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Bio-fuel Production Through Jowar And Bajra Feedstock Cultivation: A Socio-economic and Life Cycle Analysis

Dr. M. Gopinath Reddy
Dr. B. Suresh Reddy

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Foreword

The Centre for Economic and Social Studies (CESS) was established in 1980 to undertake research in the field of economic and social development in India. The Centre recognizes that a comprehensive study of economic and social development issues requires an interdisciplinary approach and tries to involve researchers from various disciplines. The Centre's focus has been on policy relevant research through empirical investigation with sound methodology. Being a Hyderabad based think tank, it has focused on, among other things, several distinctive features of the development process of Andhra Pradesh, though its sphere of research activities has expanded beyond the state, covering other states apart from issues at the nation level. In keeping with the interests of the faculty, CESS has developed expertise on themes such as economic growth and equity, rural development and poverty, agriculture and food security, irrigation and water management, public finance, demography, health, environment and other studies. It is important to recognize the need to reorient the priorities of research taking into account the contemporary and emerging problems. Social science research needs to respond to the challenges posed by the shifts in the development paradigms like economic reforms and globalization as well as emerging issues such as optimal use of environmental and natural resources, role of new technology and inclusive growth.

Dissemination of research findings to fellow researchers and policy thinkers is an important dimension of policy relevant research which directly or indirectly contributes to policy formulation and evaluation. CESS has published several books, journal articles, working papers and monographs over the years. The monographs are basically research studies and project reports done at the Centre. They provide an opportunity for CESS faculty, visiting scholars and students to disseminate their research findings in an elaborate form.

The present study on "Bio-Fuel Production Through Jowar and Bajra Feedstock Cultivation: A Socio-Economic and Life Cycle Analysis" undertaken by my faculty colleagues Prof.M.Gopinath Reddy and Dr.B.Suresh Reddy brings forth important issues regarding alternate fuels from fodder crops to meet the challenge of reducing the carbon emissions (CO2). The need for such a study arises from the fact that depletion of fossil fuels at an alarming rate coupled with ever growing challenge due to anthropogenic factors induced climate change stress that has attracted increasing attention to blending bio-fuels worldwide. According to the International Energy Agency (IEA), India will become the largest single source of global oil demand growth after 2020. Hence, India needs energy security along with environmental sustainability so that the eco-capacity of the conserved and environmental uncertainity arising from events such as climate change is mitigated. It is in this backdrop that the current study is undertaken in the state of Madhya Pradesh by my faculty colleagues that focused on knowing the existing scenario with reference to the proposed biofuel feed stocks Jowar (Sorghum) and Bajra (Pearl Millet) in the study area and understood the socioeconomic aspects of sampled farmers. The study also assessed the economics of Jowar and Bajra crop cultivation of the sampled farmers and examined the ecological, social and livelihood significance of biofuel crops cultivation. It looked at the drivers and Barriers for the cultivation of Biofuels in India. The study also conducted a thorough analysis using a Life Cycle Analysis (LCA) approach so as to figure out the better method and feed stock.

The State of Madhya Pradesh where the baseline study was undertaken is known for its vibrancy in agriculture sector. Even today, two-thirds of the total working population are engaged in agricultural pursuits as cultivators and agricultural labourers. Majority of the farmers are small and marginal farmers. Madhya Pradesh has the distinction of much diversified livestock resources. In MP, agriculture has been undergoing many changes over the past two to three decades and today it stands top in the country with respect to agricultural transformation growth. The increasing intervention of the state in agriculture, and the green and yellow revolutions, have prompted agricultural changes throughout the semiarid regions, especially in land ownership, cropping patterns, irrigation, credit and extension, agricultural productivity, prices and marketing etc,.

The research methodology adopted for the study is multi pronged in nature and the study used both qualitative and quantitative methods for understanding the farmers socio-economic and ecological aspects of jowar and bajra and the awareness about biofuels production through these crops. Personal interviews were conducted with a structured interview schedule. The study used an ex post facto research design and Focused Group Discussions (FGDs). The selected districts were Gwalior, Khargone, Dewas, Morena and Bhind. Districts hosting Sorghum and Pearl millet in large areas, were selected for the study. A total of ten villages were selected from five districts where the trials of high biomass feedstocks were conducted. Stratified proportionate random sampling was used covering 333 farmers belonging to different size classes in 10 villages for the baseline study. Second and third round of surveys were done with farmers involved in the multi-locational crop trials conducted/coordinated by ICRISAT, RVSKVV and IIMR and the emerging empirical data was analysed vis-à-vis baseline data.

The key findings of the study indicated that traditional jowar and high yielding varieties were doing well economically as compared to jowar hybrids. This means that the proposed high biomass varieties that are being encouraged as biofuel feed stocks should have comparative advantage over traditional and high yield varieties of jowar. Majority of the respondents (61.56 percent) perceived that cultivation of Jowar and Bajra as biofuel feed stocks would not affect the food security but would definitely impact (51.96 percent) the fodder security of their livestock. LCA analysis revealed that sorghum feedstock is more energy intensive than pearlmillet feedstock due to higher water requirement and yield. In view of the importance of the above findings, there is need for larger debate on the use of food crops in the production of alternate energy in place of current fossil fuel dependency. I am sure the study findings will be useful for the on going food versus fuel debate and the scholars, civil society / NGOs, policy makers and scientific bodies will find them useful.

S. Galab
Director, CESS

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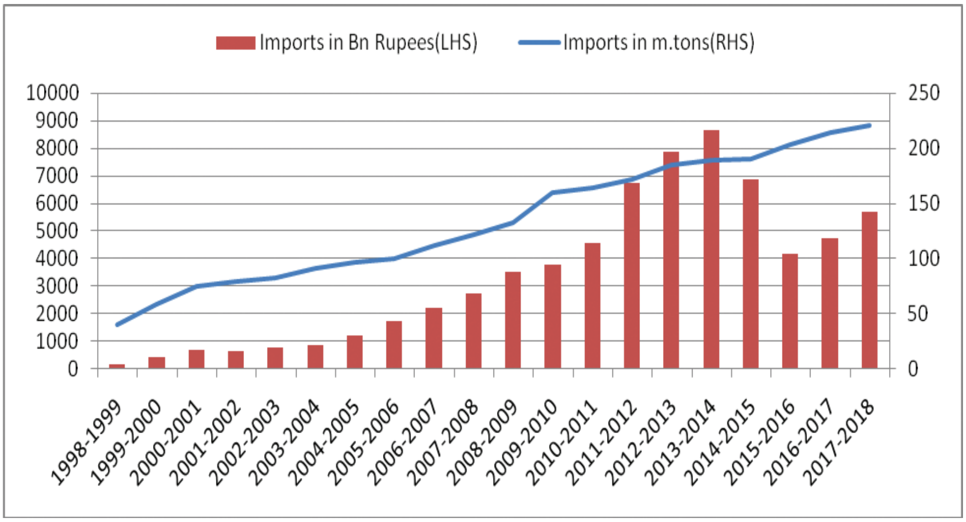
CHAPTER - 1

