimation of fuel wood species

The maximum calorific value among the fuel wood species was found in *Rhododendron arboreum* (4775.72 Kcal/Kg) followed by *Lyonia ovalifolia* (4692.88 Kcal/kg) while the minimum value was found in *Melia azedarach* (4210.59 Kcal/kg) and *Castanopsis indica* (4326.33 Kcal/Kg). The other species held moderated calorific content (Fig. 15).

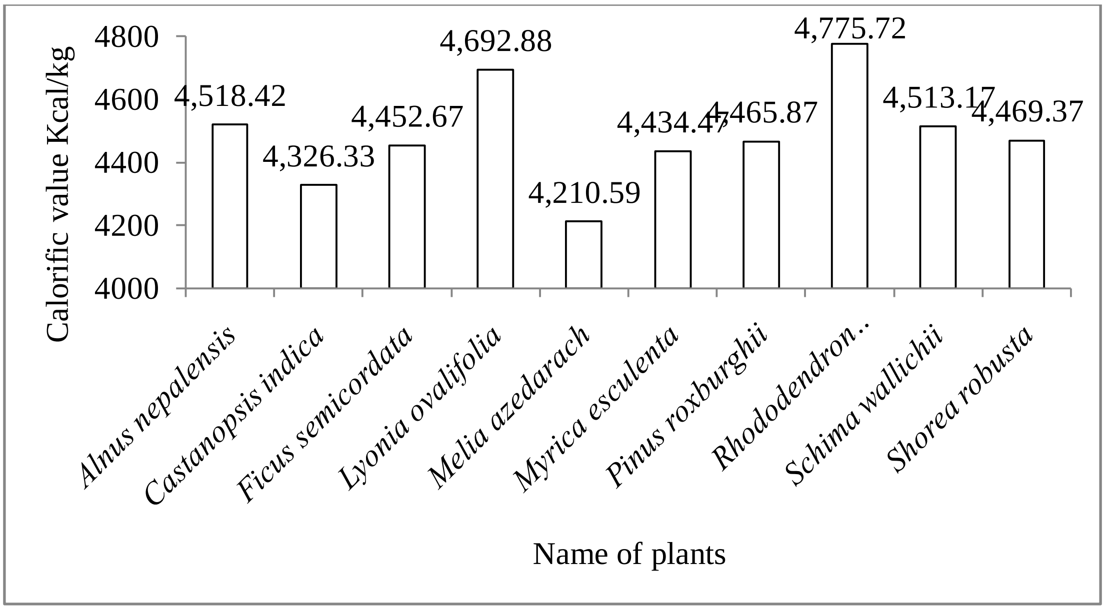



Figure 15: Calorific value determination of fuel wood species

### 4.3. Analysis of oil content and constituents

Estimation of the oil content and their constituents were major laboratory analysis made to find potentiality of the selected oil yielding plant species (Appendix: XI).

#### 4.3.1. Oil content estimation in the selected oil yielding plants

The oil content of the samples showed high variation among the selected species. The highest percentage of the oil content was found in *Ricinus communis* (46.8%), followed by *Diploknema butyracea* (43.2%), and *Guizotia abyssinica* (40%). In contrast, *Zea mays* (9.75%), *Glycine max* (23%) and *Sapindus mukorossi* (21.33%) showed lesser percentage of oil content (Fig. 16).

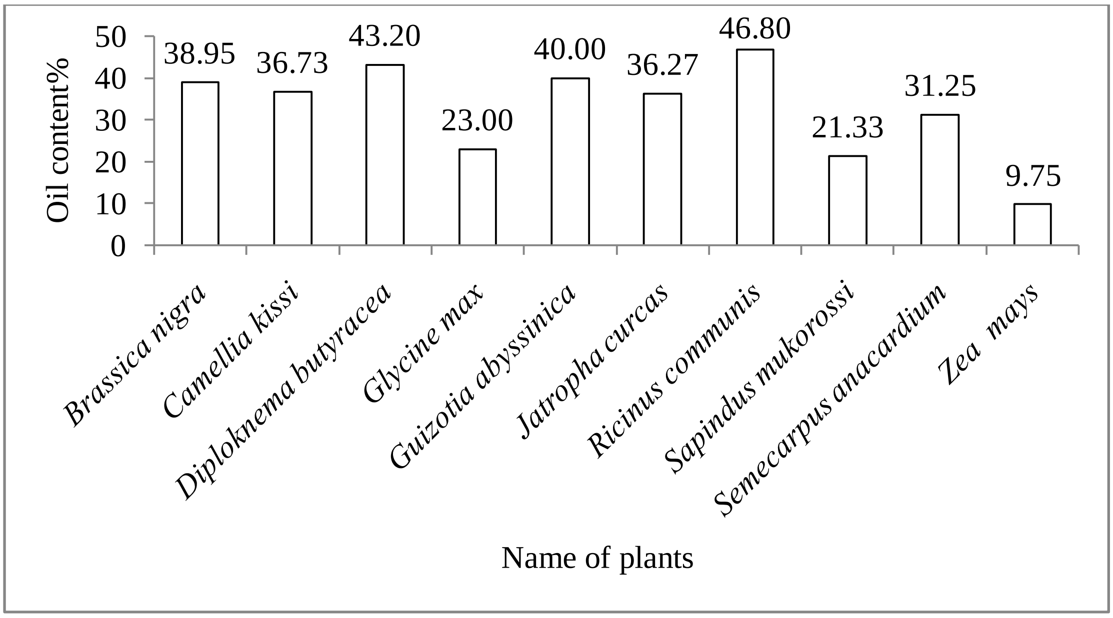
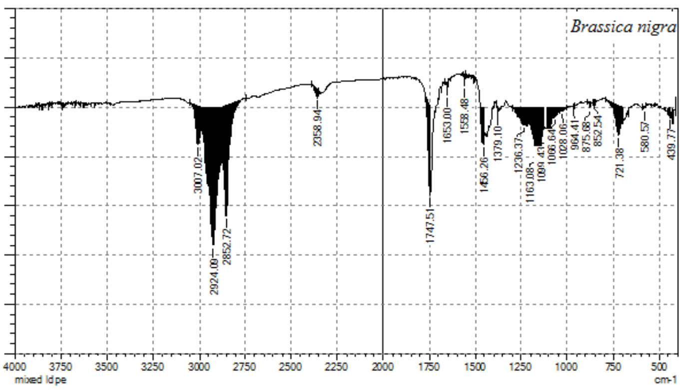
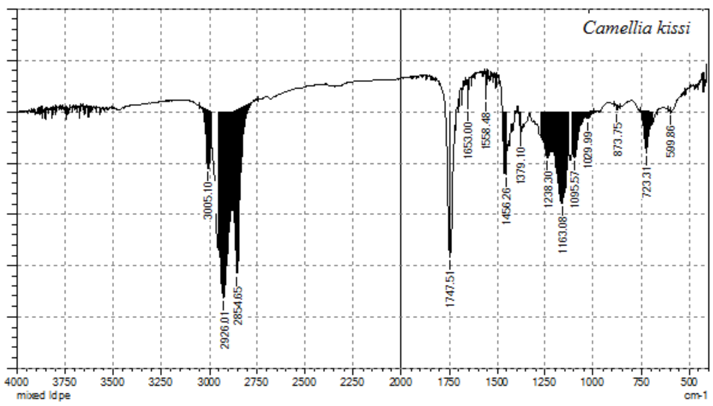



Figure 16: Estimation of oil content in selected oil yielding species

### 4.3.2. Analysis of oil constituents

Some of the plant oils showed the acidic nature, some showed basic and some others showed almost neutral nature. The species like *Semecarpus anacardium* and *Ricinus communis* showed the highest peak at 3458.37 and 3444.87cm$^{-1}$ respectively revealing the basic nature with the presence of unsaturated amide groupwhere as *Diploknema butyracea* showed the highest peak at 3005.10cm$^{-1}$representing the acidic nature with the presence of the carboxylic group. The other species revealed the peaks almost within the range of 2800 - 3000cm$^{-1}$signifying the neutral property by the result of the FTIR spectrum (Fig. 17).



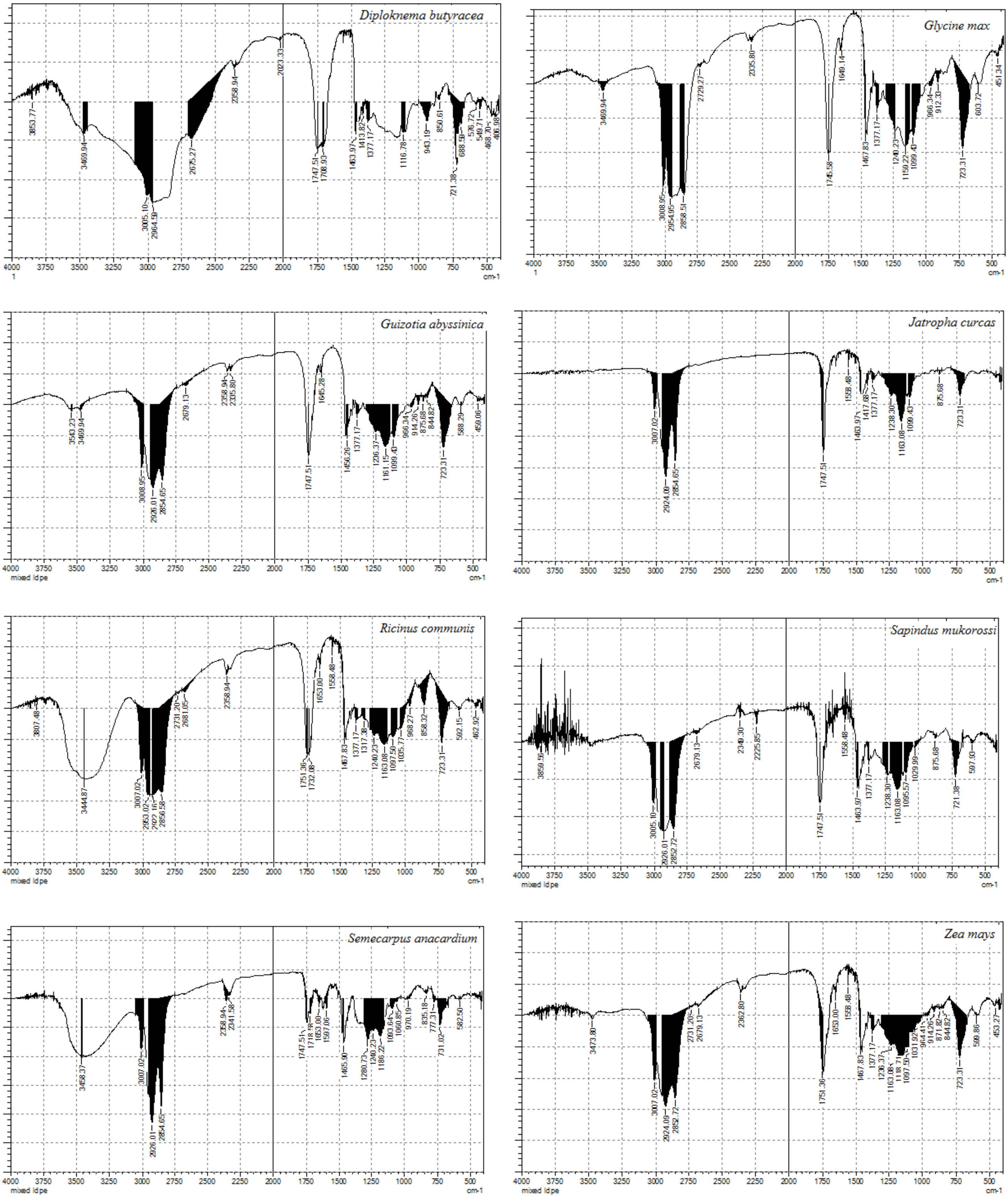



Figure 17: FTIR spectra of oil of selected oil yielding species

# 5. Discussions

## 5.1 Bioenergy plants: source of living

Bioenergy plants which are the major sources of living have got the considerable potentiality for the development of modern biofuels. This is due to the abundance of a huge number of the plants holding greater number of potentiality bearing characteristics.

