# LIGNOCELLULOSIC RESIDUES FROM AGRICULTURAL FIELD AND AGRO-BASED INDUSTRIES AS POTENTIAL SOURCE OF BIOETHANOL

**A Dissertation Submitted to**

**Central Department of Botany, Tribhuvan University**

**Kirtipur, Kathmandu, Nepal**

**For the Partial Fulfillment of the Requirements for Master of Science in Botany**


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**August, 2013**

## RECOMMENDATION

This is to certify that the dissertation entitled **"Lignocellulosic Residue from Agricultural Field and Agro-Based Industries as Potential Source of Bioethanol"** submitted by Mr. Rupesh Kumar Yadawa has been carried out under my supervision. The entire work is based on the information collected by him in the field as well as in the laboratory and the results have not been submitted for any other degree. I recommend this dissertation work to be accepted as a partial fulfillment of Master of Science in Botany (Plant Pathology and Applied Mycology).

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## LETTER OF APPROVAL

This dissertation entitled **"Lignocellulosic Residue from Agricultural Field and Agro-Based Industries as Potential Source of Bioethanol"** submitted at the Central Department of Botany, Tribhuvan University by Mr. Rupesh Kumar Yadawa has been accepted for the partial fulfillment of requirements for Master of Science in Botany (Plant Pathology and Applied Mycology).

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**ACKNOWLEDGEMENTS**

I express my sincere gratitude to my research supervisor Dr. Chandra Prasad Pokhrel for his constant guidance, invaluable suggestions, regular encouragement, throughout research period which made this study successful.

I am grateful to Prof. Dr. Pramod Kumar Jha, Head of Central Department of Botany providing laboratory facilities and administrative help throughout research period.

I am also deeply indebted to Associate Prof. Dr. Ramkailash Prasad Yadav, for his constant encouragement for completion of this study.

I would also not forget to acknowledge all the faculty members including administrative staffs of Central Department of Botany for their kind help and encouragement during research period.

I am also thankful to Mr. Dharma Bhakta Thapa (Chemist of Himalayan Brewery, Lalitpur) for providing the necessary raw material for my research work.

My specials thank goes to Cornell-Nepal study programme (CNSP) and U.G.C for their financial support to enable me to complete this work.

I am thankful to my friends Arbindra Timilsina, Sumant Kumar Yadav, Pinky Pandey, Sanjay Pandey, and Pradeep Yadav for their support during preparation of this manuscript.

Finally, I am indebted to my family members for their continuous support and encouragement for the completion my master's degree.

Rupesh Kumar Yadav

August, 2013

**ABSTRACT**

This study explores the potential of lignocellulosic biomass as a renewable source of energy and a possible alternative to fossil fuel. Nepal being agriculture based country, this study intends to identify the possible utilization of different forms/types of locally available agricultural wastes and agro based industrial waste as potential feedstock to biofuel (bio-ethanol). The study assesses implementation different types of agro/industrial lignocelluloses waste (beer factory, tobacco factory, and agricultural field) for ethanol production, economic opportunities for the national economy, and potential to reduce greenhouse gas emissions. The prime focus of this study was to record organic wastes as potential feedstock for bioethanol production, to estimate the biomass of those organic wastes (only lignocellulosic residue), to assess the opportunities for income generation through new jobs, new markets related to bioethanol production and to review the biofuel policy and legal provisions in Nepal. The study was carried out in two agro-based industries (Surya Nepal and Himalayan Brewery) chosen by simple random sampling and one cultivated field (Viruwa Guthi V.D.C, Parsa) was purposively chosen. The required data was collected through researcher-developed questionnaire and the obtained fresh biomass was set to dry in laboratory to estimate enthanol production from the dry biomass. The estimated bioethanol production from 18,825.885 Kg/yr dry biomass of tobacco was 5.836024 Kl/yr and the estimated bioethanol production from 866400 Kg/yr dry biomass of beer waste was 63.5744 Kl/yr It was concluded that among agro-industrial residue Himalyan brewery has the highest potential of producing bioethanol while the residue from Surya Nepal Tobacco Factory has the least potential of producing bioethanol. Nepal is far behind the reality of implementing the existing biofuel policy.

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| AEPC | : Alternative Energy Promotion Centre |
| CBOs | : Community Based Organizations |
| CGW | : Cotton Gin Waste |
| Dg | : Decigram |
| Fig | : Figure |
| FR | : Furfural Residue |
| FPU | : Floating Point Unit |
| G | : Gram |
| GHG | : Green House Gases |
| Gl | : Gigaliter |
| GDP | : Gross Domestic Product |
| ha | : Hectare |
| HPLC | : High Performance Liquid Chromatography |
| hr | : Hour |
| INGOs | : International Non Governmental Organization |
| Kg | : Kilogram |
| Kl | : Kiloliter |
| L | : Liter |
| Ltd | : Limited |
| LDCs | : Least Development Countries |
| Mg | : Milligram |
| MSW | : Municipal Solid Waste |

NGOs : Non Governmental organization

NMMO : N-methylemorpholine-N-oxide

Pg : Petagram

Pvt : Private

PIS : Private Irrigation System

SSCF : Simultaneous Saccharification and Cofermentation

Tg : Terragram

USCB : United States Census Bureau

UNDP : United Nations Development Programme

UNDESA : United Nations Department of Economic and Social Affairs

VDC : Village Development Committee

VDK : Vicinal Diketone

WEC : World Energy Council

Yr : Year

# CHAPTER I

# INTRODUCTION

## 1.1 Background

Rising energy consumption, depletion of fossil fuels and increased environmental concerns has shifted the focus of energy generation towards biofuel use. Based on World Energy Council (WEC) calculations, the world-wide primary energy consumption is approximately 12 billion tone coal equivalent per year. The world population is estimated to increases from 6.7 billion to 8 billion by 2030 (USCB, 2008). United Nations calculations have shown that the world's population will increase to about 10 billion people by 2050 which will in turn increase energy demands to at least 24 billion tone coal equivalent per year (twice of what we consume today) depending on economic, social and political developments.

Lignocellulose is a renewable organic material and is the major structural component of all plants. Lignocellulose consists of three major components: cellulose, hemicellulose and lignin. In addition, small amounts of other materials such as ash, proteins and pectin can be found in lignocellulosic residues, in different degrees based on the source cellulose ($C_6H_{10}O_5$), Cellulose is the major constituent, comprising roughly 50% weight of all plant material and the most abundant organic molecule on the earth, is a linear biopolymer of anhydroglucopyranose-molecules, connected by β-1,4-glycosidic bonds. The degree of polymerization and crystallinity of cellulose varies from species to species and this is shown to have a significant impact on hydrolytic process (Zhang et al., 2004). Cellulose is insoluble in water and in neutral organic solvents such as alcohol, petrol, benzene, ether, etc. but it will however dissolve in sulphuric and hydrochloric acids. Hemicelluloses ($C_5H_8O_4$), the second most abundant component of lignocellulosic biomass, are heterogeneous polymers that are comprised of simple sugar molecules. They differ from celluloses in that they yield several types of sugar when reacted with acids. Hemicellulose is less complex, its concentration in lignocellulosic biomass is 25 to 35% and it is easily hydrolysable to fermentable sugars (Saha et al., 2007). Hemicellulose is a heteropoly saccharide composed of pentoses, hexoses and sugar acids. Softwood hemicellulose mainly contains mannose as a major constituent whereas hardwoods mainly contain Xylans (Balan et al., 2009). Composition of hemicelluloses is very variable in nature and depends on the plant source, Lignin ($C_9H_{10}O_3$ ($OCH_3$) 0.9-1.7), the next largest component by weight. The lignin content can vary from species to species. Softwoods contain around 23-33% lignin whereas hardwood species can have from 16-25% content. Lignin exists largely as an intercellular material. It has a three dimensional structure. Lignin has a high-energy content. Lignin acts as cementing agent and an impermeable barrier for enzymatic attack (Howard et al., 2003). Lignin provides plants with the structural support and impermeability as a barrier for any solutions or enzymes by linking to both hemicelluloses and cellulose and prevents penetration of lignocellulolytic enzymes to the interior lignocellulosic structure they need as well as resistance against microbial attack and oxidative stress. These properties of lignin may be attributed to its amorphous nature, water insolubility and optical inactivity. The later properties also make it tough to degrade it (Fengel and Wegener, 1984). It can be used as a fuel in the paper industry.