I. Introduction

Depletion of fossil fuels at an alarming rate has attracted increasing attention to blending bio-fuels worldwide. India's energy demand is growing at an annual rate of 4.2% with highest demand growth of +129% in 2017 (BP, 2017). Depletion of fossil fuels at an alarming rate coupled with ever-growing challenges due to anthropogenic induced climate change has attracted increasing attention to blending biofuels worldwide. According to the International Energy Agency(IEA), India will become the largest single source of global oil demand growth after 2020. Hence, India needs energy security along with environmental sustainability so that the eco-capacity of the conserved and environmental uncertainty arising from events such as climate change is mitigated. Of the total primary energy supplied to Indian economy in 2016, as much as 75 per cent was from commercial fuels while 25 per cent was from non-commercial fuels. Out of the total commercial energy, coal constitutes 56.76 per cent, followed by oil (29.28 per cent), natural gas (6.2 per cent) and carbon-free hydro, nuclear, and other new renewable resources (7.4 per cent) (IEA 2016). Despite coal being the country's major resource endowment, the major source of India's energy insecurity is the heavy and growing dependence on oil imports. Of late, there have been sharp rising trends in crude oil prices coupled with volatility. India's transportation fuel requirements are unique as it consumes almost six to seven times more diesel fuel than gasoline, whereas in the rest of the world, almost all the other countries use more gasoline than diesel. The National Policy on Biofuels (2009) has an ambitious target of mainstreaming the use of biofuels-bioethanol and biodiesel by 20 per cent blending with Petrol and High Speed Diesel (HSD) by 2017. However, the policy centers around the plantations and production of Jatropha on wastelands for the achievement of this target.

As discussed earlier, most of the energy requirements in India are currently satisfied by fossil fuels - coal, petroleum-based products, and natural gas. The energy security in the country is seriously affected because its domestic production can only bridge the requirement gap by 25-30 per cent, added to the burgeoning burden of imports. In 2017-18, the country imported 285.0 million tons of crude oil, which amounts to nearly 84.83 per cent of its domestic crude oil consumption.(see fig.1.1).

Figure 1.1: India's Crude Oil Imports

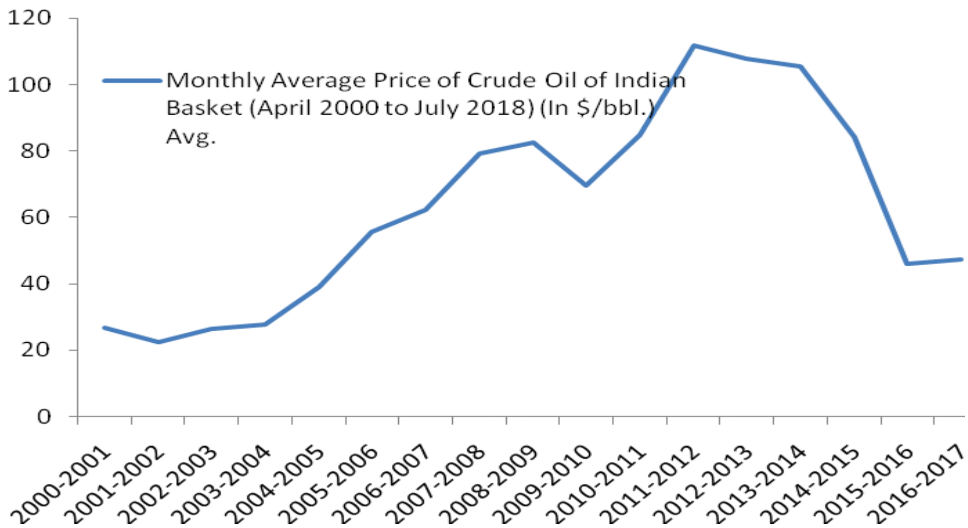


Source: IndiaStat.com

India's primary energy use is projected to expand massively to deliver a sustained GDP growth rate of 9 per cent through 2031-32, even after allowing for substantial reduction in energy intensity. In order to fuel this on a sustained basis, the growth of around 5.8 per cent per year in primary energy supply including gathered non-commercial fuels such as wood and dung would be required. Commercial energy supply would need to grow at about 6.8 per cent per annum, as it will replace non-commercial energy; but this too involves a reduction of around 20 per cent in energy use per unit of GDP over a period of 10 years. India is confronted with an energy crisis due to the depletion of resources and increased environmental problems. For example, diesel is the primary transport fuel of the country and comprises around 42 per cent of the total fuel market, majority of which comes through import market.

The rate at which the energy needs are growing demands either a greater reliance on imports (which is a strain on the depleting fiscal resources and foreign exchange) or a shift to alternative energy sources. With self-sufficiency levels in crude oil a distant dream, there is a growing interest/need in development and commercialization of a bouquet of alternative fuels. This necessitates the change of focus towards bio-fuels as a favorable alternative option. In addition to providing energy security and decreased dependence on oil imports, bio-fuels offer significant benefits such as reduced emission of pollutants and greenhouse gases. Most importantly, the industry has a potential to

Figure 1.2: India's Crude Oil Prices (brent)



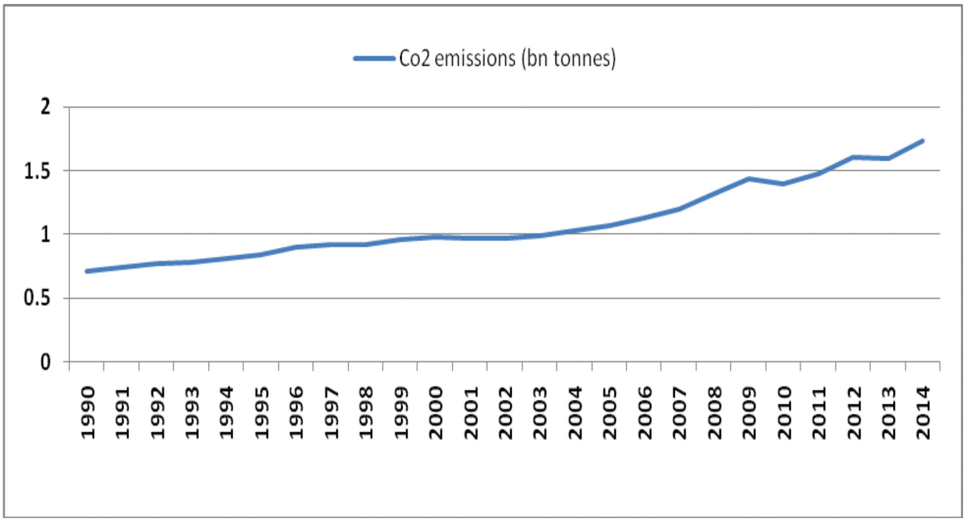
Source: eia.com

create avenues to raise farmer incomes and restore degraded lands, while at the same time contributing to climate change mitigation.

1.2 Energy and Climate Change

Climate change is one of the most important problems faced around the world and most importantly in developing countries like India. According to the International panel on climate change (IPCC) AR4, temperature has increased by 0.74°C in the last hundred years with the bulk of the warming occurring in the last 50 years. Temperatures have risen at a rate of approximately 0.13°C per decade from 1956 to 2005 (IPCC, 2007). Agriculture is the largest employer in the world and the most vulnerable to weather and climatic risks. In developing countries, around 70 per cent of the total population is dependent on agriculture. The majority of the total annual crop losses in the world agriculture is mainly due to direct weather impacts such as droughts, floods, untimely rain, frost, heat and cold waves, and severe storms (Folley, *et al.*, 2005, Hay, 2007). India accounts for only about 2.4 per cent of the world's geographical area and 4 per cent of its water resources, but has to support about 17 per cent of the world's human population, and 15 per cent of the livestock. Climate change may alter the distribution and quality of India's natural resources and adversely affect the livelihood of its people. With an economy closely tied to its natural resource base and climate-sensitive sectors such as agriculture, water and forestry, India may face major threat because of the projected changes in climate (GoI, 2008). Hence, the country has reasons to be concerned about climate change as a vast population depends on climate-sensitive sectors such as agriculture, forestry and fishery for its livelihood in the country.