### 5.1.1 Dependency of people in fuelwood to run livelihood

The study area is very far from the district head quarter and is also the hilly area where the facility of transportation is very difficult to carry LPG and other modern energy tools. This might be the reason of using fuelwood as a major source of energy by almost all the people in the site. In addition to this, fuelwood is cheap, locally available, quick and handy source of energy found abundantly in their community forest and also in their land. The feeling of ownership might have developed in people as a large number of people are found collecting fuelwood from community forest and their own land. Therefore, a maximum number of households are cultivating fuelwood species in their barren land, field bunds, river banks, road sides and as fence in their field. Hence, 96% households reported that the cultivating of the fuelwood species has been benefited for them as it saves a huge sum of money.

### 5.1.2 Enumeration of bio energy plants

A majority of the bio-energy plants enumerated in the present study belongs to the family Fabaceae or Leguminosae (25 species). This might be due to the reason that most of the species in the family Fabaceae bear pod and seed with the variation of life forms like trees, shrubs, herbs and climbers. In addition to this, the seeds of many species of angiosperms can be used for the production of oil. The dominant fuelwood species were trees and shrubs because the use of the solid biomass is easy and most importantly durable than others. Additionally, perennial plants use fewer inputs, produce more energy and reduce GHG emissions to a greater extent than annual plants (Andrews 2006; Adler *et al.* 2007). Similarly, the oil yielding species were not necessarily trees but were significantly herbs as well because a large number of oil yielding species were recorded from the family Fabaceae and Asteraceae which were mostly herbs.

### 5.1.3 Potentiality of bioenergy plants

For the selection of the potential bio-energy plants, ten characters for each category were chosen because a single character could not be assumed to determine the potentiality of the bio-energy plants and the plants chosen should be dedicated in the future so far. Moreover, the selected species should be non-invasive in nature.

The cause for the species like *Shorea robusta* and *Ficus semicordata* being highly preferred species in the low altitude and *Rhododendron arboreum* in higher altitude might be due to their abundance, convenient in burning, durable and less smoking. Similarly, *Lyonia ovalifolia* might be highly preferred due to its durability and one of the best charcoal producing plants, not only by the common user of this species but also by the people running local business of making metal utensils. *Pinus roxburghii* might have been potential species due to its greater inflammable property leading to the easy burning of the wood. The species like *Alnus nepalensis*, *Schima wallichi*, *Castanopsis indica*, *Myrica esculenta* and *Melia azedarach* were the most abundant species with greater preference and use value as reported by Chettri & Sharma (2007) for *Quercus* spp. and *Rhododendron* spp.

The oil yielding species like *Camellia kissi*, *Diploknema butyracea*, *Brassica nigra*, *Guizotia abyssinica* might have been considered as the potential bio-energy plants due to their higher oil content, easy harvest and traditionally known and used species. Whereas the species like *Ricinus communis*, *Jatropha curcas*, *Zea mays*, *Glycine max*, *Semecarpus anacardium* and *Sapindus mukorossi* might have been selected on the basis some characteristics like abundance, underutilized and agronomical integration.

## 5.2 Laboratory analysis of the selected fuel wood species

Both the proximate analysis and the calorific value estimation of the selected fuel wood species supported the local peoples' perceptions.

### 5.2.1 Proximate analysis

The analysis of the proximate analysis parameters like moisture content, volatile matter, ash content and fixed carbon estimation are discussed as following.

#### 5.2.1.1 Moisture content

Moisture content is the preliminary test of the fuewood species. The percentage of moisture content of the samples did not show a wide variation as the selected samples were regarded as the potential species by the local people. Hence, the moisture content analysis supported the social survey data. However there is slight variation in each species which further reveals the best potential species among the selected ones.

The moisture content of *Alnus nepalensis*, *Castanopsis indica*, *Schima wallichii* and *Rhododendron arboreum* was not supported by Chettri & Sharma (2007). These differences in the result may have occurred due to the differences in basis of estimating the moisture content i.e. dry and wet samples basis. The moisture content of *Pinus roxburghii* was not similar to that of Bhatt & Todaria (1992). This might have happened due to the differences in time for evaporating the moisture present in the sample.

The moisture content of *Rhododendron arboreum, Lyonia ovalifolia, Melia azedarach*, *Myrica esculenta* and *Shorea robusta* were recorded less which can be the best species for the production of bioenergy especially in preparing pellets, coals, heating purposes and producing electricity. Comparatively other species like *Pinus roxburghii*, *Schima wallichii, Alnus nepalensis, Ficus semicordata* and *Castanopsis indica* are less potential regarding the moisture content. Less moisture content is preferable in the biomass for the production of bioenergy because the produced heat energy will be lost for the vaporization of the moisture if the moisture content is high and hence the net heat energy becomes less (Kharidwar *et al*. 2013).

#### 5.2.1.2 Volatile matter

Similarly, all the selected species were rich in the volatile matter as their percentage is between 80 - 90%, which is the good sign of the potential wood species. The volatile carbon compounds however show variation within themselves which can reveal the best potential species. Higher the percentage of volatile matter, higher is the volatile carbon compounds which can liberate higher amount of heat energy during burning. Hence, the species like *Shorea robusta, Melia azedarach, Castanopsis indica, Rhododendron arboreum* and *Lyonia ovalifolia* are comparatively more potentiality holding species than *Myrica esculenta, Pinus roxburghii, Ficus semicordata, Alnus nepalensis* and *Schima wallichii* on the basis of percentage of volatile matter accumulated.

#### 5.2.1.3 Ash content

The ash content was quite low (< 1%) in the six species and the other four species showed the ash content between (1 – 2%). The percentage of ash content of *Alnus* *nepalensis* and *Rhododendron arboreum* was similar and that of *Castanopsis indica* and *Schima wallichii* was comparable to that of Chettri & Sharma (2007) due to similar estimation process. But the ash content of *Pinus roxburghii* was not similar with that of Bhatt & Todaria (1992). This might be due to the differences in the heating temperature and the time of burning samples.

*Lyonia ovalifolia, Shorea robusta,* and *Rhododendron arboreum* showed the lesser amount of the ash content whereas *Schima wallichii* and *Ficus semicordata* showed higher ash content. This might have happened due to the differences in the bark size of the samples. *Pinus roxburghii* due to highly inflammable chemicals and *Melia azedarach* due to thin bark size might be the reason for the less ash content. Higher the ash content in the wood makes the burning slower. Hence, the species with higher ash content are less selected and they hold comparatively lesser potentiality as bioenergy plant (Kharidwar *et al*. 2013).

#### 5.2.1.4 Fixed carbon

The fixed carbon of *Myrica esculenta* and *Pinus roxburghii* was higher followed by *Lyonia ovalifolia, Alnus nepalensis* and *Schima wallichii*. The reason behind the higher amount of fixed carbon may be due to the greater accumulation of the mineral containing carbon and hydrogen which can finally generate more calorific value during the combustion, pyrolysis or gasification of wood (Demirbas & Demirbas 2004). Hence the woods with greater fixed carbon are preferred. On the contrary, the species like *Castanopsis indica* comprised low value of the fixed carbon followed by *Shorea robusta, Melia azedarach, Ficus semicordata, Rhododendron arboreum.* This might be due to the presence of the high O/C ratio i.e. the mineral compounds may have contained the higher amount of the oxygen (Huang *et al*. 2009)a. Therefore, the woods with the greater oxygen composition are less preferred.

### 5.2.2 Calorific value estimation

The energy content of the woody species is related with the carbon, oxygen and hydrogen contents (Pereira *et al*. 2013). *Rhododendron arboreum* and *Lyonia ovalifolia* showed the greatest calorific value among the selected species. The reason behind this might be due to the less moisture and ash content and more volatile matter and fixed carbon in the woods as mentioned earlier. In addition to this, these woods might have higher amount of carbon, hydrogen and lesser amount of oxygen (Demirbas & Demirbas 2004; Huang *et al*. 2009). In contrast, the reason behind the low calorific value of *Melia azedarach* & *Castanopsis indica* might be the presence of higher amount of oxygen than the carbon contents. The other species might have shown the moderate calorific values due to the presence of moderate values of parameters like moisture content, ash content, volatile matter, fixed carbon, hydrogen and oxygen.

The result of calorific value content in the species like *Castanopsis indica*, *Schima wallichii* and *Rhododendron arboreum* was supported by Chettri & Sharma (2007) but it was not supported for *Alnus nepalensis*. This might have been due to the huge difference in the moisture content of *Alnus nepalensis* among two studies. Sharma *et al*. (2014) greatly supported the result of calorific value of *Shorea robusta* due to the similar methods of the estimation of the calorific values.

### 5.3 Laboratory analysis of the selected oil yielding species

Analysis of both the percentage of oil content and its constituents of the selected oil yielding species supported the local peoples' perceptions.

#### 5.3.1 Oil content

The oil content of the plant seeds depend on the life forms of the species. The tree and the shrub species mostly contain higher percentage of the oil content than the herbs (Levin 1974). This might be the reason that the species like *Ricinus communis, Diploknema butyracea, Semecarpus anacardium, Camellia kissi* and *Jatropha curcas* being trees revealed the maximum percentage of the oil content.In addition to life forms, the oil content of the plant seeds depend on the genetic traits of the species for the oil synthesis (Hobbs *et al*. 2004). Therefore, the herb species like *Guizotia abyssinica* and *Brassica nigra* had the higher amount of the oil content. However, the species like *Zea mays* and *Glycine max* may have contained lesser oil content due to the higher composition of the protein and carbohydrate than the lipid. Similarly, *Sapindus mukorossi* might have contained lesser oil content due to the thicker testae in the seed and even due to the higher percentage of the alkaloid than lipid.