Lignocellulosic material constitutes the world’s largest bioethanol renewable resource. In the U.S. alone the production of biomass from lignocellulosic materials is estimated to be nearly 1.4 billion dry tons per year, 30% originating from forest biomass. There are several groups of raw materials that are differentiated by their origin, composition and structure. The Iogen Corporation in Canada is the world's leading operating plant for bioethanol production from lignocellulosic residues, and uses up to 30 tonnes per day of wheat, oat and barley straw to produce up to 0.52 million gallons of ethanol per year. Ethanol can be a substitute to mitigate the problems associated with the rising energy demands across the world as well as a way to reduce green house gas emissions to an extent of 85% (Perlack et al., 2005). Ethanol may be produced either from petroleum products or from biomass. Today, most of the ethanol produced comes from renewable resources. Although currently most of the ethanol produced from renewable resources comes from sugarcane and starchy grains, significant efforts are being made to produce ethanol from lignocellulosic biomass (almost 50% of all biomass in the biosphere) such as agriculture residues (Bothast & Saha, 1997). The technological advances in recent years are promising to produce ethanol at low cost from lignocellulosic biomass. On the other hand, global oil production is expected to decline from 25 billion barrels to 5 billion barrels by 2050 (Campbell & Laherree, 1998). Thus the energy demands of the future are likely to play a key role in geo-political economics. Given this reality, nations around the world are investing in alternative sources of energy, including bioethanol. The leading nations in bioethanol production are Brazil and the USA and USA is the world's largest producer of bioethanol (Carere et al., 2008). Asian countries altogether account for about 14% of world's bioethanol production

*1.1.1 Pathways of Bioethanol Production from Cellulosic Feedstocks*

The majority of today's ethanol is produced via fermentation of agricultural resources. Ethanol produced by chemical synthesis is only done by a handful of companies in the world and it is ethanol sourced from renewable sources that has really driven growth. Total global demand for ethanol is well over one million barrels per day.

Lignocellulosic biomass can be transformed into bioethanol via two different approaches, (i.e. biochemical or thermochemical conversion). Both routes involve degradation of the recalcitrant cell wall structure of lignocellulose into fragments of lignin, hemicellulose and cellulose. Each polysaccharide is hydrolyzed into sugars that are converted into bioethanol subsequent followed by a purification process. However, these conversion routes do not fundamentally follow similar techniques or pathways. The thermo chemical process includes gasification of raw material at a high temperature of 800 $^{o}$C followed by a catalytic reaction. Application of high levels of heat converts raw material into synthesis gas (syngas) such as hydrogen, carbon monoxide and $CO_2$. In the presence of catalysts, the resulting syngas can be utilized by the microorganism *Clostridium ljungdahlii* to form ethanol and water can be further separated by distillation. Unlike the thermo chemical route, biochemical conversion involves physical (i.e. size reduction) or/and thermo-chemical with possible biological pretreatment.

Biochemical pretreatment is mainly used to overcome recalcitrant material and increase surface area to optimize cellulose accessibility to celluloses. The upstream operation is followed by enzymatic or acidic hydrolysis of cellulosic materials (cellulolysis) and conversion of hemicelluloses into nonnumeric free sugars (saccharification) subsequent to biological fermentation where sugars are fermented into ethanol and then purified via distillation. Concurrently, lignin, the most recalcitrant material of cell walls is combusted and converted into electricity and heat. Overall, biochemical approaches include four unit-operations namely, pretreatment, hydrolysis, fermentation and distillation. Currently the biochemical route is the most commonly used process adapted from (Ladisch et al, 2005) provides a flow diagram illustrating the major steps involved in biochemical process with lignin co product recovery for a self-sufficient energy system.

Ground cover by residues, instead of 30%, is recommended due to uncertainties of local situation (Kim & Dale, 2004).

### *1.1.2 Current Status of Biogas in Nepal*

Biogas energy is emerging as the major contributor in the current renewable energy resources development; it is a simple, reliable and cost effective solution to provide energy security to rural households in developing countries such as Nepal and to mitigate greenhouse gas emissions.

Biogas is a mixture of methane and carbon dioxide, produced by the breakdown of organic waste by bacteria without oxygen (anaerobic digestion). The majority of GHG emissions in Nepal are derived from the unsustainable use of traditional biomass and the associated deforestation for rural household energy applications for cooking and heating. The potential of biogas technology to provide energy security and reduce GHG emissions, it is crucial to assess the potential for decreasing the overall cost and increasing efficiency of biogas systems for its wider replication.

By mid of July 2011, Nepal has some 260,000 household size bio-gas plants constructed in all 75 districts of Nepal. There are over 300 institutional and some 90 community plants of size as big as 75 cubic meters. Over 260 micro finance institutions are providing credit to biogas users. Hundreds of NGOs, CBOs, Cooperative, etc. are involved in one way or another. BSP, therefore, has also been the most successful rural development programme in partnership among the government, donors, the private sector, NGOs, CBOs and civil society members. The annual household size biogas plant construction has reached around 20,000 per annum with a jump from around 16,000 until around 3 years ago. Recent Annual Biogas Users' Surveys report that 94% to 98% of the household size plants constructed under

BSP are operating, albeit sometimes with lower level of feeding and gas production. Latest two Biogas Users' Surveys of 2008/09 and 2009/10 for plants constructed in 2004 and 2005 reported that 91 to 94% of the users are satisfied with the performance (Sharestha & Huebsch, July, 2011).

The processing of lignocellulosic materials in modern bio-refineries will allow for the production of transport fuels. This research has involved the collection, estimation, and the analysis, with a high level of precision and accuracy, of biomass samples from the agro based industries and agricultural sectors. However, the waste beer waste and tobacco waste that has a chemical composition that could result in high bio-refinery yields and so could make a significant contribution to Nepal's biofuel demands.

### 1.2 Objectives

- To record organic wastes as potential feedstock for bioethanol production.
- To estimate the biomass of those organic wastes (only lignocellulosic residue).
- To review the biofuel policy and legal provisions in Nepal.

### 1.3 Hypotheses

- Organic biomass residues from Beer and Cigarette (tobacco) factories as well as residues from tobacco fields have high potential for bioethanol production.
- Biomass residue from Beer factory has greater potential for bioethanol production than that of Cigarette (tobacco) factory.

### 1.4 Limitations of the study

- There are several agro-based industries in Nepal, but due to time and resource constraints, only two industries were taken for the study.
- The direct access to the fresh biomass from the industries was not provided to the investigator by the industries administrators that may results certain level of error in actual estimation of bioethanol.

### 1.4 Justification

We live in a society with a throw away attitude which often chooses in many cases to ignore the potential that is all around it. Particularly in the case of agriculture, there can be considerable damage to the environment which is already being continually put under increasing stress by waste. Furthermore it is often quite expensive to dispose of these wastes this is not to mention the economic loss of not exploiting them properly. In view of continuously rising petroleum costs and dependence on fossil fuel resources, the outcome of this dissertation could be utilized to solve the present problem of energy crisis in Nepal has compelled to use alternative energy resource to some extent, thus we need give emphasize more on alternative energy resource, which reduce fossils fuel and green house gases. Hence production of bioethanol could be the route to the effective utilization of agricultural, industrial, herbaceous and municipal solid wastes (MSW) being considered the bioethanol feedstocks with the most potential.

# CHAPTER II

# LITERATURE REVIEW

Goshadrou et al. (2013) investigated, Birch wood was pre-treated with N-methylmorpholine-N-oxide (NMMO or NMO) followed by enzymatic hydrolysis and fermentation to ethanol or digestion to biogas. Enzymatic hydrolysis of the untreated wood resulted in 8%-10% of theoretical glucose yield after 4 days hydrolysis, while the NMMO pretreatment improved this yield to 91%. Consequently, ethanol production yield NMMO-pretreated materials, around 9- fold improvement compared to the untreated wood. On the other hand, drying of the pretreated wood had a negative impact and decreased the yield of enzymatic hydrolysis by 4%-10%. Digestion of the untreated wood with thermophilic bacteria resulted in the maximum methane yield of 158 $cm^3$ g-1 of VS in 30 days, while the NMMO pretreatment improved the methane yield up to 232 $cm^3$ g-1 of VS (80% of the theoretical biogas yield) in just 9 days.

Teghammar et al. (2013) experimented Softwood spruce (chips and milled), rice straw and triticale (a hybrid of rye and wheat) straw, were pretreated with N-methyl morpholine-N-oxide (NMMO or NMO) prior to anaerobic digestion to produce biogas. The pretreatments were performed at 130 degrees C for 1-15 h, and the digestions continued for six weeks. The digestions of untreated chips (10 mm) and milled (<1 mm) spruce, rice straw and triticale straw resulted in 11, 66, 22 and 30 Nml $CH_4$/g raw material. However, the pretreatments have improved these methane yields by 400-1200%. The best digestion results of the pretreated chips and milled spruce, rice straw and triticale straw were 125, 245, 157 and 203 Nml $CH_4$/dg raw material (or 202, 395, 328 and 362 Nml $CH_4$/g carbohydrates) respectively, which correspond to 49, 95, 79 and 87% of the theoretical yield of 415 Nml $CH_4$/g carbohydrates.

Nibedita et al. (2012) reviewed and discussed about bioethanol from agricultural waste could be a promising technology though the process has several challenges and limitations such as biomass transport and handling, and efficient pretreatment methods for total delignification of lignocellulosics. Conversion of glucose as well as xylose to ethanol needs some new fermentation technologies, to make the whole process cost effective.