Figure 1.3 : India's CO_2 Emissions 1990-2014 (Bn tonnes of CO_2)



Source: World Bank, 2015

According to the GoI report, climate change is likely to impact agricultural land use and production due to less availability of water for irrigation, higher frequency and intensity of inter and intra-seasonal droughts and floods, low soil organic matter, soil erosion, less availability of energy, and coastal flooding, which could impact agricultural growth adversely (GoI, 2013). Crop specific simulation studies, though not conclusive due to inherent limitations, project a significant decrease in cereal production by the end of this century. Parts of Western Rajasthan, Southern Gujarat, Madhya Pradesh, Maharashtra, Northern Karnataka, Northern Andhra Pradesh, and Southern Bihar are likely to be more vulnerable in times of extreme events. The impact of climate change on crop productivity is significant and diverse as its impact differs even across different agro-climatic zones within a state, thus making implementation of mitigation strategies very difficult (Steven Raj P, 2014).

Hence, in order to tackle the twin problem of burdening energy security and mitigate effects of climate change on the Indian economy, the Union Cabinet of the Government of India approved the National Policy on Biofuels on December 24, 2009, which stresses on mainstreaming of bio-fuels in India to meet its ever-increasing energy requirements and to limit the carbon foot print of the country. The policy calls for setting up a

Table 1.1: Impact of climate change on crop yields in different regions of India in PRECIS A1B scenario 2030*

	Western Region	Coastal Region	North East Region
Rice (Irrigated)	Likely to be reduced by 4%, however irrigated rice in parts of southern Karnataka and northern-most districts of Kerala is likely to gain.	Decrease by 10 - 20%, in some coastal districts of Maharashtra; northern Andhra Pradesh and Orissa are projected to marginally increase by 5% with respect to the 1970s	Irrigated rice yields in this region may decline between 5-10%
Rice (Rain-fed)	All areas in the region are likely to lose yields by up to 10%.	Projected to increase up to 15% in many districts in the east coast and reduce by 20% in west coast	Decline 5-35% with respect to 1970s
Maize/ Sorghum	Likely to impact yields by 50% depending on the region	Yield loss between 15% and 50%; Rain-fed maize loss is up to 35%; AP to reduce by 10%	Projected to reduce by about 40%
Coconut	Likely to increase yields by 30%. South-west Karnataka, parts of Tamil Nadu, and parts of Maharashtra may show reduction in yields up to 24%.	Increase by 30% in west coast (provided water level is same). and by 10% in the east coast, esp. in north coastal districts of AP	
Livestock[1]	THI > 80 during September-April to reduce productivity	THI > 80 throughout the year	THI > 80 during months of April-October

Source: Indian Network for Climate Change Assessment, MoEF
* Assessed through a simulation model called InfoCrop

[1] The Temperature Humidity Index (THI), an index used to represent thermal stress due to combined effects of air temperature and humidity. THI > 80 severely impacts livestock health and productivity.

National Biofuel Coordination Committee (NBCC) headed by the Prime Minister to provide over all coordination, effective end-to-end implementation, and monitoring of biofuel programme. Another Biofuel Steering Committee would be set up to tend to more regular and day-to-day coordination of the same which would be chaired by Cabinet Secretary (GOI, 2009). The National Biofuel Policy aims at ensuring that the next generation of technologies is based on non-food feed stocks so as to avoid conflicts with food security. The policy aims at mainstreaming of biofuels and therefore, envisions a central role for it in the energy and transportation sectors of the country in coming decades. The policy aims at bringing about accelerated development and promotion of the cultivation, production and the use of biofuels to increasingly substitute petrol and diesel for transport and be used in stationary and other applications, while contributing to energy security and climate change mitigation, apart from creating new employment opportunities and leading to environmentally sustainable development. The policy sets an indicative target of 20 per cent blending of biofuels, both for biodiesel and bio-ethanol by 2017; ethanol blending with gasoline was recorded as 2.9 per cent in 2013.

1.3 Biofuels

Sustainable development which ensures protection of resources and the environment for the future generations has become one of the important milestones to be achieved. According to the Burndtland Report (1987), sustainable development is a process which satisfies the need of the present without decreasing the ability of the future generations to supply their own demand. Given that environment is one of the most important pillars of sustainable development; the others being society and balanced treatment of the economy (Gathy, 2005), the focus shifts to renewable energy sources like biofuels, which aim to preserve the environment in a better way by substituting traditional fuels that are considered to be one of the biggest contributors to global environmental decay. Biofuel is a non-polluting, locally available, accessible and reliable fuel obtained from renewable sources. It is seen by many as a "clean" form of energy as the amount of CO_2 released when it is burned is generally equivalent to the amount of CO_2 captured during the growth of the crop that produced it. Since biofuels can be produced from diverse set of crops, each country can also adopt its local/regional/country-specific strategy in order to achieve comparative advantage. Liquid bio-fuels that are being considered world over fall into the following categories:

i) Alcohols - produced by fermentation of sugar and starchy crops, and quite recently from cellulosic biomass

ii) Plant seed oils - which comprise triglycerides of long chain saturated and un-saturated fatty acids. Bio-diesel is vegetable oils modified by trans-esterification to replace the glycerol molecules by methyl or ethyl groups

iii) Bio-crude and synthetic oils - are low molecular weight non-polar constituents of plant, which can be directly extracted from bio-mass and are generally a complex mix of lipids, triglycerides, waxes, terpenoids, polysterol, and other modified iso-perenoids that can be catalytically upgraded for use as liquid fuels.

Globally these different liquid fuels can be obtained from four different categories of biomass sources:

a) Plantations especially raised for producing energy or energy and food

b) Agricultural residues and wastes including manure, straw, bagasse and forest wastes