Jham *et al*. (2009) and Abul-Fadl *et al*. (2011) reported the oil content of mustard (*Brassica juncea* L.) as 37.9% and 31.78 -36.32% respectively. This result is similar to the present study. The similarity may have been due to the similar extraction procedure and the similar material used for extraction. However, Srinivasan (2005) evaluated the oil content of mustard to be 33%. The variation might be due to the differences in the extraction procedure, time and materials used.

Tewari *et al*. (2015) estimated the oil content of *Diploknema butyracea* ranged between 38.8 ± 1.12% to 60.6 ± 0.75% on dry wet basis. The result clearly supported the present study due to the similar extraction procedure.

Aldal'in *et al.* (2012) estimated the oil content of *Glycine max* (L.) Merr.to be 19 - 27% which supported the present study due to the similar extraction procedure of dry weight seeds. Jokic *et al*. (2013) reported the oil content as 20.08 ± 0.14% which deviated from the present study. This might have happened due to the differences in the time period for extraction procedure. Hurburgh *et al.* (1990) received 18.1 to 20.2%. oil content in the soyabean seeds which slightly differed from the present study and the reason might be the material used for extraction.

Dutta *et al*. (1994), Ramadan & Morsel (2002) and Kandel & Porter (2002) found that the oil content of *Guizotia abyssinica* seeds to be 29 - 39%, 29.6% - 49.9% and 30 - 35%. The result slightly deviated from the present study due to the differences in the procedure, time and the solvent used for extraction.

The oil content of *Jatropha curcas* L. collected from Dehradun, India was estimated to be 46.27% (dry basis) using soxhlet extraction method and gas chromatography by Joshi *et al*. (2011) which is not supported for the present study. The reason might be due to the extraction of oil by petroleum ether and also due to the addition fo anhydrous Sodium Sulphate to remove the traces of moisture content by Joshi *et al*. where as Nzikou *et al.* (2009) reported the oil content to be 50% and 47% by soxhlet and Blye & Dyer method for *Jatropha curcas* oils, variety Congo-Brazzaville which differed from the present study, the differences in solvent used for extraction might have been the reason. Villancio (2007) reported that *Jatropha curcas* seeds can produce oil content of about 30 – 40%. The result is supported for the present study. The reason might be the similarity in extraction procedure, solvent used and time duration for extraction.

Okechukwu *et al*. (2015) reported the oil content of the seeds of *Ricinus communis* collected from an open market, Onitsha, Anambra state, Nigeria to be 28.48% by solvent extraction method and Yusuf *et al*. (2015), extracted the castor oil by mechanical cold pressing (<45°C) of the castor seed found in Katsina, Nigeria and found the percentage of oil content to be 39.43% which is not supported by the present study (46.8%). The extraction apparatus was not heated by Okechukwu *et al*. (2015) and the oil was extracted by mechanical cold pressing technique by Yusuf *et al*. (2015) which might be the reason for the dissimilar percentage of estimation of oil as compared to present study.

Chhetri *et al*. (2008) found that the oil content in the soap nut kernel collected from Nepal was about 30% and that of jatropha seeds was reported to be 27.8%. The result deviated from the present study and the reason might be the different extraction method by i.e. by the cold press method and also due to the use of kernel. Huang *et al*. (2009)b concluded that the oil content in the *Sapindus mukorossi* Gaertn. seed was 42.7% which deviated from this study. The reason might be due to the use of kernel by Huang *et al*. and also due to the use of differences in solvents used and the extraction process. Ariharan & Parameswaran (2015) estimated the oil content of the seeds of *Sapindus trifoliatus* thought to be closely related to *Sapindus mukorossi* Gaertn. and found 30% oil on dry weight basis by running the soxhlet apparatus for 48 hours using petroleum ether as solvent. This result is different from the present study and the reason might be the different plant variety of plant and differences in time, solvent and procedure of extraction.

Lad *et al*. (2016) extracted the oil in terms of shell and kernel of *Semecarpus anacardium* and found to be ranging between 21.4 to 21.88% and 30.22 to 34.15% respectively. The result supported the present study and the reason might be the use of similar extraction soxhlet apparatus.

Cisse *et al*. (2013) extracted the oil from 50 grams crushed white and yellow quality protein maize seeds with 300 ml of n-hexane (40 -60°C) using soxhlet extractor. Thus the oil content of white and yellow quality protein maize was recorded 5.36±0.02% and 5.44±0.04% respectively. The result did not support the present result. The reason might be due to the differences in maize variety and the time for extraction.

### 5.3.2 Analysis of oil constituents

All the crude oils obtained from the plant seed should go through the process of neutralization to be converted into biodiesel. Types of functional groups attached to the fatty acid chains in the oils affect its usage quality. The crude oil of the species

*Semecarpus anacardium* and *Ricinus communis* showed the presence of unsaturated anide (-$NH_2$) group which needs to be neutralized before the conversion of oil to biodiesel. In contrast, the oil of *Diploknema butyracea* showed presence of unsaturated carboxylic acids which may produce water when free fatty acids are reacted with the alcohol and hence may slow down the esterification of free fatty acids and transesterfication of the glycerides (Ataya *et al*. 2007). Therefore, the oil of *Diploknema butyracea* should be neutralized. The other species although showed the presence of neutral groups, it is good to neutralize them before conversion to biodiesel.

# 6. Conclusion

Nepal comprises a huge varities of bioenergy plants due to its varying geographical conditions. Knowingly or unknowingly these plants are being used for cooking and heating purposes since the evolution of human. The characterization of such bioenergy plants can contribute a lot in the rational use of such plants. The present study revealed the proximate analysis and the calorific value estimation of selected ten fuelwood species and also analyzed the e oil content and its constituents in the selected ten oil yielding species.

The proximate analysis of the selected fuelwood species revealed that the plants have greater potential in the field of biomass based energy. On the basis of moisture content, volatile matter, ash content and fixed carbon, *Rhododendron arboreum* and *Lyonia ovalifolia* showed the most promising potential with the lesser amount of moisture and ash content and higher amount of volatile matter and fixed carbon. The result of calorific value in the woods also clearly showed that these two species *Rhododendron arboreum* and *Lyonia ovalifolia* are most potential with the calorific values 4775.72Kcal/kg and 4692.88Kcal/kg respectively. Besides these, *Shorea robusta* and *Schima wallichii* are also better fuelwood species regarding proximate analysis and calorific value estimation.

The estimation of oil content and its constituents depicts the presence of high-quality oil yielding species in the study area. *Ricinus communis*, *Diploknema butyracea*, *Guizotia abyssinica*, *Brassica nigra*, *Camellia kissi* and *Jatropha curcas* showed greater amount of oil content (46.8%, 43.2%, 40%, 38.95%, 36.73% and 36.27% respectively) in the seeds and hence are good oil yielding species and probably the potential bioenergy crops in future.

Therefore, the bioenergy potentiality can be greatly expected in Dhading district and eventually throughout the mid hills of Nepal comprising similar geographic and climatic conditions of Dhading district from mid-tropical to upper temperate region. In addition to this, the development of modern bioenergy industries and technology can contribute a lot to the poor and marginalized people in rural areas of Nepal enhancing the economic status, improving health, sustaining livelihood and minimize the effect of climate change and bring prosperity and peace in the green globe.

# 7. Recommendations

Although the present work is a preliminary study of the peoples' perception about the bioenergy plants accompanied by some laboratory analysis, it created some positive optimism in the field of bioenergy. Standing on this background, here are some recommendations that can be taken into consideration during further study.

- The peoples' traditional knowledge about the better bioenergy plants should be documented first before they are vanished.
- For the better results, the proximate analysis should be done on the basis of different analyzing procedure with varying temperature and time period.
- In this work, hexane is the only solvent used for the extraction of oil from seed sample. Different types of solvent should be used to analyze the differences in the percentage of oil content to explore the best extracting solvent.
- *Rhododendron arboreum*, *Lyonia ovalifolia*, *Shorea robusta* and *Schima wallichii* showed better results regarding proximate analysis and calorific value estimation. Further study (like elemental analysis) should be done to find the more concise results.
- The laboratory analysis of the species like *Lyonia ovalifolia*, *Ficus semicordata*, *Melia azedarach*, *Myrica esculenta* and *Camellia kissi* are rarely done. These species should be explored more.

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# Appendices

## Appendix I: Field visit records

| Date (2014) | Name of V.D.C. | No. of HH surveyed | No. of Maps | No. of Meetings | Case studies | Herbarium specimens collection | Days |
|---|---|---|---|---|---|---|---|
| May 8-10 | Budathum | 0 | 3 | 1 | 2 | 4 | 3 |
| June 3-10 | Budathum, Baseri | 22+0 = 22 | 0 | 0 | 3 | 40 | 8 |
| June 19- July 2 | Fulkharka, Mulpani | 40 & 16 = 56 | 6 | 2 | 3 | 55 | 14 |
| August 8-11 | Salyantar, Aaginchowk | 0 | 4 | 2 | 0 | 19 | 4 |
| September 21-29 | Fulkharka, Mulpani & Budhathum | 0+24+18= 42 | 0 | 0 | 0 | 0 | 9 |
| November 7-8 | Budhathum | 0 | 0 | 2 | 0 | 0 | 2 |
| Total | | 120 | 13 | 7 | 8 | 118 | 40 |

## Appendix II: Focus group discussions conducted in six VDCs of Dhading

| S.N. | Date (2014) | Site (VDCs) | Number of participants | | Remarks |
|---|---|---|---|---|---|
| | | | Male | Female | |
| 1 | April 9 | Baseri | 6 | 4 | Mostly Brahmin/chhetri |
| 2 | June 19 | Mulpaani | 10 | 4 | Mostly teachers, social workers and farmers |
| 3 | June 19 | Mulpani | 5 | 8 | Mostly dalit women |
| 4 | June 20 | Phulkharka | 4 | 7 | Mostly teachers and farmers |
| 5 | June 20 | Phulkharka | 11 | 0 | All teachers |
| 6 | August 8 | Salyantar | 9 | 6 | Mostly businessmen |
| 7 | August 9 | Aaginchowk | 7 | 8 | Mostly traditional healers |
| 8 | November 8 | Budhathum | 7 | 6 | Mostly social workers |