Daianova (2011) Studied regional transport fuel supply by considering local small scale ethanol production from straw. It presents the results of investigations of regional transport fuel supply with respect to minimizing regional $CO_2$ emissions, estimates for transport fuel supply, and the availability of lignocellulosic resources for small scale ethanol production. Regional transport fuel demand between the present and 2020 is also estimated. The results presented here show that significant bioethanol can be produced from the straw and *Salix* available in the studied regions and that this is sufficient to meet the regions' current ethanol fuel demand.

Kuila, Mukhopadhya, and Banerjee (2011) investigated the effect of enzymatic pretreatment on *Lantana camara* for improved yield of reducing sugar and bioethanol production. An optimum enzymatic delignification (88.79 %) was achieved after 8 hr of incubation. After delignification the substrate was further treated with the mixture of carbohydratases for appropriate saccharification. The enzyme treated substrate yielded maximum reducing sugar (713.33 mg/g dry substrate) after 9 hr of saccharification. Monosaccharide content in the saccharified samples was quantified using high performance liquid chromatography (HPLC) system. Using conventional yeast strain, 9.63 g/L bioethanol was produced from saccharified samples of *Lantana camara*.

Tang et al. (2011) reported the use of simultaneous saccharification and cofermentation (SSCF) of lignocellulosic residues from commercial furfural production (furfural residue, FR) and corn kernels to compare different nutritional media. The final ethanol concentration, yield, number of live yeast cells, and yeast-cell death ratio were investigated to evaluate the effectiveness of integrating cellulosic and starch ethanol.

Wiens et al. (2011) reviewed The growth of this industry has important implications for biodiversity, the effects of which depend largely on which biofuel feedstocks are being grown and the spatial extent and landscape pattern of land requirements for growing these feedstocks. Current biofuel production occurs largely on croplands that have long been in agricultural production. The additional land area required for future biofuels production can be met in part by reclaiming reserve or abandoned croplands and by extending cropping into lands formerly deemed marginal for agriculture.

Khatiwada (2010) discussed the production potential of bioethanol. Concerns relating to the fuel vs. food debate, energy security, and air pollution. the sustainability paradigm of bioethanol production, with regard to environmental stewardship, economic prosperity, and social integrity is dealt with in relation to one of the world's least developed countries (LDCs), Nepal and also important to analyzed the sustainability criteria of the renewable bioenergy systems when LDCs are living with energy and food poverty and myriad resource pressures, whilst endeavoring to sustain their livelihoods and achieve the goals of sustainable development.

Leung (2010) investigated and evaluate the efficiencies of oxygen delignification, the pretreatment used, and enzymatic hydrolysis, the compositions (lignin, pentose and hexose) of the substrates that were not pretreated and pretreated at different temperatures were determined by acid hydrolysis. By comparing the lignin contents of non-pretreated substrates from acid hydrolysis to those that were reported in literature, they are out of range. Therefore, all the lignin contents determined from acid hydrolysis will not be used for any calculation. However, these lignin values have indicated that oxygen delignification is effective on switch grass, grass and pulp mill clarifier sludge since their lignin contents reduced when the substrates are pretreated. Although oxygen delignification is not as effective for cardboard, the non-pretreated cardboard that was hydrolyzed at 10 g dry substrate/L and 40 FPU/g dry substrate has the highest sugar yield (6.12 g sugar/10 g dry substrate) among all substrates tested in all pretreatment and hydrolysis conditions. After the hydrolysate obtained from the hydrolysis of cardboard was subjected to fermentation, it has an ethanol yield of 0.32 gram of ethanol per each gram of sugar.

Arredondo et al. (2009) analyzed according to the biomass used as feedstock: banana pulp, banana fruit, hanging cluster or banana skin. Based on the energy concept, performance indicators are proposed and calculated. In order to quantify the renewability of the ethanol production processes, a new indicator called "Renewability Performance Indicator". The results show that when amilaceous material is used, better results than lignocellulosic material are obtained and four production processes studied must be classified as non-renewable.

Shi et al. (2009) reported increasing trends of MSW generation, and waste biomass-derived cellulosic ethanol potentials in relation to socio-economic development across 173 countries, and show that globally, up to 82.9 billion litres of waste paper-derived cellulosic ethanol can be produced worldwide, replacing 5.36% of gasoline consumption, with accompanying GHG emissions savings of between 29.2% and 86.1%.

Balat et al. (2008) reviewed the Production of ethanol (bioethanol) from biomass is one way to reduce both consumption of crude oil and environmental pollution. Bioethanol can be produced from cellulosic feedstocks. One major problem with bioethanol production is the availability of raw materials for the production. The availability of feedstocks for bioethanol can vary considerably from season to season depends on geographic locations. Lignocellulosic biomass is the most promising feedstock considering its great availability and low cost. Conversion technologies for producing bioethanol from cellulosic biomass resources such as forest materials, agricultural residue and urban wastes are under development and have not yet been demonstrated commercially. For designing fuel bioethanol production processes, assessment of utilization of different feedstocks (i.e. sucrose containing, starchy materials, lignocellloic biomass) is required considering the big share of raw materials in bioethnol costs.

Goldemberg et al. (2008) discussed the sustainability of ethanol production from sugarcane, considering air quality improvement, rural development, biodiversity, deforestation, soil degradation, water source contamination, food vs. fuel production, and labour conditions in the fields.

Li and Khraisheh (2008) examined the possibility of replacing the conventional biomass with biodegradable municipal solid waste. The experimental results had shown that more than 90% of the cellulose from the waste can be converted to glucose which can be easily fermented to ethanol production. They also discussed about the potential impacts on related environmental issues, such as sustainable waste management, climate change, water issues, land use and biodiversity.

Mitchell (2008) Estimated and clearly point to the fact that first generation ethanol production process can not sufficiently provide the global energy needs. Therefore, second generation processes to produce bioethanol are gaining momentum. The second generation processes will use lignocellulosic materials for this purpose and biosphere clearly has sufficient supplies of lignocellulosic materials. The production of ethanol from lignocellulosic biomass such as corn stover, wheat straw, sugarcane bagasse, beer waste, tobacco waste, rice straw, rice hull, corn cob, oat hull, corn fiber, woodchips and cotton stalk; energy crops like switch grass and various weeds such as *Saccharum spontaneum, Lantana camara, Eichhornia crassipes* (water hyacinth).

Pokhrel et al. (2008) discussed about food security and cost-effective conversion of biomass technologies the most common renewable fuel today is ethanol de rived from corn grain (starch) and sugar cane (sucrose). It is expected that there will be limits to the supply of these raw materials in the near future as well as these are directly associated with food security. Therefore, lignocellulosic biomass is seen as an attractive alternative feedstock for the future supplies of bioethanol. About 491 GL of bioethanol might be produced from the wasted crops and their associated lignocelllosic raw materials, about 16 times higher than the current world ethanol production (31 Gl).

Tekle (2008) worked in bio-ethanol production and use for transport fuel in Ethiopia, focusing on current status and potential, barriers, implications and recommendations for a sustainable market. The need for such research is justified as it paves the way for bio-ethanol development in Ethiopia towards a more sustainable path as challenges are surmounted. The result indicates that technical and economic as well as issues related to policies and regulations are main factors for hindering the progress of the bio-ethanol use and production expansion in Ethiopia.

Prasad et al. (2007) reviewed the potentiality of sugar crops, agro and urban/industrial residues feedstocks for production of ethanol as an alternative fuel and energy sources, which is renewable, sustainable, efficient, and safe for environment. The cost of ethanol production from lignocellulosic material is relatively high based on current technologies, and the main challenges are to lowyield and high cost of hydrolysis. There is need of process optimization for detoxification and maximize conversion of agro and urban/industrial residues feedstocks for production of ethanol as a cheaper substrate like molasses and other directly fermentable materials.

UNDESA (2007) has also discussed the technical, socio-economic, and environmental benefits of small scale biofuel production as a means of promoting sustainable development in sub-Saharan Africa, focusing on the poor's access to energy, the reduction of oil imports, income generation, rural development and the improvement of local environmental pollution.

Versteeg (2007) has evaluated the environmental sustainability of sugarcane bioethanol production in Fiji, a small island developing state in the Pacific, estimating reductions in life cycle GHG emissions, net energy balances, and ecological footprints in the context of sustainable development.

According to Agblevor et al. (2005), about 17.1 million bales of cotton were ginned in the United States and the estimated cotton gin waste was 2.25×109 kg. The disposal of cotton gin waste (CGW) is a significant problem in the cotton ginning industry, but CGW could be potentially used as feedstock for bioethanol production.

Sakamoto (2004) reviewed the financial feasibility analysis of municipal solid waste to ethanol conversion. He discussed the trends in MSW generation, composition and disposal practices, and evaluates the aggregate and regional potential of MSW as a feedstock.

The most widely used biofuels is bioethanol which is mainly produced from agricultural products such as sugarcane, corn, wheat and beets. From sugarcane over 60% bioethanol is produced and 40% from other crops. Wheat straw is the next most important feedstock for bioethanol production in Europe (Kim, 2003).