c) Uncultivated biomass such as weeds

d) Organic urban or industrial wastes

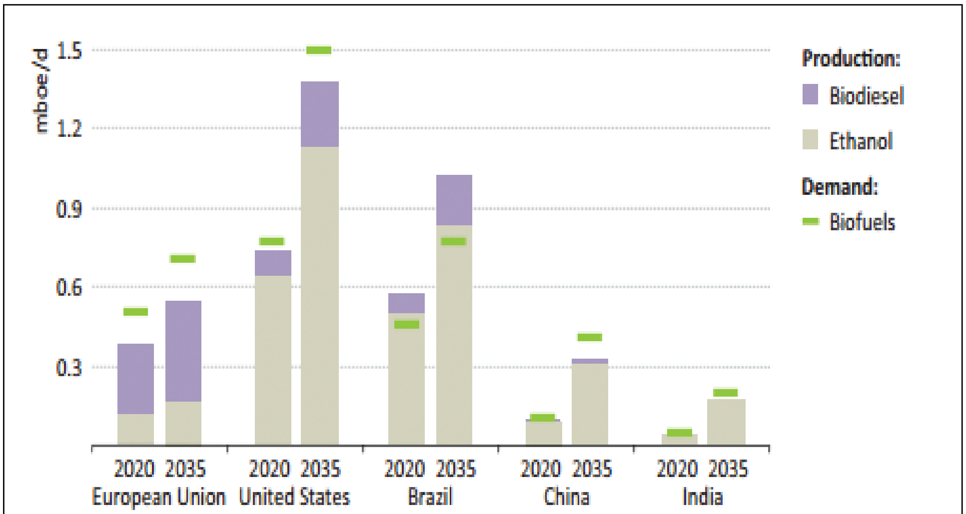
Table 1.2: Biofuels Classification

First Generation Biofuels (from grains, seeds, sugars)	**Second Generation Biofuels** (from lingo-cellulosic biomass, such as crop residues, woody crops, or energy grasses)
Petroleum-gasoline substitutes - Ethanol or butanol by fermentation of starches (corn, wheat, potato) or sugars (sugar-beets, sugarcane)	Biochemically produced petroleum-gasoline substitutes - Ethanol or butanol by enzymatic hydrolysis
Petroleum diesel substitutes - Biodiesel by trans-esterification of plant oils, also called fatty acid methyl ester (FAME) and fatty acid ethyl ester (FAEE) - From rapeseed (RME), Soybeans (SME), sunflower, coconut, palm, jatropha, recycled cooking oil, and animal fats	Thermo-chemically produced petroleum-gasoline substitutes - Methanol - Fischer-Tropsch gasoline - Mixed alcohols Pure plant oils (straight vegetable oil)
Thermo-chemically produced petroleum-diesel	substitutes Fischer-Tropsch diesel - Dimethyl ether (also a propane substitute) - Green diesel

Source: UNCTAD, 2008

Consumption of biofuels is projected to rise from 1.3 million barrels of oil equivalent per day (mboe/d) in 2011 to 2.1 mboe/d in 2020, and 4.1 mboe/d in 2035 (see fig.4). By 2035, biofuels are expected to meet 8% of the total road-transport fuel demand, up from 3% today. Ethanol remains the dominant biofuel, making up about three-quarters of global biofuels use throughout the period. Consumption of biodiesel in road transport more than triples over the outlook period to 1.1 mboe/d in 2035. Combined United States, Brazil, the European Union, China, and India account for about 90% of world biofuels demand throughout the outlook period, with government policies driving the expansion in these regions. In addition to the use of biofuels in road transport, its use in aviation begins to make inroads over the projection period (IEA 2013).

Figure 1.4: Biofuels Demand and Production in Selected Regions



Source: World Energy Outlook, 2013

1.3.1 Advantages

Added to its uniqueness as an environmentally friendly fuel compared to either gasoline or petroleum diesel, biofuel is also recognized due to its portability, ready availability, renewability, higher combustion efficiency, lower sulfur and aromatic content, and higher biodegradability (Ma F 1999; Konthe et al., 2006). Bio-diesel has higher flash point temperature (>1000C), higher octane number and lower aromatics than that of conventional fuels. Added to this, biodiesel can be used in any diesel engine without any modification. Blends up to 20 per cent biodiesel mixed with petroleum diesel fuels can be used in nearly all diesel equipment and are compatible with most storage and distribution equipment.

Table 1.3: Technical Properties of Biodiesel

Common name	Biodiesel
Common chemical name	Fatty acid ethyl ester
Chemical formula range	C14-C24 methyl esters or C15-25H28-48O2
Kinematic viscosity range (mm2/s, at 313 K)	3.3-5.2
Density range (kg/m3, at 288 K)	860-894
Boiling point range (K)	>475
Flash point range (K)	420-450
Distillation range (K)	470-600
Vapor pressure (mm Hg, at 295 K)	<5
Solubility in water	Insoluble in water
Physical appearance	Light to dark yellow, clear liquid
Odor	Light musty/soapy odor
Biodegradability	More biodegradable than petroleum diesel
Reactivity	Stable, but avoid strong oxidizing agents

Source: Demirbas, 2009

The clamor for shift to biofuel driven energy, especially in the transportation sector is gathering ground of late, more in developing countries like India, given its potential to reduce the dependency on imported fuel and thus reducing the burden on the exchequer. Moreover given that biodiesel can be manufactured from domestically cultivated crops would also contribute to better farm level incomes and also increased employment generation both at the field and factory level.

1.3.2 Disadvantages

Despite their appeal as an alternative to fossil fuels, biofuels are also subject of considerable controversy. The major disadvantages of biodiesel are its higher viscosity, lower energy content, higher cloud point and pour point, higher nitrogen oxide (NO_x) emissions, lower engine speed and power, injector choking, engine compatibility and high price. The specific fuel consumption values of biodiesel are greater than those of commercial diesel fuel, while the effective efficiency and effective pressure values of commercial diesel fuels are greater than those of biodiesel. Biofuel production is not considered truly as carbon-neutral because the stages of production needs non-renewable energy while transporting and processing.

Table 1.4: Biodiesel emissions compared to conventional diesel

Emissions regulated emissions	**B100** (100 per cent biodiesel)	**B20** (20 per ce nt biodiesel)
Total unburned Hydrocarbons	-93 per cent	-30 per cent
Carbon Monoxide	-50 per cent	-20 per cent
Particulate Matter	-30 per cent	-22 per cent
NO_x	13 percent	2 per cent
Non-Regulated Emissions		
Polycyclic Aromatic Hydrocarbons (PAH)	-80 per cent	-13 per cent
NPAH (Nitrated PAH)	-90 per cent	-50 per cent
Life Cycle Emissions		
Carbon Dioxide (LCA)	-80 per cent	
Sulfur Dioxide (LCA)	-100 per cent	

Source: GOI, 2003

The primary concern is that the substitution of agricultural crops to produce biofuels may be inherently unsustainable (Peer *et al.,* 2008) as crops require land and water to grow and this would inadvertently in the long run result in the shift from food to non-food/fuel crops given higher incentives. Crops of any nature in industrialized agriculture require synthetic inputs such as fertilizers and pesticides, both of which are produced and transported using fossil fuel energy. This fact adds to the overall energy required to produce crops that provide energy and raises questions about whether the finished product provides more energy than is spent to produce it (Giampietro *et al.,* 1997). Another issue of concern is the impact on food security in the context of diversion of land to biofuel crops. It is interesting to note that the soaring food inflation during 2002-2008 is attributed to shift of food commodities to biofuels. Though increase in internationally traded food prices during 2002-2008 is attributed to a confluence of factors, it is chiefly attributed to increase in biofuel production from grains and oilseeds in the US and EU. The IMF estimated that the increased demand for biofuels accounted for nearly 70 and 40 per cent of the increase in maize and soya bean prices respectively (Lipsky, 2008). Land use changes in wheat exporting countries had occurred in response to increased plantings of oilseeds for biodiesel production and resulted in limited expansion of wheat production. Impact of food prices on developing countries like India is much pronounced given that they spend nearly half their household income on food (Donald Mitchell, 2008).

There is also considerable debate on whether the end fuel product will truly be better for the environment than fossil fuels when subjected to a Life Cycle Analysis (Heintzman and Solomon, 2009; Puppán, 2003). LCA is defined by the International Standards Organization (ISO) as "a compilation and evaluation of inputs, outputs and potential environmental impacts of a products system throughout its life cycle" (Guinée *et al.,* 2001).