## Appendix III: Enumeration of bioenergy plants

| S.N. | Latin name | Family | Local name | Life form | Use |
|---|---|---|---|---|---|
| 1 | *Abies spectabilis* (D. Don) Mirb. | Pinaceae | Ghongre salla | T | W |
| 2 | *Acer caesium* subsp. *giraldii* (Pax) E. Murray | Sapindaceae | Pre-pre | T | W |
| 3 | *Acer oblongum* subsp. *itoanum* (Hayata) Hatusima | Sapindaceae | Fir Fire | T | W |
| 4 | *Actinodaphne angustifolia* Nees | Lauraceae | Thosne/ thokse | T | W |
| 5 | *Aegle marmelos* (L.) Correa | Rutaceae | Bel | T | W, EO |
| 6 | *Ageratina adenophora* (Spreng.) R.M.King & H.Rob. | Asteraceae | Banmaara | S | W |
| 7 | *Alangium chinense* (Lour.) Harms | Cornaceae | Amphi | T | W, NO |

| | | | | | |
|---|---|---|---|---|---|
| 8 | *Albizia chinensis* (Osbeck) Merr. | Fabaceae | Kaalo sirish | T | W |
| 9 | *Albizia julibrissin* Durazz. | Fabaceae | Rato siris | T | W |
| 10 | *Alnus nepalensis* D.Don | Betulaceae | Uttis | T | W |
| 11 | *Antidesma acidum* Retz. | Phyllanthaceae | Archal | S | W |
| 12 | *Areca* sp.? | Arecaceae | Raam Pwaa | T | W, NO |
| 13 | *Artemisia dubia* L. ex B.D.Jacks. | Asteraceae | Titepaati | S | W, EO |
| 14 | *Artocarpus heterophyllus* Lam. | Moraceae | Rukh katahar | T | W, EO |
| 15 | *Artocarpus lacucha* Buch.-Ham. ex D.Don | Moraceae | Badahar | T | W |
| 16 | *Bambusa nepalensis* Stapleton | Poaceae | Baans | T | W |
| 17 | *Bauhinia purpurea* L. | Fabaceae | Tanki | T | W |
| 18 | *Bauhinia vahlii* Wight & Arn. | Fabaceae | Bhorla | Cl | W |
| 19 | *Bauhinia variegata* L. | Fabaceae | Koiralo | T | W, EO |
| 20 | *Benincasa pruriens* f. *hispida* (Thunb.) de Wilde & Duyfjes | Cucurbitaceae | Kuvindo | Cl | EO |
| 21 | *Berberis aristata* DC. | Berberidaceae | Chutro | S | W |
| 22 | *Berberis asiatica* Roxb. ex DC. | Berberidaceae | Chutro | S | W, NO |
| 23 | *Bombax ceiba* L. | Malvaceae | Simal | T | W, NO |
| 24 | *Brassaiopsis hainla* (Buch.-Ham.) Seem. | Araliaceae | Chuletro | S | W |
| 25 | *Brassica oleracea* L. | Brassicaceae | Brokauli | H | EO |
| 26 | *Brassica juncea* (L.) Czern. | Brassicaceae | Raayo | H | EO |
| 27 | *Brassica napus* L. | Brassicaceae | Kalo sarsyun | H | EO |
| 28 | *Brassica nigra* (L.) W.D.J. Koch | Brassicaceae | Kaalo Tori | H | EO |
| 29 | *Brassica rapa* L. | Brassicaceae | Tori | H | EO |
| 30 | *Bridelia retusa* (L.) A.Juss. | Phyllanthaceae | Gayo | T | W |
| 31 | *Brucea javanica* (L.) Merr. | Simaroubaceae | Bhakimlo | T | W |
| 32 | *Buddleja asiatica* Lour. | Scrophulariaceae | Bhimsen paati | S | W |
| 33 | *Butea monosperma* (Lam.) Taub. | Fabaceae | Palans | T | W |
| 34 | *Caesalpinia decapetala* (Roth) Alston | Fabaceae | Arile kada | T | W |
| 35 | *Cajanus cajan* (L.) Millsp. | Fabaceae | Rahar | S | EO |
| 36 | *Callicarpa arborea* Roxb. | Lamiaceae | Dai Kamle | T | W |
| 37 | *Calotropis gigantea* (L.) W. T. Aiton | Apocynaceae | Aank | S | W |
| 38 | *Camellia kissi* var. *confusa* (Craib) T. L. Ming | Theacae | Goldhari | T | W, EO |
| 39 | *Carica papaya* L. | Caricaceae | Mewa | S | EO |
| 40 | *Casearia graveolens* Dalzell | Salicaceae | Barkamle | T | W |
| 41 | *Cassia fistula* L. | Fabaceae | RajbrikSa | T | W, EO |
| 42 | *Castanopsis indica* (Roxb. ex Lindl.) A.DC. | Fabaceae | Dhale Katus, Katus | T | W, EO |
| 43 | *Castanopsis tribuloides* (Sm.) A.DC. | Fabaceae | Musure katus | T | W |
| 44 | *Cedrus deodara* (Lamb.) G. Don | Pinaceae | Devdar | T | W |
| 45 | *Celtis australis* L. | Cannabaceae | Khari | T | W |
| 46 | *Choerospondias axillaris* (Roxb.) B.L. | Anacardiaceae | Lapsi | T | W, EO |

| | | | | | |
|---|---|---|---|---|---|
| | Burtt & A.W.Hill | | | | |
| 47 | *Chromolaena odorata* (L.) R.M.King & H.Rob. | Asteraceae | Banmaasa | S | W |
| 48 | *Cicer arietinum* L. | Fabaceae | Chanaa | H | EO |
| 49 | *Cipadessa baccifera* (Roth) Miq. | Meliaceae | Kaali Kath | T | W |
| 50 | *Cipadessa baccifera* (Roth) Miq. | Meliaceae | Kaali Kath | S | W |
| 51 | *Citrus aurantiifolia* (Christm.) Swingle | Rutaceae | Kaagati | T | W |
| 52 | *Citrus grandis* (L.) Osbeck | Rutaceae | Bhogate | T | W, EO |
| 53 | *Citrus limon* (L.) Burm.f. | Rutaceae | Amilo | T | W |
| 54 | *Citrus medica* L. | Rutaceae | Bimiro | T | W |
| 55 | *Coffea arabica* L. | Rubiaceae | Kafi/Coffee | T | W, EO |
| 56 | *Cordia dichotoma* G. Forster | Boraginaceae | Bohori | T | W, EO |
| 57 | *Crateva unilocularis* Buch.-Ham. | Capparaceae | Siplikaan | T | W |
| 58 | *Cucurbita pepo* L. | Cucurbitaceae | Farsi | Cl | EO |
| 59 | *Cudrania cochinchinensis* (Lour.) Yakuro Kudo & Masamune (*Maclura cochinchinensis* (Lour.) Corner) | Moraceae | Main kada | S | W |
| 60 | *Dalbergia sissoo* DC. | Fabaceae | Sisau | T | W |
| 61 | *Daphne bholua* Buch.-Ham. ex D. Don | Thymelaeaceae | Lokta | S | W, EO |
| 62 | *Datura stramonium* L. | Solanaceae | Dhaturo | S | NO |
| 63 | *Debregeasia saeneb* (Forssk.) Hepper & Wood | Urticaceae | Daar | T | W |
| 64 | *Dendrocalamus hamiltonii* Nees & Arn. ex Munro | Poaceae | Baans | T | W |
| 65 | *Dendrophthoe falcata* (L. f.) Bl. | Loranthaceae | Aijeru | S | W |
| 66 | *Diospyros lanceifolia* Roxb. | Ebenaceae | Teju | T | W |
| 67 | *Diospyros malabarica* (Desr.) Kostel. | Ebenaceae | Tinju / Tindu | T | W |
| 68 | *Diploknema butyracea* (Roxb.) H.J.Lam | Sapotaceae | Chiuri | T | W, EO |
| 69 | *Duabanga grandiflora* (Roxb. ex DC.) Walp. | Lythraceae | Odaane | T | W |
| 70 | *Duranta erecta* L. (Syn. *Durenta repens* L.) | Verbenaceae | Nil Kaanda | S | W |
| 71 | *Elaegnus infundibularis* Momiyama | Elaegnaceae | Guheli | T | W |
| 72 | *Eleusine coracana* (L.) Gaertn. | Poaceae | Kodo | H | EO |
| 73 | *Engelhardia spicata* Lesch. ex Bl. | Juglandaceae | Mauwa | T | W |
| 74 | *Entada phaseoloides* (L.) Merr. | Fabaceae | Pangraa | Cl | NO |
| 75 | *Erythrina arborescens* Roxb. | Fabaceae | Phaledo | T | W |
| 76 | *Erythrina stricta* Roxb. | Fabaceae | Phaledo | T | W |
| 77 | *Euphorbia pulcherrima* Willd. ex Klotzsch | Euphorbiaceae | Lalupate | S | W |
| 78 | *Eurya acuminata* DC. | Pentaphylacaceae | Baakle/Sano Jhigaane | S | W |
| 79 | *Fagopyrum esculentum* Moench | Polygonaceae | Faapar | H | EO |
| 80 | *Falconeria insignis* Royle (Syn. *Sapium* | Euphorbiaceae | Khirro | T | W, NO |

| | | | | | |
|---|---|---|---|---|---|
| | *insigne* Royle (Trimen) | | | | |
| 81 | *Ficus auriculata* Lour. | Moraceae | Nimaaro | T | W |
| 82 | *Ficus benghalensis* L. | Moraceae | Bar | T | W |
| 83 | *Ficus benjamina* L. | Moraceae | Swami | T | W |
| 84 | *Ficus concinna* (Miq.) Miq. | Moraceae | Kabhro | T | W |
| 85 | *Ficus glaberrima* Blume | Moraceae | Pakhuri | T | W |
| 86 | *Ficus hispida* L. f. | Moraceae | Khasreto | T | W |
| 87 | *Ficus neriifolia* Sm. | Moraceae | Dudhilo | T | W |
| 88 | *Ficus racemosa* L. | Moraceae | Dumri | T | W |
| 89 | *Ficus religiosa* L. | Moraceae | Peepal | T | W |
| 90 | *Ficus semicordata* Buch.-Ham. ex Sm. | Moraceae | Khanayo, Khanyu | T | W |
| 91 | *Ficus sp.* | Moraceae | Gede | T | W |
| 92 | *Fraxinus floribunda* Wall. | Oleaceae | Laakuri | T | W |
| 93 | *Garuga pinnata* Roxb. | Burseraceae | Dabdabe | T | W |
| 94 | *Gaultheria fragrantissima* Wall. | Ericaceae | Dhasingare | S | W, NO |
| 95 | *Glycine max* (L.) Merr. | Fabaceae | Bhatmas | H | EO |
| 96 | *Gmelina arborea* Roxb. ex Sm. | Lamiaceae | Khamari | T | W |
| 97 | *Gossypium hirsutum* L. | Malvaceae | Kapaas | S | W, EO |
| 98 | *Guizotia abyssinica* (L.f.) Cass. | Asteraceae | Jhuse til | H | EO |
| 99 | *Helianthus annuus* L. | Asteraceae | Suryamukhi Phul | H | EO |
| 100 | *Heynea trijuga* Roxb. | Meliaceae | Aakhatare | T | W, NO |
| 101 | *Himalayacalamus hookerianus* (Munro) Stapleton | Poaceae | Nigaalo | T | W |
| 102 | *Holarrhena pubescens* (Buch.-Ham.) Wall. ex G.Don | Apocynaceae | Khirro | T | W |
| 103 | *Hypericum cordifolium* Choisy | Hypericaceae | Areli | H | NO |
| 104 | *Ilex excelsa* (Wall.) Hook. f. | Aquifoliaceae | Puwaley | T | W |
| 105 | *Inula grandiflora* Willd. | Asteraceae | | H | EO |
| 106 | *Jatropha curcas* L. | Euphorbiaceae | Sajiwan | S | W, NO |
| 107 | *Juglans regia* L. | Juglandaceae | Sano Okhar | T | EO |
| 108 | *Justicia adhatoda* L. | Acanthaceae | Asuro | S | W |
| 109 | *Lablab purpureus* (L.) Sweet | Fabaceae | Simi | Cl | EO |
| 110 | *Lagerstroemia parviflora* Roxb. | Lythraceae | Bot dhairo | T | W |
| 111 | *Lantana camara* L. | Verbenaceae | Banmara | S | W |
| 112 | *Lens culinaris* Medik. | Fabaceae | Masuro | H | EO |
| 113 | *Leucaena leucocephala* (Lam.) de Wit | Fabaceae | Epil ipil | T | W, |
| 114 | *Leycesteria formosa* Wall. | Capprifoliaceae | | S | W |
| 115 | *Lindera neesiana* (Wall. ex Nees) Kurz | Lauraceae | Siltimur | T | W |
| 116 | *Lindera pulcherrima* (Nees) Benth. | Lauraceae | Fusre | S | W |
| 117 | *Linum usitatissimum* L. | Linaceae | Aalas | H | EO |
| 118 | *Litchi chinensis* Sonn. | Sapindaceae | Litchi | T | W |
| 119 | *Litsea glutinosa* (Lour.) C.B.Rob. | Lauraceae | Harchur | T | W |