McKendry (2002) reviewed the background to biomass production (in a European climate), energy conversion technologies and particular gasification technologies and their potential for biomass gasification. The use of renewable energy sources is becoming increasingly necessary, if we are to achieve the changes required to address the impacts of global warming. Biomass is the most common form of renewable energy, widely used in the third world but until recently, less so in the Western world. Latterly much attention has been focused on identifying suitable biomass species, which can provide high-energy outputs, to replace conventional fossil fuel energy sources. The type of biomass required is largely determined by the energy conversion process and the form in which the energy is required. The production of a gaseous fuel to supplement the gas derived from the land filling of organic wastes (landfill gas) and used in gas engines to generate electricity.

Sun and Cheng (2002) reviewed Lignocellulosic biomass can be utilized to produce ethanol, a promising alternative energy source for the limited crude oil. There are mainly two processes involved in the conversion: hydrolysis of cellulose in the lignocellulosic biomass to produce reducing sugars, and fermentation of the sugars to ethanol. The cost of ethanol production from lignocellulosic materials is relatively high based on current technologies, and the main challenges are the low yield and high cost of the hydrolysis process.

Renewable resources are more evenly distributed than fossil and nuclear resources, and energy flows from renewable resources are more than three orders of magnitude higher than current global energy use. Today’s energy system is unsustainable because of equity issues as well as environmental, economic, a geopolitical concerns that have implications far into the future (UNDP, 2000).

Wyman (1999) analyzed Biomass ethanol is a versatile fuel and fuel additive that can provide exceptional environmental, economic, and strategic benefits of global proportions. Bioethanol can play a particularly powerful role in the quest to reduce greenhouse gas emissions that will be difficult for any other transportation fuel options to match. Because of the widespread abundance of biomass, bioethanol can also be invaluable for meeting the growing international demand for fuels by developing nations as well as enhancing the energy security of developed countries.

Renkow and Rubin (1998) surveyed 19 MSW composting facilities around the United States. Results indicate that MSW composting generally costs around $50 per ton, and that very few facilities receive any revenues from the sale of compost to offset operating costs. Additional economic analysis indicates that. At present, MSW composting cannot be justified on financial grounds in most parts of the US, but may be competitive with land disposal where the cost of land filling is high.

Razin (n.d.) studied current biofuel situation (Bioethanol in Sweden) and (Biodiesel in Netherlands), similarities and dissimilarities between these two countries which country is more advanced about the concern of sustainable biofuel production countries, Huge amount of fossil fuels has been using by the industries for biofuel production, which is the main cause of increasing the concentrations of substance extracted from earth's crust and also the green house gas emissions. Between Sweden and the Netherlands, it shows that the Netherlands depends heavily on fossil fuels to produce biofuels, while Sweden uses agricultural by products and other renewable energies to produce biofuels.

Biofuels can be developed to enhance their coexistence with biodiversity. Landscape heterogeneity can be improved by interspersion of land uses, which is easier around facilities with smaller or more varied feedstock demands. The development of biofuel feedstocks that yield high net energy returns with minimal carbon debts or that do not require additional land for production, such as residues and wastes, should be encouraged. Competing land uses, including both biofuel production and biodiversity protection, should be subjected to comprehensive cost-benefit analysis, so that incentives can be directed where they will do the most good.

# CHAPTER III

# MATERIALS AND METHODS

## 3.1 Study Sites (Industries)

For study on organic residues produced from agro-based industries and their potentiality for bioethanol production, two types of industries and agricultural field of tobacco using raw materials sources of lignocellulosic residues. The industries were chosen based on their accessibility. The details of the industries (Table 3.1) are given below.

**Table 3.1: Studied Industries /Agricultural Field and Their Location**

| S. N. | Name of Industry/Field survey | Location |
|---|---|---|
| 1 | Surya Nepal Pvt. Ltd. | Simara, Bara. |
| 2 | Himalayan Brewery Pvt. Ltd. | Godawari, Lalitpur. |
| 3 | Agricultural field of tobacco | Viruwa Guthi V.D.C, Parsa |

*Sources: Field Survey, 2013*

### *3.1.1 Surya Nepal Pvt. Ltd., Simara, Bara*

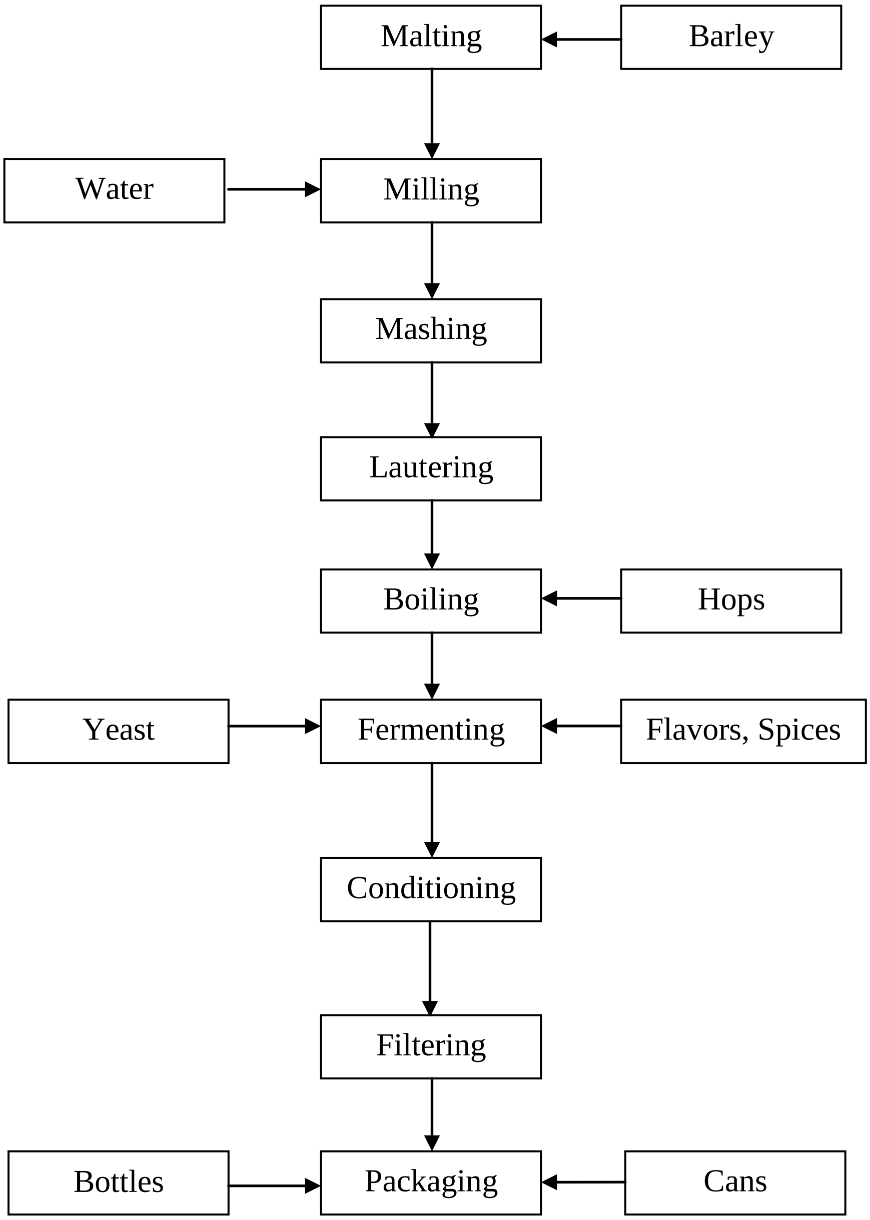
Surya Nepal Private Limited is an Indo-Nepal-UK joint venture, which started operations in Nepal in 1986. Surya Nepal is now the largest private sector enterprise in Nepal and a subsidiary of ITC Limited, India. It plays important role in manufacturing and marketing of cigarettes in Nepal. It operates round the year. Currently it uses about 5000 tons of raw materials (tobacco leafs) to manufacture cigarettes. The residue left after manufacturing cigarettes is used to generate biogas which is used in office canteen.

### *3.1.2 Himalayan Brewery Ltd., Lalitpur*

Himalayan Brewery Ltd. was established in 1980. HBL signed a joint venture and technical agreement with the pioneer Indian Brewer, Mohan Meakin Ltd.

Construction of the brewery commenced in early 1982. The first brew was produced on December 18, 1982. Regular beer production started from February 2, 1983 under the Mohan Meakin's technical supervision. Iceberg Premium Beer is hygienically brewed with pristine natural spring water and special blend of imported Australian and European malts flavored with selected German and Czech hops. It is carefully matured to develop its distinct full-bodied smoky flavor. Barley, broken rice, sugar, herbs, water, and some natural additive are used as raw material for production of beer. Malt is directly brought from India because technology of malting in not available in Nepal.