Experiences worldwide suggest that the conventional fuels can be successfully substituted with biofuels. There are many successful experiences the world over from Canada, USA in North America, Brazil, Argentina and Columbia in South America; France, Germany and the European Union, India, China, Indonesia, Malaysia and Thailand in Asia, and Australia. Over the last decade that is between the years 2000 and 2009 biofuel production has increased dramatically from 16.9 to 72.0 billion liters, while biodiesel grew from 0.8 to 14.7 billion liters. The United States remains the largest biofuels market, spurred on by the Renewable Fuel Standard (RFS) through 2022 and assumed continuation of support thereafter, with consumption increasing from around 0.7 mboe/d to 1.5 mboe/d in 2035, by which time biofuels meet 15% of road-transport energy needs. Driven by blending mandates and strong competition between ethanol and gasoline, Brazil remains the second-largest market and continues to have a larger share of biofuels in its transport fuel consumption than any other country.

In 2035, biofuels meet 30% of the Brazilian road-transport fuel demand up from 19% today. Supported by the Renewable Energy Directive and continued policy support, use of biofuels in the European Union more than triples over the period to 0.7 mboe/d in 2035, representing 15% of road-transport energy consumption. In China, government plans for expansion lead to demand for biofuels reaching 0.4mboe/d in 2035, many times the current level. India established an ambitious National Mission policy on biofuels in 2009, but the infancy of the ethanol industry and difficulty in meeting current targets constrains future demand growth in the projections (IEA, 2013).

Of all the biofuel experiences, sugarcane-based ethanol being used in Brazil has been regarded as the most successful one as all gasoline sold in Brazil is a blend of 18 to 25 per cent ethanol in Brazil. The Brazilian national ethanol program-Proalcool, was launched in 1975. After the second oil crisis in 1979, Brazil launched to shift to cars powered by entire hydrous ethanol. This was very successful as by 1985, as much as 95 per cent of the light vehicles produced in Brazil were built to use hydrous ethanol. In 2003, flex fuel vehicles were launched and currently account for 90 per cent of the new sales constituting the high point of Brazilian ethanol success story in the present decade. Brazil ethanol program is more consolidated because:

a) gasoline contains 25 per cent of ethanol,

b) ethanol is available in all gas stations, and

c)50 per cent of the car fleet and 90 per cent of new car sales are of flex fuel.

This was all possible due to the strong sugarcane sector that is already established in the country. Brazil produced 717 million tons of sugarcane, which yielded 36.1 million tons of sugar and 27 billion liters of ethanol. Most of the ethanol produced is absorbed in the domestic market where it is sold as either ethanol fuel or blended with gasoline.

Table 1.5: Biofuel consumption in road transport (bioethanol and biodiesel), 2005-2012 (in TJ)

	2005	2006	2007	2008	2009	2010	2011	2012
USA	337,941	473,793	601,146	819,755	928,090	1,012,973	1,068,621	1,070,660
EU27	130,415	230,762	283,830	397,878	495,048	554,991	580,531	598,371
Brazil	291,533	270,201	373,039	502,514	550,826	588,900	521,186	517,495
China	0	42,200	39,056	49,188	51,742	50,696	63,217	63,217
India	4,556	5,038	5,601	6,191	6,861	7,611	11,736	11,736
Global	777,605	1,039,354	1,354,706	1,855,104	2,143,083	2,377,504	2,482,683	2,498,870

Source: Trends in Global CO2 Emissions: 2013

1.4 Biofuels in India

The two prominent biofuels in India are bio-ethanol (or simply ethanol) and biodiesel made from biomass containing sugar like molasses and vegetable oil like non-edible jatropha oil respectively. The policy document on biofuels defines biomass as "biodegradable fraction of products, wastes and residues from agriculture, forestry and related industries as well as the biodegradable fraction of industrial and municipal wastes" (GoI, 2009).

Ethanol is manufactured in India by fermentation of molasses, which is a by-product of the sugar industry. India is the fourth largest producer of ethanol in the world after Brazil, the United States and China, with distillation capacity of 2,900 million liters per year. The Government of India made 5 per cent blending of ethanol with petrol mandatory in nine sugarcane producing states in September 2002. However, due to supply shortage the mandate was made optional in October 2006. In October 2007, the government again made it mandatory for 5 per cent ethanol blend in petrol across the country with exception of J&K, the Northeast, and island territories. Now, the policy on biofuels has an ambitious target of 20 per cent blending by 2017 (See table 1.6).

Table 1.6: Projected demand for petrol and diesel and the biofuel requirements of India

Year	Petrol demand in Mt	Ethanol blending requirement (in metric tons)			Diesel demand in Mt	Biodiesel blending requirements (in metric tons)		
		@5 per cent	@10 per cent	@ 20 per cent		@5 per cent	@ 10 per cent	@ 20 per cent
2006-2007	10.07	0.50	1.01	2.01	52.32	2.62	5.23	10.46
2011-2012	12.85	0.64	1.29	2.57	66.91	3.35	6.69	13.38
2016-2017	16.40	0.82	1.64	3.28	83.58	4.18	8.36	16.72

Source: Planning Commission, Government of India. Report of the Committee on Development of Biofuel,16th April 2003.

Unlike in the US, Brazil and EU, the biodiesel industry, however, is not as mature and is still in its incubation stage. The demand for diesel is four times the demand for petrol in India. Keeping this and other costs associated with conventional diesel fuel, the GOI formulated the National Biodiesel Mission in 2003. According to the Planning Commission's report, by 2016-17, the demand for diesel is estimated to be around 84 million tones and with a 20 per cent blending requirement, and the need for biodiesel would be around 17 million tones, cultivated in over 14 million hectares in the country.

Table 1.7: Ethanol and biodiesel consumption in road transport by region in the New Policy Scenario (mboe/d)

	Ethanol		Biodiesel		Biofuels total		Share of road transport energy use (in per cent)	
OECD	0.7	1.5	0.2	0.8	0.9	2.3	4.0	12.0
Americas	0.6	1.3	0.1	0.3	0.7	1.6	4.0	13.0
United States	0.6	1.2	0.1	0.3	0.7	1.5	5.0	15.0
Europe	0.0	0.2	0.2	0.5	0.2	0.7	4.0	12.0
Non-OECD	0.3	1.4	0.1	0.4	0.4	1.8	2.0	5.0
E.Europe/Eurasia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0
Asia	0.0	0.7	0.0	0.1	0.1	0.8	1.0	4.0
China	0.0	0.4	0.0	0.0	0.0	0.4	1.0	4.0
India	0.0	0.2	0.0	0.0	0.0	0.2	0.0	4.0
Latin America	0.3	0.8	0.1	0.2	0.4	1.0	10.0	20.0
Brazil	0.2	0.6	0.0	0.2	0.3	0.8	19.0	30.0
World	1.0	2.9	0.4	1.1	1.3	4.1	3.0	8.0
European Union	0.0	0.2	0.2	0.5	0.2	0.7	5.0	15.0

Source: World Energy Outlook, 2013

Indian biodiesel mandate is driven by multiple motivations. Biofuels are seen as a source of renewable energy with potential to create a new industry, to raise farmer incomes and to restore degraded lands, while promoting independence from oil imports and contributing to climate change. Second generation biofuel crops are seen as a possible solution to the biofuel-driven land use change that has raised concerns in both developed and developing countries. The potential diversion or displacement of food crops is now considered a serious problem. Though Indian policy makers were careful and sensitive on this aspect by envisaging bio-fuel cultivation only on uneconomic lands, the government has not accounted for the displacement of the existing resource gathering and grazing activities by assuming them as wastelands.