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|---|---|---|---|---|---|
| 120 | *Litsea monopetala* (Roxb. ex Baker) Pers. | Lauraceae | Kutmiro | T | W |
| 121 | *Lonicera angustifolia* Wall. | Capprifoliaceae | | S | W |
| 122 | *Lyonia ovalifolia* (Wall.) Drude | Ericaceae | Angeri | T | W |
| 123 | *Machilus odoratissima* Nees | Lauraceae | Kaulo | T | W, EO |
| 124 | *Macrotyloma uniflorum* (Lam.) Verdc. | Fabaceae | Gahat | H | EO |
| 125 | *Maesa chisia* Buch.-Ham. ex D. Don | Primulaceae | Bilaaune, Bilauni | T | W |
| 126 | *Maesa macrophylla* Wall. ex Roxb. | Primulaceae | Bhogate | T | W |
| 127 | *Magnolia champaca* (L.) Baill. ex Pierre | Magnoliaceae | Chaanp | T | W |
| 128 | *Mallotus philippensis* (Lam.) Mull.Arg. | Euphorbiaceae | Sindure | T | W |
| 129 | *Mangifera indica* L. | Anacardiaceae | Aanp | T | W |
| 130 | *Melastoma malabathricum* L. | Melastomataceae | Angeri | S | W, NO |
| 131 | *Melia azedarach* L. | Meliaceae | Bakaaino | T | W, EO |
| 132 | *Mesua ferrea* L. | Calophyllaceae | Naag keshar | T | W, NO |
| 133 | *Momordica charantia* L. | Cucurbitaceae | Tite Karela | Cl | EO |
| 134 | *Morus alba* L. | Moraceae | Kimmu | T | W |
| 135 | *Mussaenda macrophylla* Wall. | Rubiaceae | Dhobini | S | W |
| 136 | *Morella esculenta* (Buch.-Ham. ex D.Don) I.M.Turner (*Myrica esculenta* Buch.-Ham. ex D.Don) | Moraceae | Kafal | T | W |
| 137 | *Myrsine seguinii* H. Lev. (Syn. *Myrsine capitellata* Wall.) | Primulaceae | Seti kath | T | W |
| 138 | *Myrsine semiserrata* Wall. | Primulaceae | Kali kath | T | W |
| 139 | *Neonauclea purpurea* (Roxb.) Merr. | Rubiaceae | Kadam | T | W |
| 140 | *Nicotiana tabacum* L. | Solanaceae | Kaancho paat, surti | S | W. NO |
| 141 | *Nyctanthes arbor-tristis* L. | Oleaceae | Paarijaat | T | W |
| 142 | *Osbeckia nepalensis* Hook. | Melastomataceae | Chuwa | S | W |
| 143 | *Osyris wightiana* Wall. ex Wight | Santalaceae | Nundhiki | S | W, NO |
| 144 | *Parthenium hysterophorus* L. | Asteraceae | | S | W |
| 145 | *Perilla frutescens* (L.) Britton | Lamiaceae | Silam | H | EO |
| 146 | *Phyllanthus emblica* L. | Phyllanthaceae | Amala | T | W, EO |
| 147 | *Phyllanthus parvifolius* Buch.-Ham. ex D.Don | Phyllanthaceae | Khareto | S | W |
| 148 | *Pieris formosa* (Wall.) D.Don | Ericaceae | Chimal | T | W |
| 149 | *Pinus roxburghii* Sarg. | Pinaceae | Khote Salla, Salla | T | W, NO |
| 150 | *Piptanthus nepalensis* (Hook.) D.Don | Fabaceae | | S | W |
| 151 | *Plumeria rubra* L. | Apocynaceae | Chwaa/Chuwa | T | W |
| 152 | *Pouzolzia rugulosa* (Wedd.) Acharya & Kravtsova (Syn. *Boehmeria rugulosa* Wedd.) | Urticaceae | Dar / Githaa | T | W |
| 153 | *Premna barbata* Wall. ex Schauer | Lamiaceae | Gineri | T | W |
| 154 | *Premna serratifolia* L. | Lamiaceae | Gidari | T | W |
| 155 | *Prinsepia utilis* Royle | Rosaceae | Dhatelo | S | W, EO |

| | | | | | |
|---|---|---|---|---|---|
| 156 | *Prunus armeniaca* L. | Rosaceae | Khurpani | T | W, EO |
| 157 | *Prunus cerasoides* D.Don | Rosaceae | Painyu | T | W |
| 158 | *Prunus domestica* L. | Rosaceae | Aalubakhara | T | W |
| 159 | *Prunus persica* (L.) Stokes | Rosaceae | Aaru | T | W, EO |
| 160 | *Psidium guajava* L. | Myrtaceae | Belauti/Amba | T | W |
| 161 | *Pyrus communis* L. | Rosaceae | Naaspati | T | W, EO |
| 162 | *Pyrus pashia* Buch.-Ham. ex D.Don | Rosaceae | Mel | T | W |
| 163 | *Quercus lamellosa* Sm. | Fagaceae | Gogan | T | W |
| 164 | *Quercus glauca* Thunb. | Fagaceae | Falaat | T | W |
| 165 | *Quercus semecarpifolia* Sm. | Fagaceae | Khasru | T | W |
| 166 | *Raphanus sativus* L. | Brassicaceae | Mula | H | EO |
| 167 | *Rhododendron arboreum* Sm. | Ericaceae | Lali Gurans | T | W |
| 168 | *Rhododendron barbatum* Wall. ex G.Don | Ericaceae | Chimal | T | W |
| 169 | *Rhododendron lepidotum* Wall. | Ericaceae | Sundhup | S | W |
| 170 | *Ricinus communis* L. | Euphorbiaceae | Aderi, Ander | S | W, NO |
| 171 | *Rubia manjith* Roxb. | Rubiaceae | Majitho | Cl | W |
| 172 | *Rubus ellipticus* Sm. | Rosaceae | Aiselu | Cl | W |
| 173 | *Salix babylonica* L. | Salicaceae | Bains | T | W |
| 174 | *Sambucus javanica* Reinw. ex Bl. | Adoxaceae | | T | W |
| 175 | *Sapindus mukorossi* Gaertn. | Sapindaceae | Riththa | T | W, NO |
| 176 | *Schefflera venulosa* (Wight & Arn.) Harms | Araliaceae | | Cl | W |
| 177 | *Schima wallichii* Choisy | Theaceae | Chilaune | T | W |
| 178 | *Semecarpus anacardium* L. F. | Anacardiaceae | Bhalaayo | T | W, NO |
| 179 | *Senegalia catechu* (L.f.) P.J.H.Hurter & Mabb. (*Acacia catechu* L.f.) | Fabaceae | Khayar | T | W |
| 180 | *Senna tora* (L.)Roxb. | Fabaceae | Taapre | S | W |
| 181 | *Sesamum indicum* L. | Pedaliaceae | Sisam/Til | H | EO |
| 182 | *Shorea robusta* Gaertn. | Dipterocarpaceae | Sal | T | W, NO |
| 183 | *Sida rhombifolia* L. | Malvaceae | Saano Chilya | S | W |
| 184 | *Sorbus cuspidata* (Spach) Hedl. | Rosaceae | Lapanaa | T | W |
| 185 | *Sphaerosacme decandra* (Wall.) Pennington | Meliaceae | | T | W |
| 186 | *Spondias pinnata* (L. fil.) Kurz | Anacardiaceae | Amaro | T | W, EO |
| 187 | *Sterculia villosa* Roxb. | Malvaceae | Odaane | T | W |
| 188 | *Symplocos kuroki* H. Nagamasu (Syn. *Symplocos theifolia* D.Don) | Symplocaceae | Kholme/Kharaane | T | W, NO |
| 189 | *Syzygium cumini* (L.) Skeels | Myrtaceae | Jamun | T | W |
| 190 | *Syzygium nervosum* A.Cunn. ex DC. (Syn. *Cleistocalyx operculatus* (Roxb.) Merr. & L.M.Perry) | Myrtaceae | Kyamunaa | T | W |
| 191 | *Taxus baccata* L. (Syn. *Taxus wallichiana* Zucc.) | Taxaceae | Dhengra salla/Lauth salla | T | W |
| 192 | *Terminalia bellirica* (Gaertn.) Roxb. | Combretaceae | Barro | T | W, EO |

| | | | | | |
|---|---|---|---|---|---|
| 193 | *Terminalia chebula* Retz. | Combretaceae | Harro | T | W, EO |
| 194 | *Terminalia tomentosa* Wight & Arn. | Combretaceae | Saj | T | W |
| 195 | *Thespesia lampas* (Cav.) Dalzell & A. Gibson | Malvaceae | Ban Kapaash | T | W |
| 196 | *Toona ciliata* M. Roem. | Meliaceae | Tooni | T | W |
| 197 | *Toxicodendron acuminatum* (DC.) C.Y.Wu. T. L.Ming | Anacardiaceae | Rani bhalayo | T | W |
| 198 | *Toxicodendron wallichii* (Hook. f.) Kuntze | Anacardiaceae | sano bhalaayo | T | W |
| 199 | *Tsuga dumosa* (D. Don) Eichler | Pinaceae | Thingre/Gobre salla | T | W |
| 200 | *Viburnum erubescens* Wall. | Adoxaceae | | S | W |
| 201 | *Viburnum mullaha* Buch.-Ham. ex D.Don | Adoxaceae | Malo/Malaayo | S | W, NO |
| 202 | *Vigna mungo* (L.) Hepper | Fabaceae | Maas | H | EO |
| 203 | *Vitex negundo* L. | Lamiaceae | Simali | S | W |
| 204 | *Wendlandia puberula* DC. | Rubiaceae | Kainyo | T | W |
| 205 | *Woodfordia fruticosa* (L.) Kurz | Lythraceae | Dhayaro | S | W |
| 206 | *Wrightia arborea* (Dennst.) D.J.Mabberley | Apocynaceae | Rani khirro | T | W |
| 207 | *Xylosma controversa* Clos | Salicaceae | Dade kada | T | W |
| 208 | *Zanthoxylum armatum* DC. | Rutaceae | Timur | S | W, EO |
| 209 | *Zanthoxylum oxyphyllum* Edgew. | Rutaceae | Ban timur | S | W, EO |
| 210 | *Zea mays* L. | Poaceae | Makai | H | W, EO |
| 211 | *Ziziphus jujuba* Miller | Rhamnaceae | Bayar, Thulo bayar | S | W, EO |