**Figure 3.1: The Process of Production of Brewing Beer**



*Malting:* To loosen up the endosperm by degrading the endosperm cell walls and to produce enzyme for the further degradation of the content of endosperm cell during mashing

*Milling*: To provide for optimal conditions for enzymatic activities during mashing for solubilation of fermentable carbohydrates and provide for best possible mash separation thus highest possible yield

*Mashing:* To form an extract with a desired profile of sugars, desired level of protein and minor chemical constituents.

*Lautering:* To separate the wort from spent grain (malt husk)

*Boiling:* To sterilize wort, halting enzyme action, concentrate wort, isomerizes hop alpha acid into iso-alpha acid, reduce volatile compound (such as DMS), increase wort color, reduce wort pH, protein coagulate and to produce reducing compounds.

*Cooling:* To cooling down wort temperature to fermentation temp such as from 100$^{o}$C to 14 $^{o}$C

*Fermenting:* To convert fermentable sugar to ethanol, carbon dioxide and beer flavors

*Maturation:* To improve/remove unpleasant flavors such as diacetyle (VDK), acetaldehyde, DMS, amylacetate etc

*Filtering:* To make bright beer (gives beer its polished shine and brilliance) and more stable

*Packaging:* To putting the beer into the containers in which it will leave the brewery

*3.1.3 Viruwa Guthi V.D.C Parsa*

Biruwa Guthi is a village development committee in Parsa District in the Narayani Zone of southern Nepal. According to 2011 Nepal census it had a population of 13,248 people living in 2,350 individual households. The major economy and livelihood sources are farming where about 80% of the total population depends on agriculture and livestock. Total income people are being generated from agriculture sector, especially tobacco farming.

## 3.2 Sampling

Sampling was done at two leading agro-based industries in Nepal. Information about issues related with cultivation of crops as raw materials for these industries and generation of biomass residues were taken from farmers and relevant stakeholders. Samples from industries were taken for three times during the month of Falgun (February to March) whereas crop growers were contacted once for tobacco growers. Data were collected from both primary and secondary sources.

## 3.3 Data collection

### *3.3.1 Data Collection from Primary Sources*

The total biomass (lignocellulosic residue) was estimated on the dry weight basis. For this, fresh samples from the target industries sources were brought to the laboratory. The types of residues both from industrial sources and agricultural fields are given in Table 3.2. Five samples were taken from each source at every sampling time. Each sample contained 100 g of the residues both from industry and from agricultural field from industries for beer; and from agricultural field for tobacco. Samples were carried in closed plastic bags to the laboratory. Each sample was placed in hot air oven at about $70^{o}$C. These dried samples were then weighted and their mass was recorded until there was a constant reading. The information about organic residues were also collected from different stakeholders such as industry owners, key informants (technicians in the industries) etc.

**Table 3.2: Types of Residues and Their Sources**

| **S.N.** | **Residue** | **Source Industries / Agricultural Field** |
|---|---|---|
| 1 | Not Provided | Surya Nepal Pvt. Ltd, Simra, Bara |
| 2 | Fresh biomass (beaten barley) | Himalyan Brewery, Godawari Lalitpur |
| 3 | Green stem of tobacco | Biruwa Guthi V.D.C, Parsa |

*Sources: Field Survey, 2013*

The information on other aspects of residues was collected from field study. Questionnaires and observation were carried out to obtain these data. Data on biomass residues remaining in the cultivated land was collected from farmers using questionnaire methods. The questionnaire is given in the Annex I.

#### *3.3.2 Data Collection from Secondary Sources*

Relevant literature/records were used to collect information on organic wastes. On the basis of reviewed sources, a checklist of organic wastes from target industries and agricultural field was prepared (Table 3.2). From the listed organic residues, the potential content of bioethanol in them was estimated using information from relevant literatures. The existing policies for bioethanol production and its use, legal provisions and their implementation status in Nepal were also reviewed.

### 3.4 Estimation of Bioethanol from Organic Residues

To estimate bioethanol production from (beer residue & tobacco residue) these organic residues, estimation done by Kim and Dale (2004) was taken as reference and total estimation of bioethanol from these organic residues were calculated accordingly. According to them if we use corn stover as comparable to tobacco, it contains 0.29 L ethanol per kg of dry biomass. It means that tobacco can yield 0.31 L of ethanol per Kg of dry biomass (8% of 0.29= 0.023; therefore, yield is 0.31 L/Kg dry mass).

### 3.5 Data Analysis

Data obtained from various sources were processed (preparation of matrix, editing, summarization etc.) and were presented in appropriate tabular/graphical forms. Comparison of results from different sources were made using analysis of variance (ANOVA) test.

# CHAPTER IV

# RESULTS

In order to estimate the dry biomass of residues coming from industries and/or from agricultural fields, samples were processed in the laboratory and the averaged dry biomass was used to estimate the total dry residues produced from that agro-based industry that can be used to produce bioethanol.

## 4.1 Lignocellulosic Residues from Cigarette (Tobacco) Industry

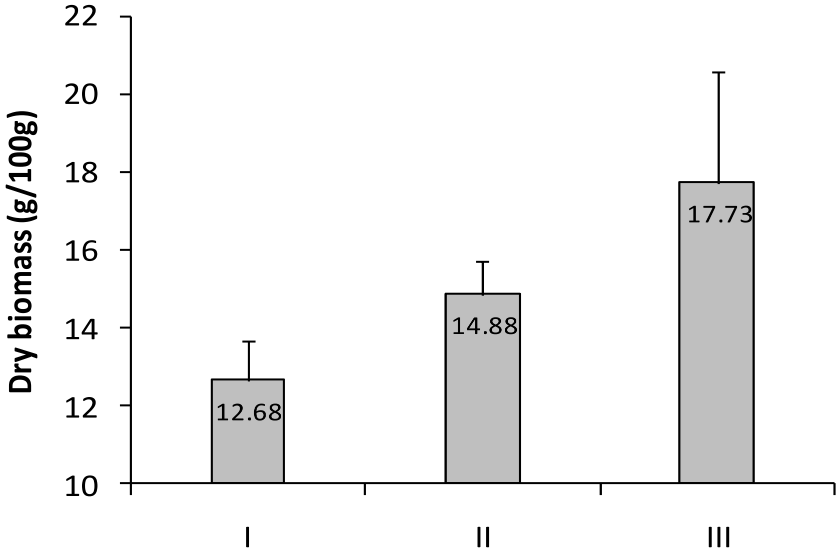



**Figure 4.1: Estimated Dry Biomass of Lignocellulosic Residues from Harvested Tobacco Crop for I, II and III Samplings**

(Columns represent average values with vertical bars as SD of the means, N=5)

The average values of dry biomass residues produced from the harvested tobacco crop varied from 12.68 to 17.73 g/100g of the fresh residues (Fig. 4.1). Higher dry biomass was obtained for the III sampling. Moreover, the dry biomass varied significantly ($p < 0.01$) among the sampling periods. The average dry biomass of all samples is 15.095 g/100g of the fresh residues which is used in the calculation of bioethanol content.

**Calculation of Potential Bioethanol Content**

Total fresh biomass produce from tobacco cultivated field = 65.883 Kg/ha

Total dry biomass produce from tobacco cultivated field = 15.095% of 65.883

= 9.945 Kg/ha

In Nepal, the total area of tobacco cultivation is = 1893 ha. (Statistical Information on Nepalese Agriculture 2011-2012, Gov. of Nepal, 2012)

So total dry residues that is produced from whole Nepal = 9.945* 1893 Kg

= 18,825.885 Kg/yr

Although there is no direct estimation of bioethanol production from dry biomass of tobacco, a US company based in Virginia is using genetically modified tobacco as a feedstock to produce both ethanol and biodiesel. It claims that one acre of tobacco can replace between eight to 12 acres of corn and soya.

(http://www.thebioenergysite.com/news/8706/producing-ethanol-and-biodiesel-from-tobacco, accessed on June 8, 2013)

If we use corn stover as comparable to tobacco, it contains 0.29 L ethanol/Kg dry biomass (Kim & Dale, 2004). It means that tobacco can yield 0.31 L of ethanol per Kg of dry biomass (8% of 0.29 = 0.023; therefore, yield is 0.31 L/Kg dry mass).

Now, total bioethanol that can be produced from dry tobacco residue from whole Nepal

= 18,825.885*0.31

= 5,836.024 L/yr

**= 5.836024 Kl/yr**

Total Fresh Biomass produce from Surya Nepal = 5000000 Kg/year

= 5000 ton/year

Important is the fact that fresh residues could not be obtained from Surya Nepal Pvt. Ltd., therefore dry biomass residues could not be calculated. Hence, estimation of potential bioethanol content in the residues from that industry was not calculated.

## 4.2 Lignocellulosic residues from beer industry

The average dry biomass residues produced at the beer industry vary from 17.03 to 18.62 g/100g of the fresh residues (Fig. 4.2). However, there is no significant variation ($p > 0.05$) in the dry biomass produced in this case. For all the samplings, the average dry biomass residues produced was 17.897 g/100g.