India has a mature ethanol industry, however the country is the world's largest sugar consumer, coupled with the fact that the manufacturing costs of ethanol is similar to that of petrol/diesel. The higher cost of cultivation of sugarcane/beets, highly sensitive molasses rates, and the resultant instabilities in the prices has created a ground to search for shift to other bio-diesel options.

In January 2003, the Government of India launched the Ethanol Blended Petrol Programme (EBPP) in nine states and four Union Territories promoting the use of ethanol for blending with gasoline and the use of biodiesel derived from non-edible oils for blending with diesel (5% blending). In April 2003, the National Mission on Biodiesel launched by the Government identified *Jatropha Curcas* as the most suitable tree-borne oilseed for biodiesel production. Due to ethanol shortage during 2004-05, the blending mandate was made optional in October 2004, and resumed in October 2006 in 20 states and 7 Union Territories in the second phase of EBPP. These ad-hoc policy changes continued until December 2009, when the government came out with a comprehensive National Policy on Biofuels formulated by the Ministry of New and Renewable Energy (MNRE) which targeted a 20 per cent blending of biodiesel and bioethonal with mineral diesel and gasoline respectively.

1.5 National Biodiesel Mission 2009

National Biodiesel Mission was proposed in a Planning Commission report of the Committee on Development of Bio-fuel, with an aim to meet 20 per cent of the country's fuel requirements with biodiesel by 2011-12. The policy aims at mainstreaming biofuels and, therefore, envisions a central role for it in the energy and transportation sectors of the country in the coming decades. The policy is expected to bring about accelerated development and promotion of the cultivation, production and use of biofuels to increasingly substitute petrol and diesel for transport and to be used in stationary and other applications, while contributing to energy security and climate change mitigation, apart from creating new employment opportunities and leading to environmentally-sustainable development.

The key aspect of the policy is to employ non-edible oil seeds cultivated on marginal and wastelands to achieve this target. After extensive research, jatropha seed was considered feasible for oil extraction in Indian Biodiesel mission. It would concentrate on producing enough feedstock for production, testing the viability of processes and to inform and educate the potential participants. The Indian government initially intended to plant jatropha on 11.2 million hectares of wasteland by 2012 and achieve a 10% blending target. However, biodiesel production costs surpassed its purchasing price (which is predetermined by national regulators on a six month basis), thus effectively hindering the ambitious targets proposed by the government. jatropha has never been grown as a commercial crop and its long term response to drought conditions and poor soil fertility is uncertain. Added to this, very little is known about its seed and oil yields when grown in relatively dense block plantations (Achten *et al.,* 2008). The plant's response to fertilizers, water and pruning has not been well established in planting and management practices that vary widely. The annual growth and biomass production are highly variable - even between adjacent plants in the same filed - because the plant material has not yet been defined (Divakara *et al.,* 2009). Large scale cultivation of jatropha must be established before biodiesel production can meet even a 5 per cent blending requirement nationally. However, amid reports of unavailability of the jatropha seed and the overall negative energy balance of biofuel processes, the National Biofuel mission and policy recommendations seems to hang in jeopardy (Negi *et al.*, 2006; Gonsalves, 2006; Singhal and Gupta, 2012).

The target set by the Planning Commission, to be achieved through jatropha cultivation, on wastelands, leads to several unanswered questions. In India, the true availability of wastelands is highly uncertain, a situation largely caused by the overlapping and improper classification of common land, wasteland, and pasture land (Agoramoorthy et al., 2009). The classification of wastelands in India is very ambiguous, with several reports coming up with several different estimations (Table 8). According to the Mohan Dharia Committee on wastelands (1995), who studied the land use statistics available for 305 million hectares out of the 329 million hectares land in the country, there is much confusion regarding wastelands in India ranging from 38.4 million hectares reported by Department of Agriculture and Cooperation to 75.5 million hectares reported by National Remote Sensing Agency (NRSA-1995) to 187million hectares reported by the National Bureau of Soil Survey and Land Use Planning (ICAR). The TERI (2005) report notes that about 5.6 million hectares of wastelands have been allotted to many poor families under various programmes, in addition to a large amount of encroachments for which there is no proper record. Given the widespread poverty in the developing countries that there is no such non-productive or wasteland as the more marginal people are more dependent on land for their livelihood and for their day to day survival.

A government's definition of degraded or wasteland is perhaps informed by the land's previous productivity or by the current absence of agricultural systems that produce commodities for the world market, i.e., bringing in foreign currency and/or tax revenue, which is in odds with the view by local people (Dan Van der Horst and SaskiaVermeylen, 2011). Estimates of biodiesel capacity based on wasteland availability are therefore likely to be inaccurate, which may create misleading cost-benefit analyses. When combined with highly variable seed yields, the displacement of informal land uses creates large uncertainties when determining the implications of widespread jatropha plantation development.

Table 1.8: Wasteland Status in India

Sl. No.	Report	Waste land (m.ha)
1	Dept of Agriculture and Cooperation	38.4
2	National Remote Sensing Agency	75.5
3	National Bureau of Soil Survey and Land use	187
4	National Waste Land inventory Project (2000)	63.85
5	National Waste Land Updation project (2003)	55.64
6	Ministry of Rural Development (2010)	47.3
7	Wasteland Atlas of India 2010	63.85

Source: Mohan Dharia Committee (1995) and Wasteland Atlas of India

In the long term, lingo-cellulosic materials are likely to become the primary source of biofuels. It is important in each particular case to evaluate the sustainability of raw material production to ensure that biofuels are developed in areas that do not affect the use of the basic resources of agricultural ecosystems such as soil, water, air and biodiversity (World Energy Council, 2010). Although biofuels for aviation and shipping seem to be the most suitable solution, the implications for land use are enormous for the development of road transport biofuels (Philip *et al.,* 2013). A major debate continues world over about biofuels production and its impact on traditional agriculture, i.e., the perceived competition for land and the risk of displacing production of human and animal food by biofuels. Although land devoted to fuel production could reduce land available for food production, this is at present not a serious problem.

It is against this background that an Indo-US bilateral JCERDC project for Development of Sustainable Advanced Ligno-Cellulosic Biofuels Systems was initiated in America and India with multiple partners in Consortium in each country. The Consortium was led by the University of Florida (UF) in America and the Indian Institute of Chemical technology (IICT) in India. There were three work packages in the project. First work package was responsible for the development of new feedstocks biofuel production and was led by International Research Institute for Semi-Arid Tropics (ICRISAT). Second work package was led by Indian Institute of Chemical Technology (IICT), Hyderabad and was responsible for the chemical analysis leading to ethanol production and the third work package component was related to Sustainability, Marketing and Policy of Biofuels. The Centre for Economic and Social Studies (CESS) was associated with the third work package component in the state of Madhya Pradesh and looked into the socio-economic and Life Cycle Analysis of biofuels production through cultivation of Jowar and Bajra feed stocks in India. As a part of this work, CESS has conducted a baseline survey and two rounds of survey of Multi Locational Trials (MLTs) of High Biomass Varieties of Jowar and Bajra in farmers' fields in the state of Madhya Pradesh.