T=Tree, S=shrub, Cl=climber, H=herb
W=fuelwood, EO=edible oil, NO=non-edible oil

**Appendix IV: Enumeration of potential fuelwood species**

| S.N. | Latin Names | Local Names | Family | Characteristics of plants | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | A | B | C | D | E | F | G | H | I | J | |
| 1 | *Rhododendron arboreum* Sm. | Gurans | Ericaceae | 2 | 3 | 2 | 3 | 3 | 2 | 3 | 3 | 1 | 1 | 23 |
| 2 | *Lyonia ovalifolia* (Wall.) Drude | Anger | Ericaceae | 2 | 3 | 2 | 3 | 2 | 2 | 3 | 3 | 2 | 1 | 23 |
| 3 | *Shorea robusta* Gaertn. | Saal | Dipterocarpaceae | 2 | 3 | 3 | 2 | 3 | 2 | 3 | 3 | 1 | 1 | 23 |
| 4 | *Schima wallichii* Choisy | Chilaune | Theaceae | 3 | 2 | 2 | 3 | 2 | 3 | 3 | 2 | 1 | 1 | 22 |
| 5 | *Pinus roxburghii* Sarg. | Salla | Pinaceae | 2 | 3 | 2 | 2 | 3 | 3 | 2 | 2 | 2 | 1 | 22 |
| 6 | *Alnus nepalensis* D.Don | Uttish | Betulaceae | 2 | 3 | 2 | 2 | 2 | 2 | 3 | 2 | 2 | 2 | 22 |
| 7 | *Ficus semicordata* Buch. ex J.E. Sm. | Khanaayo | Moraceae | 2 | 1 | 2 | 2 | 2 | 3 | 3 | 3 | 2 | 2 | 22 |
| 8 | *Castanopsis indica* (Roxb. ex Lindl.) A.DC. | katush | Fagaceae | 1 | 2 | 2 | 1 | 3 | 3 | 3 | 3 | 2 | 2 | 22 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | *Myrica esculenta* Buch.-Ham. ex D.Don | Kaafal | Myricaceae | 2 | 2 | 2 | 2 | 3 | 2 | 3 | 3 | 2 | 1 | 22 |
| 10 | *Melia azedarach* L. | Bakaino | Meliaceae | 2 | 3 | 2 | 2 | 3 | 1 | 3 | 2 | 2 | 2 | 22 |
| 11 | *Artocarpus heterophyllus* Lam. | Rukh katahar | Moraceae | 1 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 2 | 2 | 21 |
| 12 | *Maesa chisia* Buch.-Ham. ex D.Don | Bilaaune | Primulaceae | 2 | 3 | 2 | 2 | 2 | 1 | 3 | 3 | 1 | 1 | 20 |
| 13 | *Woodfordia fruticosa* (L.) Kurz | Dhayeri | Lythraceae | 2 | 3 | 2 | 2 | 2 | 1 | 3 | 3 | 1 | 1 | 20 |
| 14 | *Psidium guajava* L. | Amba | Myrtaceae | 1 | 2 | 2 | 2 | 3 | 1 | 3 | 2 | 2 | 2 | 20 |
| 15 | *Fraxinus floribunda* Wall. | Laakuri | Oleaceae | 1 | 2 | 2 | 2 | 2 | 1 | 3 | 3 | 2 | 2 | 20 |
| 16 | *Ficus hispida* L. f. | Kharset o | Moraceae | 1 | 2 | 2 | 1 | 2 | 1 | 3 | 3 | 3 | 2 | 20 |
| 17 | *Mangifera indica* L. | Aanp | Anacardiaceae | 1 | 2 | 2 | 2 | 3 | 1 | 3 | 3 | 2 | 1 | 20 |
| 18 | *Litsea monopetala* (Roxb. ex Baker) Pers. | kutmero | Lauraceae | 1 | 1 | 2 | 2 | 2 | 2 | 3 | 3 | 1 | 2 | 19 |
| 19 | *Ficus neriifolia* Sm. | Dudhilo | Moraceae | 1 | 1 | 2 | 1 | 2 | 1 | 3 | 3 | 3 | 2 | 19 |
| 20 | *Ficus concinna* (Miq.) Miq. | Kaapro | Moraceae | 1 | 2 | 2 | 1 | 2 | 1 | 3 | 3 | 2 | 2 | 19 |
| 21 | *Lagerstroemia parviflora* Roxb. | Botdhair o | Lythraceae | 2 | 3 | 2 | 1 | 1 | 1 | 3 | 3 | 2 | 1 | 19 |
| 22 | *Bauhinia purpurea* L. | Tanki | Fabaceae | 1 | 2 | 2 | 1 | 3 | 1 | 3 | 3 | 2 | 1 | 19 |
| 23 | *Hypericum cordifolium* Choisy | Areli | Hypericaceae | 1 | 3 | 2 | 1 | 2 | 1 | 3 | 3 | 2 | 1 | 19 |
| 24 | *Terminalia chebula* Retz. | Harro | Combretaceae | 1 | 2 | 2 | 1 | 3 | 1 | 3 | 3 | 2 | 1 | 19 |
| 25 | *Terminalia bellirica* (Gaertn.) Roxb. | Barro | Combretaceae | 1 | 2 | 2 | 1 | 3 | 1 | 3 | 3 | 2 | 1 | 19 |
| 26 | *Dendrocalamus hamiltonii* Nees & Arn. ex Munro | baans | Poaceae | 1 | 3 | 2 | 1 | 3 | 1 | 3 | 2 | 1 | 1 | 18 |
| 27 | *Prunus cerasoides* D.Don | Paiyu | Rosaceae | 2 | 1 | 2 | 1 | 1 | 1 | 3 | 3 | 2 | 2 | 18 |
| 28 | *Ficus sp.* | Gede | Moraceae | 1 | 2 | 2 | 2 | 1 | 1 | 3 | 2 | 2 | 2 | 18 |
| 29 | *Elaeagnus infundibularis* Momiyama | Guyelo | Elaeagnaceae | 1 | 2 | 2 | 1 | 2 | 1 | 3 | 3 | 2 | 1 | 18 |
| 30 | *Casearia graveolens* Dalzell | Barkaml e | Salicaceae | 1 | 2 | 2 | 1 | 1 | 1 | 3 | 3 | 2 | 2 | 18 |
| 31 | *Ficus racemosa* L. | Dumri | Moraceae | 1 | 2 | 1 | 1 | 3 | 1 | 3 | 2 | 2 | 2 | 18 |
| 32 | *Pyrus pashia* Buch.-Ham. ex D.Don | Mel | Rosaceae | 1 | 2 | 1 | 1 | 2 | 1 | 3 | 3 | 2 | 2 | 18 |
| 33 | *Actinodaphne gullavara* (Buch.-Ham. ex Nees) M.R.Almeida | Thosne | Lauraceae | 2 | 2 | 1 | 2 | 2 | 1 | 3 | 3 | 1 | 1 | 18 |
| 34 | *Debregeasia saeneb* (Forssk.) Hepper & Wood | Daar | Urticaceae | 1 | 1 | 2 | 2 | 2 | 1 | 3 | 3 | 1 | 1 | 17 |
| 35 | *Leucaena leucocephala* (Lam.) de Wit | Epil ipil | Fabaceae | 2 | 3 | 2 | 2 | 1 | 1 | 1 | 2 | 2 | 1 | 17 |
| 36 | *Engelhardia spicata* Lesch. ex Bl. | Mauwa | Juglandaceae | 2 | 2 | 2 | 1 | 1 | 1 | 3 | 3 | 1 | 1 | 17 |
| 37 | *Citrus grandis* (L.) Osbeck | Bhogate | Rutaceae | 1 | 1 | 2 | 1 | 2 | 1 | 3 | 3 | 2 | 1 | 17 |
| 38 | *Chromolaena odorata* (L.) | Banmaa | Asteraceae | 2 | 3 | 2 | 1 | 1 | 2 | 1 | 2 | 2 | 1 | 17 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | R.M.King & H.Rob. | sa | | | | | | | | | | | | |
| 39 | *Diospyros lanceifolia* Roxb. | Tindu | Ebeniaceae | 1 | 2 | 2 | 1 | 2 | 1 | 3 | 3 | 1 | 1 | 17 |
| 40 | *Toona ciliata* M. Roem. | Tooni | Meliaceae | 1 | 2 | 2 | 1 | 1 | 1 | 3 | 3 | 2 | 1 | 17 |
| 41 | *Syzygium nervosum* A.Cunn. ex DC. | Kyamuna | Myrtaceae | 1 | 1 | 1 | 2 | 3 | 1 | 3 | 3 | 1 | 1 | 17 |
| 42 | *Erythrina stricta* Roxb. | Faledo | Leguminosae | 1 | 2 | 1 | 1 | 3 | 1 | 3 | 3 | 1 | 1 | 17 |
| 43 | *Eurya acuminata* DC. | Jhigaane | Pentaphylaceae | 2 | 1 | 1 | 1 | 1 | 2 | 3 | 2 | 2 | 1 | 16 |
| 44 | *Holarrhena pubescens* (Buch.-Ham.) Wall. ex G.Don | Khirro | Apocynaceae | 2 | 1 | 1 | 1 | 1 | 1 | 3 | 2 | 2 | 2 | 16 |
| 45 | *Acer oblongum* subsp. *itoanum* (Hayata) Hatusima | Firfire | Sapindaceae | 1 | 1 | 2 | 1 | 2 | 1 | 3 | 3 | 1 | 1 | 16 |
| 46 | *Myrsine semiserrata* Wall. | kaalikaath | Primulaceae | 2 | 1 | 1 | 2 | 1 | 1 | 3 | 3 | 1 | 1 | 16 |
| 47 | *Brucea javanica* (L.) Merr. | Bhakimlo | Simaroubaceae | 1 | 1 | 2 | 1 | 1 | 1 | 3 | 3 | 2 | 1 | 16 |
| 48 | *Premna barbata* Wall. ex Schauer | Gineri | Verbenaceae | 1 | 2 | 1 | 1 | 2 | 1 | 3 | 3 | 1 | 1 | 16 |
| 49 | *Lantana camara* L. | Banmara | Verbenaceae | 3 | 2 | 2 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 16 |
| 50 | *Albizia chinensis* (Osbeck) Merr. | Siris | Fabaceae | 1 | 1 | 1 | 1 | 2 | 1 | 3 | 3 | 1 | 1 | 15 |
| 51 | *Neonauclea purpurea* (Roxb.) Merr. | Kadam | Rubiaceae | 1 | 2 | 1 | 1 | 1 | 1 | 3 | 3 | 1 | 1 | 15 |
| 52 | *Albizia julibrissin* Durazz. | ghokre | Fabaceae | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 3 | 1 | 1 | 14 |
| 53 | *Cordia dichotoma* G. Forst. | Bohori | Cordiaceae | 1 | 1 | 0 | 1 | 2 | 1 | 3 | 2 | 2 | 1 | 14 |
| 54 | *Bauhinia variegata* L. | Koiralo | Fabaceae | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 3 | 1 | 1 | 14 |

A= Abundance, B= burning, C= smoking, D= durability, E= use value, F= preference ranking, G= chorotype, H= stress tolerance, I= propagation and J= agronomical integration.