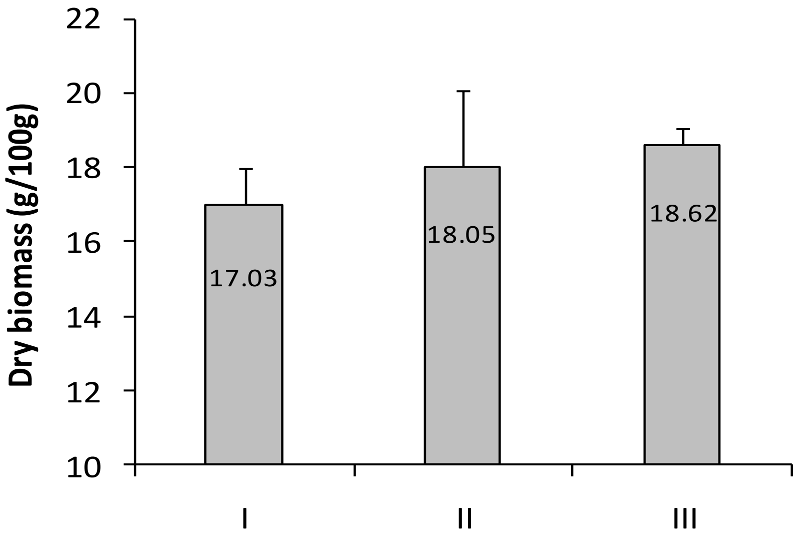



**Figure 4.2: Estimated Dry Biomass of Lignocellulosic Residues from Beer Industry for I, II and III Samplings.**

(Columns represent average values with vertical bars as SD of the means, N=5)

**Calculation of Potential Bioethanol Content**

| | |
|---|---|
| Total fresh biomass produce from the Himalayan Brewery | = 866400 Kg/yr |
| | = 866.4 ton/yr |
| Total dry biomass produce from the Himalayan Brewery | = 17.897% of 866.4 |
| | = 155.0596 ton/yr |
| So residues from Himalayan Brewery can produce | = 1155.0596*0.41 Kl of bioethanol per year |
| | **= 63.5744 Kl/year** |

The above results depict that the total bioethanol production from beer residue is 63.5744 Kl/year in Nepal which is significantly greater than the bioethanol production from tobacco residue which is 5.836024 Kl/year. This result is also in agreement with the hypothesis set already stated that residue from beer industry has greater potential for bioethanol production than tobacco residue.

### 4.3 Uses of Tobacco Residues

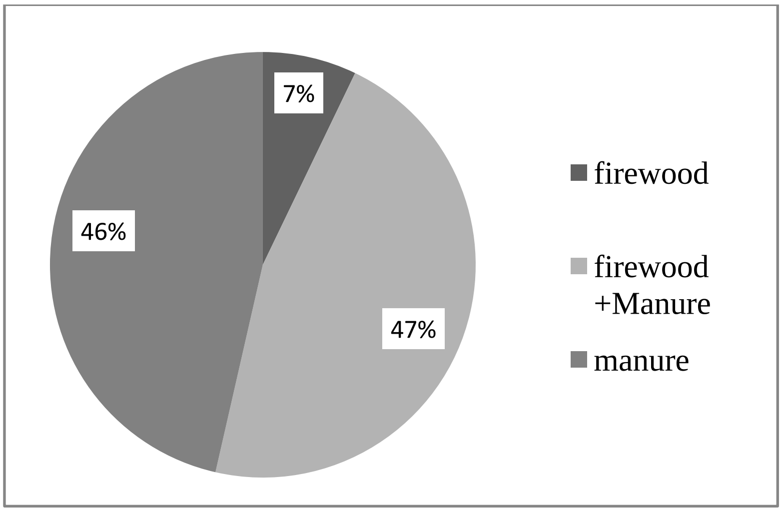



**Figure 4.3: Uses of Tobacco Residues by Farmers**

47% of the respondents use tobacco crop residue in the form of fire wood and manure followed by only manure (46%) and only 7% were found using crop residue as fire wood (Figure 4.3).

### 4.4 Agricultural Land Used for Tobacco Cultivation

Most of the farmers use to cultivate tobacco crop in their cultivated land. Almost three quarter (72%) of the respondents cultivate tobacco crops in more than half of their cultivated land as depicted in Figure 4.4.

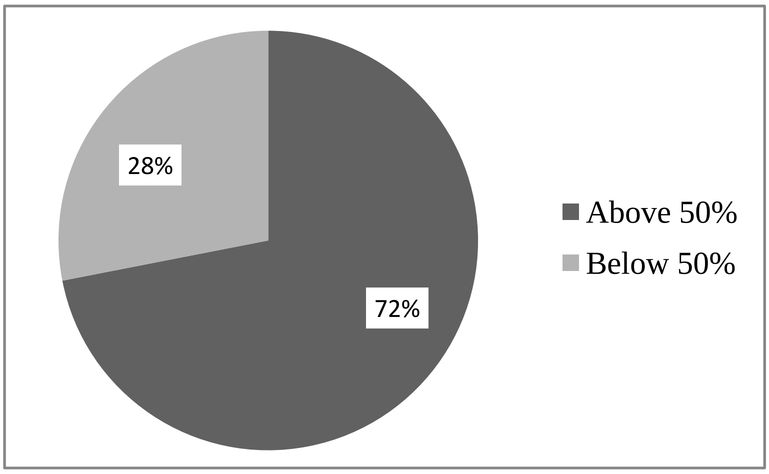



**Figure 4.4: Proportion of Respondent Using Their Land for Tobacco Cultivation**

### 4.5 Types of Fertilizer Used in Tobacco Cultivation

In case of tobacco cultivation, farmers use both organic manure and chemical fertilizer. However, of the total fertilizer amount, they use 51% manure followed by urea (Figure 4.5).

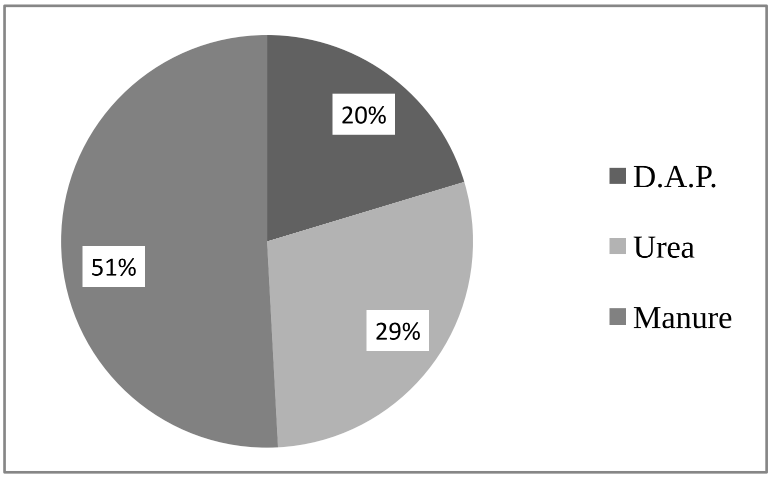



**Figure 4.5: Types of Fertilizer Used in Tobacco Cultivation**

### 4.6 Economic Improvement of Farmers Due to Tobacco Cultivation

Majority (80%) of the respondents were benefited with the cultivation of tobacco crops while 20% of the respondents didn't realize any improvement in their economic status.

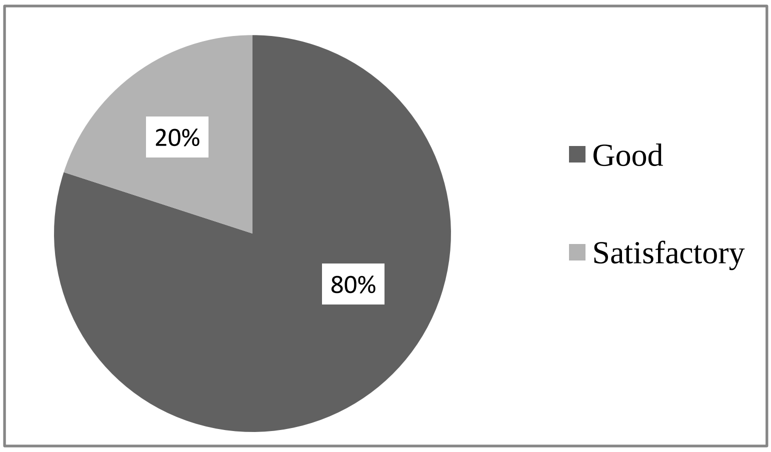



**Figure 4.6: Economic Improvement Due to Tobacco Cultivation**

### 4.7 Help from Any Organization

This chart show 87% people didn’t get organizational assistance in any form which needs to priorities by various NGOs/INGOs to empower Agricultural System.