1.6 Research Objectives and Methods

Indo-US bilateral Joint Clean Energy Research and Development Centre (JCERDC) project for Development of Sustainable Advanced Ligno-cellulosic Biofuels Systems had an important work package component of Sustainability, Marketing and Policy. In this project as mentioned above the Centre for Economic and Social Studies (CESS) looked into the socio-economic and Life Cycle Analysis of biofuels production through cultivation of Jowar and Bajra feed stocks in India with the following objectives:

1.6.1 Objectives of the Study

1) To understand the Socio-economic aspects of sample farmers in the state of Madhya pradesh.
2) To assess the economics of Jowar and Bajra crop cultivation of the sample farmers.
3) To understand the impact of biofuel cultivation on food and fodder security and examine the drivers and barriers in cultivation of biofuel crops.
4) To conduct Life Cycle Analysis of Sorghum and Bajra feed stocks for biofuel production
5) To contribute to the overall policy discourse on biofuels cultivation in India.

1.6.2 Study Area, Data Collection, and Methodology

The total crop area covered in India during 2012-13 was 165,098 thousand hectares. Out of this Kharif and Rabi area was 103,849 and 61,249 thousands respectively. In Madhya Pradesh during the year 2012-13, the total cropped area was 23,461 thousand hectares. The area under Kharif and Rabi crops was 12,025 and 10,316 thousand hectares respectively. Table 1.9 indicates that Maharashtra and Rajasthan ranked first in the area under jowar and bajra cultivation respectively, followed by Karnataka and Rajasthan in case of jowar and Maharashtra and Karnataka in case of bajra. However, the JCERDC Project on Sustainable Advanced Lignocellulosic Biofuel Systems (SALBs) has decided to work in the states of Madhya Pradesh and Gujarat. One of the important reasons for choosing Madhya Pradesh could be the presence of Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalay (RVSKVV) and the strong support they extend in conducting the multi-locational trials in the research stations as well as farmers' fields. CESS is coordinating the work package component of SALBs in the State of Madhya Pradesh (MP) and hence has undertaken the baseline study during the year by May 2013. It can be seen from table 1.9 that the biofuel crops jowar and bajra account for only 3.78 per cent and 5.32 per cent respectively to the total cropped area covered.

1.6.3 Basic Demographic Features of the Madhya Pradesh State

In Madhya Pradesh, the total population (Census 2011) is 72.6 million as against India's 1210.6 million. The growth rate of population in India during the last decade is 17.7% whereas it is 20.3% in Madhya Pradesh. The sex ratio in Madhya Pradesh which was 919 in 2001 has increased by 12 points to 931 in 2011 (as against India's 933). In India, the proportion of the Scheduled Caste population constitutes 16.6% of the total population according to the2011 Census and it is 15.6% of the state's population in MP. Contrary to this, the Scheduled Tribe population constitutes 21.1% of the state's total population whereas at the all India level it is only 8.6%(2011 Census). The effective literacy rate in Madhya Pradesh is 69.3% (Rural - 63.9%; Urban - 82.8%) marking an increase of 5.6 percentage points (6.1 percentage points in rural areas and 3.4 percentage points in urban areas) during the last decade. In Madhya Pradesh, as per Census 2011, out of 31.6 million total workers, 9.8 million are cultivators and another 12.2 million are agricultural labourers. Thus, nearly 69.8% of the workers are engaged in agricultural activities compared to nearly 71.5% in Census 2001. Therefore, still more than two-thirds of the total working population is engaged in agricultural pursuits either as cultivators or as agricultural labourers. Two out of every three males and four out of every five females are engaged in agricultural activities either as cultivators or as agricultural labourers. Of the remaining workers, 1.0 million are in household industries and 8.6 million are among other workers.

Table 1.9 : Area under different cereal and millet crops in India during 2011-12 (000' hectares)

State	Rice	Jowar	Bajra	Maize	Ragi/ Maura	Wheat	Barley	Other Cereals and Millets	Total Cereals and Millets
Andhra Pradesh	4096	276	43	864	42	8	-	29	5358
Arunachal Pradesh	124	-	-	47	-	4	-	22	196
Assam	2537	-	-	21	-	53	-	6	2617
Bihar	3324	2	5	675	8	2142	11	6	6172
Chattisgarh	3774	5	0	104	8	109	3	149	4151
Goa	47	-	-	-	0	-	-	-	47
Gujarat	836	124	867						
(3rd)	516	16	1351	-	69	3779			
Haryana	1235	65	577						
(5th)	9	-	2522	42	-	4450			
Himachal Pradesh	77	-	-	294	2	357	22	6	758
Jammu and Kashmir	262	-	19	314	-	296	7	14	913
Jharkhand	1469	1	-	216	12	159	-	-	1856
Karnataka	1416	1142							
(2nd)	286								
(6th)	1349	680	225	-	24	5122			
Kerala	208	-	-	-	-	-	-	-	209
Madhya Pradesh	1662	395							
(4th)	179								
(7th)	863	-	4889	81	249	8318			
Maharashtra	1543	3279							
(1st)	838								
(4th)	881	130	843	3	67	7548			
Manipur	224	-	-	25	1	2	-	-	251
Meghalaya	109	-	-	17	-	-	-	2	129
Mizoram	39	-	-	7	-	-	-	-	46
Nagaland	182	-	1	69	-	3	1	9	263
Odisha	4005	9	3	103	55	2	-	17	4193
Punjab	2818	-	3	126	-	3528	12	-	6487
Rajasthan	134	554 (3rd)	5020						
(1st)	1046	-	2935	278	16	9983			
Sikkim	12	-	-	40	5	3	1	3	63
Tamil Nadu	1904	198	47	281	83	-	-	30	2544
Tripura	266	-	-	4	-	-	-	-	270
Uttarakhand	280	-	-	28	125	369	23	72	897
Uttar Pradesh	5947	192	888						
(2nd)	787	-	9731	158	9	17712			
West Bengal	5434	-	-	98	8	316	2	1	5859
Total	43964	6242	8776	8784	1175	29847	644	800	100191

Source: Ministry of Agriculture, GOI 2012.

Even today, two-thirds of the total working population are engaged in agricultural pursuits either as cultivators or as agricultural labourers. Majority of the farmers are small and marginal farmers. Madhya Pradesh has the distinction of much diversified livestock resources. In MP, agriculture has been undergoing many changes over the past two to three decades and today it stands first in the country with respect to agricultural transformation growth. The increasing intervention of the state in agriculture, and the green and yellow revolutions, have prompted agricultural changes throughout the semi-arid regions, especially in land ownership, cropping patterns, irrigation, credit and extension, agricultural productivity, prices and marketing. The use of fertilizers was lesser in MP than the national average. In the year 2012-13, the total NPK per hectare consumption was 84.8 kg/ha as against the India's 128.11 kg/ha (Fertiliser Association of India, 2013). All the above-mentioned aspects have a huge bearing on the biofuels cultivation, especially in the dryland regions. It was in this context that Madhya Pradesh was selected as the study site by CESS to carry out the baseline survey and other suveys with farmers involved in multilocational trials. These different round of studies focused on the socio-economic, ecological, food security, and livelihood dimensions of biofuels production through the food crops such as Sorghum and Pearl millet.