**Appendix V: Enumeration of potential oil yielding species**

| **S.N.** | **Latin name** | **Local name** | **Family** | **Characteristics of plants** | | | | | | | | | | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | A | B | C | D | E | F | G | H | I | J | |
| 1 | *Guizotia abyssinica* (L.f.) Cass. | jhuse til | Asteraceae | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 29 |
| 2 | *Jatropha curcas* L. | sajiban | Euphorbiaceae | 3 | 3 | 3 | 1 | 3 | 3 | 3 | 3 | 3 | 3 | 28 |
| 3 | *Brassica nigra* (L.) W.D.J.Koch | tori | Brassicaceae | 3 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 3 | 3 | 27 |
| 4 | *Camellia kissi* var. *confusa* (Craib) T.L.Ming | Goldhari | Theacae | 2 | 3 | 2 | 3 | 3 | 2 | 3 | 3 | 1 | 3 | 25 |
| 5 | *Zea mays* L. | Makai | Poaceae | 1 | 3 | 2 | 3 | 2 | 3 | 3 | 3 | 3 | 2 | 25 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | *Glycine max* (L.) Merr. | Bhatmass | Fabaceae | 2 | 3 | 1 | 3 | 2 | 3 | 2 | 3 | 3 | 2 | 24 |
| 7 | *Ricinus communis* L. | Areth | Euphorbiaceae | 1 | 3 | 2 | 1 | 3 | 3 | 2 | 3 | 3 | 3 | 24 |
| 8 | *Diploknema butyracea* (Roxb.) H.J.Lam | Chiuri | Sapotaceae | 3 | 3 | 1 | 3 | 3 | 1 | 3 | 2 | 1 | 3 | 23 |
| 9 | *Semecarpus anacardium* L.f. | Bhalaayo | Anacardiaceae | 2 | 3 | 3 | 1 | 3 | 1 | 3 | 2 | 2 | 3 | 23 |
| 10 | *Raphanus sativus* L. | Mula | Brassicaceae | 1 | 3 | 1 | 3 | 2 | 3 | 2 | 3 | 3 | 1 | 22 |
| 11 | *Helianthus annuus* L. | Surya mukhi | Asteraceae | 1 | 3 | 1 | 3 | 1 | 3 | 2 | 2 | 3 | 3 | 22 |
| 12 | *Brassica juncea* (L.) Czern. | Raayo | Brassicaceae | 2 | 3 | 1 | 3 | 2 | 3 | 1 | 3 | 3 | 1 | 22 |
| 13 | *Sapindus mukorossi* Gaertn. | Riththa | Sapindaceae | 2 | 3 | 1 | 1 | 3 | 1 | 3 | 3 | 2 | 3 | 22 |
| 14 | *Melia azedarach* L. | bakaino | Meliaceae | 2 | 3 | 2 | 2 | 2 | 2 | 3 | 2 | 2 | 2 | 22 |
| 15 | *Gossypium hirsutum* L. | Kapaas | Malvaceae | 1 | 3 | 1 | 2 | 3 | 3 | 2 | 3 | 2 | 2 | 22 |
| 16 | *Vigna mungo* (L.) Hepper | Maas | Fabaceae | 1 | 3 | 1 | 3 | 2 | 3 | 2 | 3 | 3 | 1 | 22 |
| 17 | *Sesamum indicum* L. | til | Pedaliaceae | 1 | 3 | 1 | 3 | 1 | 3 | 2 | 2 | 3 | 2 | 21 |
| 18 | *Arachis hypogaea* L. | Badaam | Fabaceae | 1 | 3 | 1 | 3 | 1 | 2 | 2 | 3 | 3 | 2 | 21 |
| 19 | *Linum usitatissimum* L. | Aalas | Linaceae | 1 | 3 | 1 | 3 | 1 | 2 | 1 | 3 | 3 | 3 | 21 |
| 20 | *Heynea trijuga* Roxb. | Aankha tare | Meliaceae | 2 | 3 | 2 | 1 | 3 | 1 | 2 | 3 | 1 | 3 | 21 |
| 21 | *Castanopsis indica* (Roxb. ex Lindl.) A.DC. | Katush | Fagaceae | 1 | 3 | 2 | 3 | 3 | 1 | 3 | 2 | 1 | 2 | 21 |
| 22 | *Prunus persica* (L.) Stokes | Aaru | Rosaceae | 1 | 3 | 1 | 2 | 3 | 3 | 3 | 2 | 2 | 1 | 21 |
| 23 | *Lablab purpureus* (L.) Sweet | simi | Fabaceae | 1 | 3 | 2 | 3 | 2 | 3 | 2 | 2 | 2 | 1 | 21 |
| 24 | *Benincasa pruriens* f. *hispida* (Thunb.) de Wilde & Duyfjes | Kuvindo | Cucurbitaceae | 1 | 3 | 1 | 2 | 2 | 3 | 2 | 2 | 3 | 1 | 20 |
| 25 | *Alangium chinense* (Lour.) Harms | Amphi | Alangiaceae | 1 | 3 | 1 | 1 | 3 | 2 | 2 | 3 | 2 | 2 | 20 |
| 26 | *Eleusine coracana* (L.) Gaertn. | kodo | Poaceae | 1 | 3 | 2 | 3 | 2 | 3 | 2 | 2 | 1 | 1 | 20 |
| 27 | *Macrotyloma uniflorum* (Lam.) Verdc. | gahat | Fabaceae | 1 | 3 | 1 | 3 | 2 | 2 | 1 | 2 | 2 | 2 | 19 |
| 28 | *Juglans regia* L. | Okhar | Juglandaceae | 1 | 3 | 1 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 19 |
| 29 | *Lens culinaris* Medik. | masuro | Fabaceae | 1 | 3 | 1 | 3 | 2 | 2 | 1 | 2 | 2 | 1 | 18 |
| 30 | *Zanthoxylum armatum* DC. | Timur | Rutaceae | 1 | 3 | 1 | 2 | 3 | 1 | 2 | 2 | 1 | 2 | 18 |
| 31 | *Citrus grandis* (L.) Osbeck | Bhogate | Rutaceae | 1 | 3 | 1 | 1 | 3 | 2 | 2 | 2 | 2 | 1 | 18 |
| 32 | *Artocarpus heterophyllus* Lam. | rukh katahar | Moraceae | 1 | 3 | 1 | 3 | 2 | 1 | 2 | 2 | 2 | 1 | 18 |
| 33 | *Symplocos kuroki* H. Nagamasu | Kharaani | Symplocaceae | 1 | 3 | 1 | 1 | 3 | 1 | 2 | 2 | 1 | 2 | 17 |
| 34 | *Perilla frutescens* (L.) Britton | silam | Lamiaceae | 1 | 3 | 1 | 2 | 2 | 1 | 2 | 2 | 2 | 1 | 17 |
| 35 | *Pinus roxburghii* Sarg. | Salla | Pinaceae | 1 | 3 | 2 | 1 | 2 | 1 | 3 | 1 | 2 | 1 | 17 |
| 36 | *Areca* sp.? | Raam Pwaa | Arecaceae | 1 | 3 | 1 | 1 | 3 | 1 | 2 | 1 | 1 | 1 | 15 |
| 37 | *Machilus odoratissima* Nees | kaulo | Lauraceae | 1 | 3 | 1 | 2 | 2 | 1 | 1 | 2 | 1 | 1 | 15 |

A= Preference rank, B= chorotype, C= abundance, D= edibility, E= stress tolerence, F= agronomical integration, G= use value, H= harvest flexibility, I= propagation and J= oil content.

**Appendix VI: Moisture content of selected fuelwood species**

| Species Names | Moisture Content (%) | | | | STDEV | Standard Error |
|---|---|---|---|---|---|---|
| | A | B | C | Mean | | |
| *Alnus nepalensis* D.Don | 12.19 | 10.92 | 10.27 | 11.13 | 0.98 | 0.56 |
| *Castanopsis indica* (Roxb. ex Lindl.) A.DC. | 9.26 | 10.13 | 9.71 | 9.70 | 0.44 | 0.25 |
| *Ficus semicordata* Buch. ex J.E.Sm. | 9.38 | 10.55 | 10.14 | 10.02 | 0.59 | 0.34 |
| *Lyonia ovalifolia* (Wall.) Drude | 8.69 | 9.12 | 8.59 | 8.80 | 0.28 | 0.16 |
| *Melia azedarach* L. | 8.22 | 9.62 | 9.36 | 9.07 | 0.74 | 0.43 |
| *Myrica esculenta* Buch.-Ham. ex D.Don | 9.59 | 9.34 | 8.94 | 9.29 | 0.33 | 0.19 |
| *Pinus roxburghii* Sarg. | 10.70 | 12.35 | 12.24 | 11.76 | 0.92 | 0.53 |
| *Rhododendron arboreum* Sm. | 8.29 | 8.37 | 7.83 | 8.16 | 0.29 | 0.17 |
| *Schima wallichii* Choisy | 10.76 | 11.49 | 11.22 | 11.16 | 0.37 | 0.21 |
| *Shorea robusta* Gaertn. | 9.50 | 9.93 | 9.16 | 9.53 | 0.39 | 0.22 |