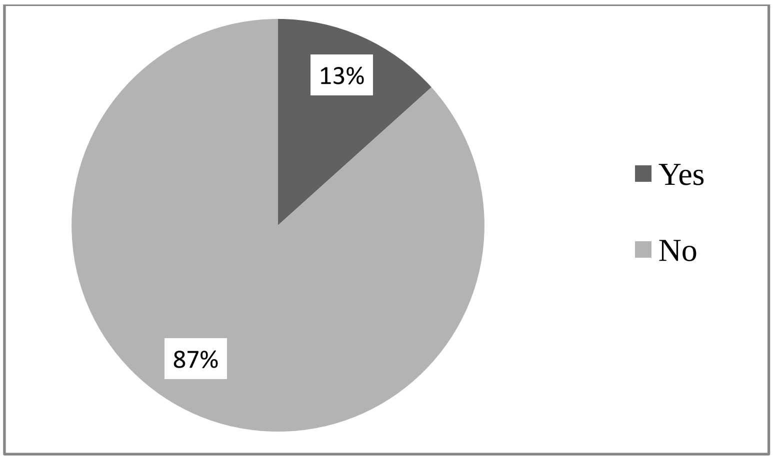



**Figure 4.7: Help from Any Organization**

### 4.8 Sources of Livelihood

Prominent livelihood of most of the People depends on agriculture. This Chart shows 87% people’s of livelihood depends on the farming and 13% People’s of livelihood depends on labour. This chart show that labour is the source of livelihood for the poor people.

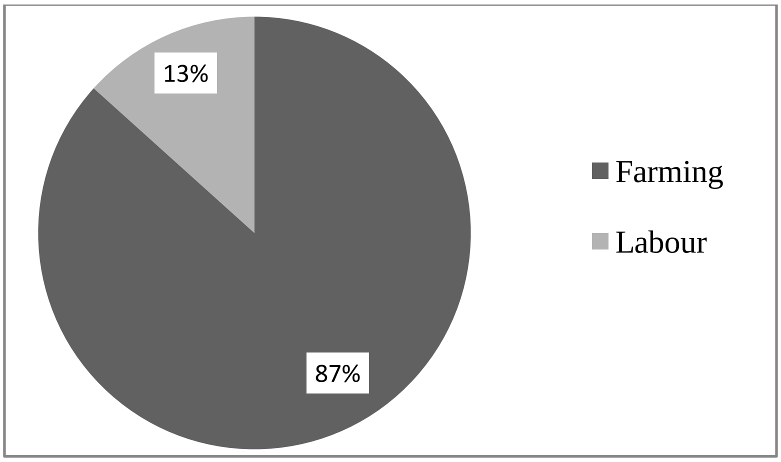



**Figure 4.8: Sources of Livelihood**

### 4.9 Issues Related to Tobacco Cultivation

In case of tobacco cultivation, the major problems faced by the farmers are lack of fertilizer, insufficient irrigation facility and unavailability of pesticides on time simultaneously (Fig. 4.9).

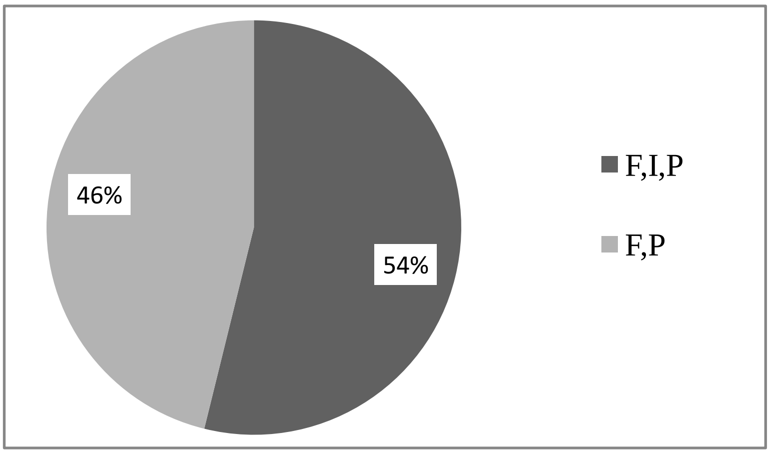



**Figure 4.9: Issues Related to Tobacco Cultivation**

**(F = Fertilizer, I = Irrigation, P = Pesticide)**

### 4.10 Continuity/Discontinuity of the Traditional Occupation

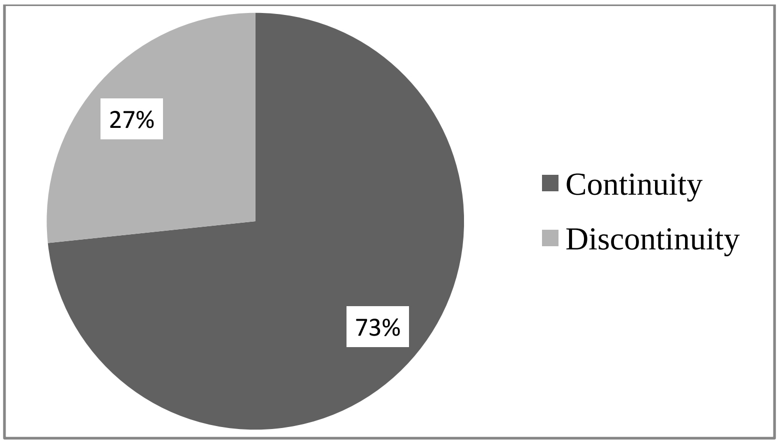



**Figure 4.10: Continuity/Discontinuity of the Traditional Occupation**

Majority of the respondents liked to continue their traditional occupation through their generation which might be the consequences of their ignorance about education and global touch while 27% of the respondents want to discontinue the traditional occupation and like to transform it into more immediate and economic jobs.

Along with tobacco, farmers also to cultivate mustard as cash crop. Some farmers have been cultivating tobacco for the last 40 years. Nevertheless, they are not getting any assistance from government agencies either in terms of fertilizer supply or seeds.

### 4.11 Biofuel Policy Review

Alternative Energy Promotion Center (AEPC) was set up to promote the use of alternative /renewable energy technologies to meet the energy needs in Nepal. Acting as an intermediary institution between the operational level NGOs/private promoters of renewable energy and the policy decision levels in relevant ministries, AEPC's activities include renewable energy policy formulation, planning and facilitating the implementation of the policies/plans. However, policy on production and use of bio-fuel is yet to be formulated. Nonetheless, AEPC has proposed a draft of National Bio-fuel Strategies for the gradual replacement of fossil fuel through the production of biodiesel from plant resources, as an alternation energy source. Some initiations are being undertaking at the testing level (AEPC, 2009). Moreover, policy regarding bioethanol production is to be formulated. But its discussions at academic, community and NGOs levels have been initiated.

The vision of the strategy is to fulfill the national demand of energy through the promotion and production of clean energy within the country. The mission of the strategy is to develop the commercial cultivation technology of *Jatropha*, which makes a significant contribution in alternative bio-energy development, environmental conservation and economic development.

The vision and mission of bio-fuel will be achieved by adopting following strategies: using waste land as major Natural Resources, plantation of *Jatropha* at commercial csale, production of oil from *Jatropha* seeds, production of bio-diesel from *Jatropha* oil, socio-economic study and development of *Jatropha,* techno-economic study and development, development of act, regulation and guidelines, development of micro-industry and Industrial academy, production and sale of bio-fuel, formation of small farmers groups, commercial farmers and business firm, identification of available land for *Jatropha*, subsidies from government sectors, infrastructure development in biofuel production

# CHAPTER V

# DISCUSSION

Result explicates that more dry biomass of lignocellolic residues is available from that of beer residue which is potentially the most favorable feedstock that can produce bioethanol. Total fresh biomass produced from the Himalayan Brewery is 866.4 tons/yr which result 155.0596 tons/yr dry biomass. According to Kim and Dale (2004) 1 Kg of barley waste (dry) can produce 0.41 liter of bioethanol. Whereas the estimated bioethanol produced from Himalayan Brewery is 63.5744 Kl/year.

The next suitable raw materials are green stem of tobacco in terms of quantity and quality in producing bioethanol. 100 tons fresh tobacco biomass per acre yields 4-8 tons of dry weight cellulose 5000 acres biomass tobacco at 100 tons/acre at 1500 gallons/acre = 7.5 million gallons/year (7500 vehicles at 20,000 miles/year).

Total fresh biomass produced from Tobacco cultivated field is 65.883 Kg/ha which result 9.945 Kg/ha dry biomass. In Nepal, the total area of tobacco cultivation is = 1893 ha. (Statistical Information on Nepalese Agriculture 2011-2012, Gov. of Nepal, 2012). The total dry residue that is produced from whole Nepal is 18,825.885 Kg/yr. If we use corn stover as comparable to tobacco, it contains 0.29 L ethanol/Kg dry biomass (Kim & Dale, 2004). It means that tobacco can yield 0.31 L of ethanol per Kg of dry biomass (8% of 0.29 = 0.023; therefore, yield is 0.31 L/Kg dry mass). So the total bioethanol that can be produced from dry tobacco residue from whole Nepal 5.836024 Kl/yr

Nepal has great potential to produce lignocellulosic based ethanol and to use it as part of a blend in gasoline-run vehicles. The increased use of biofuels not only reduces dependency on fossil fuels but also reduces the greenhouse gas (GHG) emissions and local air pollution caused by vehicular emissions. In addition, the production of biofuels can serve as a driver for improvements in agriculture.