**Appendix VII: Volatile matter of selected fuelwood species**

| Species Names | Volatile matter (%) | | | | STDEV | Standard Error |
|---|---|---|---|---|---|---|
| | A | B | C | Mean | | |
| *Alnus nepalensis* D.Don | 85.93 | 86.83 | 86.22 | 86.33 | 0.46 | 0.27 |
| *Castanopsis indica* (Roxb. ex Lindl.) A.DC. | 86.92 | 89.31 | 87.98 | 88.07 | 1.20 | 0.69 |
| *Ficus semicordata* Buch. ex J.E.Sm. | 86.09 | 86.83 | 84.84 | 85.92 | 1.01 | 0.58 |
| *Lyonia ovalifolia* (Wall.) Drude | 86.50 | 87.40 | 88.04 | 87.31 | 0.78 | 0.45 |
| *Melia azedarach* L. | 86.16 | 89.90 | 88.42 | 88.16 | 1.88 | 1.09 |
| *Myrica esculenta* Buch.-Ham. ex D.Don | 82.56 | 82.48 | 82.34 | 82.46 | 0.11 | 0.06 |
| *Pinus roxburghii* Sarg. | 83.16 | 85.49 | 86.26 | 84.97 | 1.61 | 0.93 |
| *Rhododendron arboreum* Sm. | 87.13 | 88.08 | 87.62 | 87.61 | 0.47 | 0.27 |
| *Schima wallichii* Choisy | 85.61 | 87.12 | 86.66 | 86.47 | 0.77 | 0.45 |
| *Shorea robusta* Gaertn. | 87.34 | 88.25 | 89.06 | 88.22 | 0.86 | 0.50 |

**Appendix VIII: Ash content of selected fuelwood species**

| Species Name | Ash content (%) | | | | STDEV | Standard Error |
|---|---|---|---|---|---|---|
| | A | B | C | Mean | | |
| *Alnus nepalensis* D.Don | 1.64 | 1.62 | 1.55 | 1.60 | 0.04 | 0.03 |
| *Castanopsis indica* (Roxb. ex Lindl.) A.DC. | 1.76 | 1.64 | 1.52 | 1.64 | 0.12 | 0.07 |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Ficus semicordata* Buch. ex J.E. Sm. | 1.67 | 1.86 | 1.96 | 1.83 | 0.15 | 0.09 |
| *Lyonia ovalifolia* (Wall.) Drude | 0.43 | 0.36 | 0.31 | 0.37 | 0.06 | 0.03 |
| *Melia azedarach* L. | 0.77 | 0.72 | 0.65 | 0.71 | 0.06 | 0.04 |
| *Myrica esculenta* Buch.-Ham. ex D.Don | 0.86 | 0.82 | 0.85 | 0.84 | 0.02 | 0.01 |
| *Pinus roxburghii* Sarg. | 0.45 | 0.39 | 0.35 | 0.40 | 0.05 | 0.03 |
| *Rhododendron arboreum* Sm. | 0.68 | 0.92 | 0.76 | 0.78 | 0.12 | 0.07 |
| *Schima wallichii* Choisy | 1.71 | 1.83 | 1.84 | 1.79 | 0.07 | 0.04 |
| *Shorea robusta* Gaertn. | 0.70 | 0.68 | 0.61 | 0.66 | 0.05 | 0.03 |

**Appendix IX: Fixed carbon of selected fuelwood species**

| Species Names | Fixed carbon (%) | | | | STDEV | Standard Error |
|---|---|---|---|---|---|---|
| | A | B | C | Mean | | |
| *Alnus nepalensis* D.Don | 12.43 | 11.55 | 12.22 | 12.07 | 0.46 | 0.27 |
| *Castanopsis indica* (Roxb. ex Lindl.) A.DC. | 11.97 | 8.95 | 10.53 | 10.48 | 1.51 | 0.87 |
| *Ficus semicordata* Buch. ex J.E.Sm. | 11.35 | 10.65 | 11.99 | 11.33 | 0.67 | 0.39 |
| *Lyonia ovalifolia* (Wall.) Drude | 13.08 | 12.24 | 11.65 | 12.32 | 0.72 | 0.41 |
| *Melia azedarach* L. | 13.07 | 9.38 | 10.93 | 11.13 | 1.85 | 1.07 |
| *Myrica esculenta* Buch.-Ham. ex D.Don | 16.58 | 16.70 | 16.81 | 16.70 | 0.12 | 0.07 |
| *Pinus roxburghii* Sarg. | 16.40 | 14.12 | 12.79 | 14.44 | 1.82 | 1.05 |
| *Rhododendron arboreum* Sm. | 12.19 | 11.00 | 11.62 | 11.60 | 0.60 | 0.34 |
| *Schima wallichii* Choisy | 13.07 | 11.25 | 11.50 | 11.94 | 0.99 | 0.57 |
| *Shorea robusta* Gaertn. | 11.97 | 11.07 | 10.34 | 11.12 | 0.82 | 0.47 |

**Appendix X: Calorific value of selected fuelwood species**

| Species Name | Calorific value (Kcal/Kg) |
|---|---|
| *Alnus nepalensis* D.Don | 4518.42 |
| *Castanopsis indica* (Roxb. ex Lindl.) A.DC. | 4326.33 |
| *Ficus semicordata* Buch. ex J.E. Sm. | 4452.67 |
| *Lyonia ovalifolia* (Wall.) Drude | 4692.88 |
| *Melia azedarach* L. | 4210.59 |
| *Myrica esculenta* Buch.-Ham. ex D.Don | 4434.47 |
| *Pinus roxburghii* Sarg. | 4465.87 |
| *Rhododendron arboreum* Sm. | 4775.72 |
| *Schima wallichii* Choisy | 4513.17 |
| *Shorea robusta* Gaertn. | 4469.37 |

**Appendix XI: Oil content of selected oil yielding species**

| Species name | Wt. of sample (gm) | Oil Content | |
|---|---|---|---|
| | | Wt. of oil (ml) | Percentage of Oil |
| *Brassica nigra* (L.) W.D.J.Koch | 40 | 15.58 | 38.95 |
| *Camellia kissi* var. *confusa* (Craib) T.L.Ming | 40 | 14.69 | 36.73 |
| *Diploknema butyracea* (Roxb.) H.J.Lam | 40 | 17.68 | 44.20 |
| *Glycine max* (L.) Merr. | 40 | 9.20 | 23.00 |
| *Guizotia abyssinica* (L.f.) Cass. | 40 | 16.00 | 40.00 |
| *Jatropha curcas* L. | 40 | 14.51 | 36.27 |
| *Ricinus communis* L. | 40 | 18.72 | 46.80 |
| *Sapindus mukorossi* Gaertn. | 40 | 8.53 | 21.33 |
| *Semecarpus anacardium* L. fil. | 40 | 12.50 | 31.25 |
| *Zea mays* L. | 40 | 3.90 | 9.75 |

## Appendix XII: Questionnaire

### STUDY OF BIOENERGY STATUS IN DHADING DISTRICT

**Namaste!**

Would you like to participate in the interview? If Yes, then go to question number 1.

**Q.No.1 Demographic information**

**a) Name of VDC, Ward no.:………… …..b) Name of Respondent:…………………....…**

**c) Gender:…… d) Caste:……… e) Religion:…………f) Occupation:…..................**

**Q.No. 2 Which source of the energy do you use for following purposes? (Firewood, Agricultural residues/wastes, Animal dung, Biogas, LPG, Kerosene, Solar, Electricity, others…….)**

| Tasks | Main source of fuel |
|---|---|
| Cooking | |
| Heating(eg. Room) | |
| Lighting | |
| Cooking for business purpose | |
| For alcohol preparation | |
| Others(specify) ……………….. | |

**Q.No. 3 Have you (or any member) suffered any health complications as a result of using firewood as a source of fuel?**

…….Yes ……..No

If Yes, tick as many as apply to you.

a) Eye irritation b) Bronchitis c) Asthma d) Cough e) Others (specify)……………..

**Q.No. 4 Where do you mainly collect firewood from?**

a) Own land b) Community managed forest c) Government forest

d) Protected areas e) Road side f) River side g) Others (specify)

**Q.No. 5 What is the reason for the use of traditional sources of energy (fuelwood, dung and agricultural residues)?**

a) Lack of financial resources b) Cheap and readily availability of fuelwood

c) Lack of technical support d) All the above e) Others (specify)…………

**Q.No. 6 Have you cultivated plants for biofuel production in your field?**

a) Yes b) No

If no, then what is the reason

a) Happy with food crops b) lack of market c) lack of resources(seed/fertilize…...)

d) Others(specify)……..

**Q.No. 7 Where have you cultivated biofuel plants?**

a) Fields b) Uncultivated land c) Field-bunds d) others(specify)…………

**Q.No. 8 How are/will be the costs and benefits of biofuels related?**

a) Benefits greatly outweigh costs b) Benefits moderately outweigh costs

c) Benefits equal costs d) Costs moderately outweigh benefits

e) Costs greatly outweigh benefits

**Q.No. 9 Is there any organizations which is promoting bio fuel plants cultivation?**

a) Government b) NGO/INGOs c) Community partnership

d) Others(specify)……………

**Q.No.10 Name the fuelwood species you have been using and give reason for using those Fuelwood species?**

a) Highly abundant (……….........................…..) b) Fast and easily burning (……...)

c) Less/ no smoking (…………………………) d) Durable (……………..………)

e) More use values (………………...…………..) f) Stress tolerance (….……………)

g) Easy propagation (…………………………..) h) Agronomical integration (...…)

i) Others (…………………………..………………..)

**Q.No.11 What is the reason for using those oil yielding species?**

a) Highly abundant (…………………………..) b) Edible (………………………)

c) Harvest flexibility (…………………………..) d) High oil content (…………….)

e) More use values (……………...……………...) f) Stress tolerance (…………….)

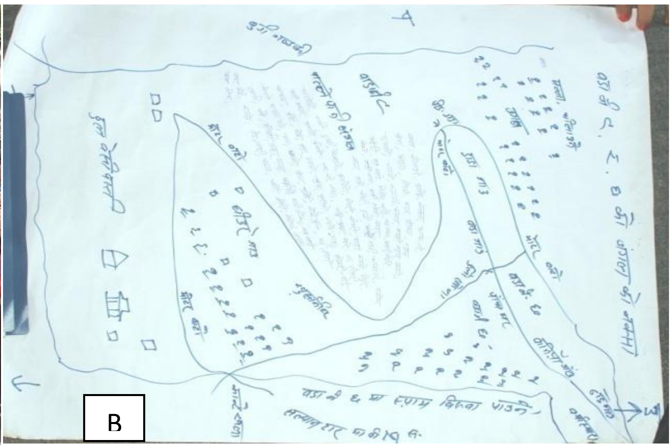
g) Easy propagation (…………………….……..) h) Agronomical integration (..…)

i) Others (…………………………………………………………..)

…………………..………

Participant's signature

# Photo plates






A= Conducting meeting, B= Resource map preparation, C= Key informant interview, D= Questionnaire survey, E= Sample collection, F=Taking photographs, G= Oil extraction from Soxhlet apparatus, H=Using Rotatory evaporator