In Nepal, the economy is dominated by agriculture. Approximately 20 percent of the total land area was cultivable, it accounted for, on average, about 33 percent of the GDP and approximately 75 percent of exports. According to the World Bank, agriculture is the main source of food, income, and employment for the majority. According to Statistical Information on Nepalese Agriculture (2008/2009) only 65.6% of people depend on agriculture.

Globally 4.2 million tons of tobacco leaf was produced during 1971 while during 1997, 5.9 million tons of leaf were produced which shows an increment of 40% from 1971 to 1997. According to the Food and Agriculture organization of the UN, tobacco leaf production was expected to hit 7.1 million tons by 2010. This number is a bit lower than the record high production of 1992, during which 7.5 million tons of leaf were produced. The production growth was almost entirely due to increased productivity by developing nations, where production increased by 128%. During that same time period, production in developing countries actually decreased. Every year 6.7 million tons of tobacco is produced throughout the world. The top producers of tobacco are China (39.6%), India (8.3%), Brazil (7.0%) and the United States (4.6%).

The individual view of the farmers towards the cultivation of tobacco as livelihood sources means of economic improvement, job opportunity problems showed mixed responses. Majority of farmers felt tobacco cultivation is good. The minority of respondent responded as not good.

The growth performance of the people's economy of Biruwa Guthi V.D.C is determined by the performance of the growth in the agricultural products as it contributes 80.0 percent to GDP, and generates 20 percent of total export earnings. It supplies raw materials for the production of Cigarettes to Surya Nepal Pvt. Ltd. The agricultural products consist of mainly cash crops, like tobacco and maize.

Irrigation facility is limited to a few seasonal water courses. Irrigation systems in the Biruwa Guthi, there are Private Irrigation Systems (PIS) which are mostly operated and maintained by landlords as like tube well irrigation schemes and individual farmer owned and operated tube wells and pumps (mostly utilizing shallow aquifers, streams, ponds, and dug wells).

Brazil and the US are global leaders in the production of biofuels from corn, sugarcane and lignocellulosic crops. Countries in Asia are also emerging players in the biofuel market. Among them, China produces an enormous amount of agricultural residue suitable for biofuel production, with ethanol blended fossil fuel comprising

20% of total Chinese petroleum consumption. In India, first generation biofuel technology is more mature than second-generation technologies, with India supporting its bioethanol production with sugarcane molasses and biodiesel from Jatropha (Puri et. al, 2012). So production of bioethanol has increased year after year because of it being renewable energy. Hence Nepal cannot keep away itself from this scenario.

There are no proven fossil fuel deposits available in the country yet and hundred percent of the petroleum products are imported. Nepal being a developing country the energy consumption rate increases as the country steps forward in development; then the demand for fuels increases accordingly. But, because of rapid fluctuations of fossil fuel prices in the world market and the political instability in the country, shortage of petroleum products has become very common experience in Nepal (Dhakal et al., 2010). The total import of petrol in Nepal in fiscal year 2011/12 is 202467 Kl. If implemented, bioethanol blending to petrol in Nepal could reduce Nepal's fuel import which could directly save our lot of money and indirectly could minimize the environmental pollution. From the present study, it is estimated that about 57,841.3754 Kl of bioethanol could be produced when these residue are fully utilized in producing bioethanol. If E10 is used in total import of petrol about 20,246.7 Kl of bioethanol could be utilized. And rest 37,594.6754 Kl of bioethanol could be utilized for many other purposes.

Till now no biofuel acts and rules are in place in Nepal. However, Alternative Energy Promotion Center (AEPC), Gov. of Nepal has proposed a strategy for biofuel policy, mainly focusing on biodiesel production. Few preliminary works are underway (AEPC, 2009). Issues concerning production of bioethanol from organic residues are still in the state of research discussions at academic institutions, NGOs and communities. Production of bioethanol in Nepal has been envisaged in the report Field study of Labour and Industrial coordination committee (2064).

# CHAPTER VI

# CONCLUSIONS AND RECOMMENDATIONS

## 6.1 Conclusions

This study investigated the potential for utilization of wasted biomass and lignocellulosic feedstocks of some major agro-based industry for production of bioethanol. Agro-industrial residues and agro-residues are used for different propose other than bioethanol production in Nepal. The dry biomass of residue from Himalayan Brewery Pvt. Ltd. is 155.0596 ton/year and estimated bioethanol production from this residue is 63.5744 Kl/year. Among residue that comes from field, the residue from tobacco field is least i.e. 18,825.885 Kg/year so its estimated bioethanol production is also less i.e. 5.836 Kl. And also tobacco is cultivated in less area, so this may be also a reason of less dry biomass and bioethanol production.

From the present study, it is estimated that about 57,841.3754 Kl of bioethanol could be produced when these residue are fully utilized in producing bioethanol. If E10 is used in total import of petrol about 20,246.7 Kl of bioethanol could be utilized. And rest 37,594.6754 Kl of bioethanol could be utilized for many other purposes.

So it is concluded that among agro-industrial residue Himalyan berewery has the highest potential of producing bioethanol while the residue from Surya Nepal tobacco factory has the least potential of producing bioethanol. And residue from field Green tobacco stem has the more capacity of producing bioethanol than residue of tobacco factory in Nepal.

## 6.2 Recommendations for Further Studies

- Similar sorts of studies could be conducted regarding bioethanol production from other lignocellulosic residues like Municipal Solid Wastes (MSW), and domestic sewage etc.
- Studies related to bioethanol production could also be conducted by taking lignocellulogic residue from a wide range of agro based industries of Nepal.
- A study on bioethanol production from farm residue could be conducted to encourage and improve the economic status of farmers.

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# ANNEXES

## Lignocellulosic Residue from Agricultural Field and Agro-Based Industries as Potential Source of Bioethanol


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Dear respondents,

I am conducting a survey about **Lignocellulosic Residue Produced from Agricultural Field as well as from Agro-Based Industries** with the people and stakeholders in this area.

You have been selected for this study and your answer will help me to better understand the prospect of bioethanol production from these residues.

I assure you to protect your confidentiality and privacy. I would be grateful to your every effort and assistance.

**ANNEX I**

**Questionnaire**

**(Part - I)**

**Name of Industries:** **Date:**

**District:** **VDC:**

## <u>TOBACCO</u>

1. How many days does your mill operate?

2. How many tobacco leaves are used in each year?

3. Which parts of tobacco leaves are used for making cigarette?

4. How much tobacco stem or others parts of tobacco are used in each 100 Kg of tobacco leaves?

5. How much residues are produced after making cigarettes per year?

6. How do you use these residues?

**(Part - II)**

**Name of Industries:** **Date:**

**District:** **VDC:**

**BEER**

1. What sorts of raw material do you use in making beer?

2. From where do you bring these raw materials?

3. How much residues are produced while refining these raw materials?

4. How much residues are produced after making beer?

5. How do you use these residues?

6. What sorts of fermentation techniques are used and which organisms are used in these fermentations?

**(Part - III)**

**Name:** **Date:**

**Sex:** ☐ Male ☐ Female **Age:**

**District:** **VDC:**

**Education:** **Number of Family Members:**

1. What is the main source of livelihood?
2. Since how many years, you are involved in agriculture?
3. What sorts of cash crop farming do you practice?
4. What is the purpose of your farming?
   ☐ Livelihood ☐ Commercial ☐ Both
5. If for commercial purpose, for how many years are you involved in?
6. What problems do you face in commercial farming?
7. How much is your cultivable land and how much do you use of it for cash crop?
8. How do you use the residues after harvesting the crops?
9. How much residues are produced from one Kattha of land?
10. Has any organization helped you ever?
    ☐ Yes ☐ No

11. If yes, which and how?

12. Has government helped you ever?

☐ Yes ☐ No

13. If yes, how?

14. Is there any market nearby to sell your crop?

☐ Yes ☐ No

15. How do you sell your crop?

☐ Through Cooperative Organization ☐ Directly to the Mill

16. Is there irrigation facility?

☐ Yes ☐ No

17. If yes, what types of facility?

18. Do you think agriculture has improved your economic condition?

☐ Yes ☐ No

19. How many people are employed by your agriculture?

20. Do you want your further generation to continue this profession?

☐ Yes ☐ No

21. What types of diseases do you find in your farm?

22. What are the problems of using insecticides/pesticides?

23. What do you use as fertilizers? And how much do you use it?

# ANNEX II

# PHOTO PLATE

Green Stem of Tobacco Left in Farm

Tobacco Leaf  Hanged for Drying

Interviewing with Farmer


Beer Factory Residue Taken Away by the Local People for Cattle Feed