The selected districts were Gwalior, Khargone, Dewas, Morena and Bhind. Districts hosting Sorghum and Pearl millet in large areas, were selected for the study. A total of ten villages were selected from five districts where the trials of high biomass feedstocks are to be conducted by work package one partners of the project. Stratified proportionate random sampling was used covering 333 farmers belonging to different size classes in 10 villages (See table 1.10). The study used both qualitative and quantitative methods for understanding the farmers socio-economic and ecological aspects of jowar and bajra and the awareness about biofuels production through these crops. Personal interviews were conducted with a structured interview schedule. The study used an *ex post facto* research design and Focused Group Discussions (FGDs). Secondary data on land use, fertilizer use, and demographic features of the district were collected from the survey reports by the Directorate of Census, Madhya Pradesh, Fertiliser News, and Ministry of Agriculture.

1.6.4 Household Questionnaire

A structured questionnaire was used to collect the data from the selected sample households from the ten selected villages. The interview schedule, comprising the measurement of variables was prepared in consultation with experts, keeping in view the objectives of the study. Piloting of the questionnaire was done in Santa and Janarpura villages outside the sample area. In the light of the experience gained in the pre-testing, suitable modifications were made before finalizing the interview schedule. The field survey was carried out during May to July 2013.

Table 1.10: Details of the sample households selected for the baseline study in Madhya Pradesh

District/ Block/Village	Total Landed Households in the village	Total Jowar/ Bajra Households in the village	Sample Households				Total Sample
			0.1 - 2.5 acres	2.51 - 5.0 acres	5.1 - 10 acres	10.1 and above	
<u>Gwalior District</u>							
Bijoli	332	119	12	8	1	1	22
Daheli	110	107	5	4	5	3	17
Jhakara	368	350	23	17	6	6	52
Morena District							
Ummedganbhasi	372	362	38	12	8	4	62
Nahardowki	144	142	12	6	3	1	22
Khargone District							
Nagazari	475	357	21	14	12	7	54
Rupkheda	167	103	5	9	1	0	15
<u>Dewas District</u>							
Nagdha	250	114	9	4	3	1	17
Chinvani	133	113	9	5	3	1	18
Bhind District							
Baraha	374	363	27	13	6	8	54
Total sample			**161**	**92**	**48**	**32**	**333**

Enumerators were used for collecting the information through the household questionnaire. In the beginning, the selected enumerators were given three days of training at Rajamata Vijayraje Krishi Vishwa Vidyalay (RVSKVV) on how to canvas the questionnaire and help them to understand the general issues of jowar and Bajra cultivation. After the training exercises, a trial field visit was undertaken to one of the five sample districts where enumerators were asked to canvass the household interview schedule. This was useful for enumerators to get to know the local conditions and clarify further doubts on the concepts used in the questionnaire.

The structured questionnaire used for the baseline study covered aspects such as household description, demographic particulars, farm cycle, land-related plot-wise details, farm economics, crop-wise cost of cultivation, livestock economy prevalent in the village, household savings and credit details, household expenditure, migration details of household, awareness on biofuels and questions related to farmers' response with respect to biofuels vis-à-vis food/fodder security.

1.6.5 Focused Group Discussions (FGDs)

FGDs were conducted with land owners of all sizes of holdings. The objective of these discussions was to have a general idea on jowar and bajra cultivation and the related issues. FGDs helped to understand the livelihoods, food and fodder security issues of biofuels. This helped to bring out the perspectives of various categories of people with reference to jowar and bajra cultivation for biofuels production.

1.6.6 Methods for Data Analysis

The data analysis was basically conducted in two ways. One was comparing between the various size classes of large, medium and small farmers. The results of the study are discussed at two levels: one at the household level and the other at the plot level. The data gathered was analysed using different statistical tools. Averages, frequency and percentages were used to analyse the various information related to jowar and bajra cultivation.

1.6.7 Scheme of Presentation

The monograph is organised in 7 chapters. Chapter one gives an introduction to this work. In this chapter, the overall scenario about biofuel cultivation in India is presented. The research objectives and methods are discussed in this chapter. The second chapter reviews the literature on biofuels cultivation in general and Indian experiences in particular. Drivers and Barriers of biofuels are discussed in third chapter. The fourth chapter discusses the socio-economics of sample households. Data on demographic features, land use patterns, livelihoods, socio-economic aspects of the sample households are discussed in this chapter. Empirical analysis of multi-locational field trials conducted by scientists of International Crop Research Institute for Semi-Arid Tropics (ICRISAT) and Indian Institute for Millet Research (IIMR) are discussed in fifth chapter. Life Cycle analysis is presented in the sixth chapter. The final chapter presents the summary of the study followed by conclusions and policy recommendations and way forward.

CHAPTER - 2

Review of Literature

The study tried to review the experiences from existing literature both from the global context in general and the Indian context in specific. Though there has been little research on Biofuels in India, most research projects are confined to jatropha cultivation and issues related to it. The following section reviews the various issues relating to Biofuels including the national biofuel policy. In India little research has been done on the socio-economic, ecological, food security, and livelihood dimensions of biofuels cultivation, especially on the impacts of the biofuels production from main dryland staple food crops such as Sorghum and Pearl millet. In this study, an attempt has been made to critically review different studies, which have a direct and indirect bearing on the Biofuels cultivation. This review also looks at the sustainability of large-scale biofuel projects and their impact in delivering twin benefits of energy security and environmental sustainability.

Mario Giampietro *et al.,* (1997) assessed the feasibility of biofuel production as an alternative to oil by relating the performance of the biofuel energy system to the characteristics of both the socio-economic and environmental system in which the biofuel production and consumption takes place. They highlighted that biofuel can substitute for fossil energy only if the large-scale production of biofuel is biophysically feasible (i.e., not constrained by the availability of land and fresh water sources of energy crop production), environmentally sound (i.e., does not cause significant soil degradation, air and water pollution, or biodiversity loss); and compatible with the socio-economic structure of the society (i.e., requires labor productivity that is consistent with the existing labor supply and per capita energy consumption in the society). They observe that the biofuel system must deliver a sufficiently large amount of net energy to the society per hour of labor employed in the cycle of biofuel production to make the process economically convenient for the society, while generating a sufficiently low environmental loading per unit of net energy supplied to keep the process environmentally sound. They concluded that large-scale biofuel production is not an alternative to the current use of oil and is not even an advisable option to cover a significant fraction on it.

George Francis *et al.,* (2005) in their article "A concept for simultaneous wasteland reclamation, fuel production and socio-economic development in degraded areas in

India: Need, potential and perspectives of jatropha plantations" highlighted the need for alternative energy for India in the wake of its ever-growing transport needs. Noting that there is more than potential mismatch between the demand and supply of energy needs, they pitched for producing biofuel from jatropha on eroded soils as it promises to achieve both wasteland reclamation and fuel security goals which is in line with Government of India's policy of national development. The authors pitched for the cultivation of jatropha given its advantages to achieve the triple benefits of transportation substitution fuel, soil protection, and economic development. Citing the example of Soybean bio-diesel, they opined that the lifecycle analysis shows that it can reduce CO_2 and SO_2 emissions by 80 and 100 per cent respectively compared to petro-diesel. They further opined that the life-cycle carbon dioxide emissions resulting from the production of bio-diesel from low-input, no-tillage, perennial jatropha plantations (no application of chemicals) would be lower and is likely to be less than 15 per cent compared to petro-diesel.

The study centers on preliminary economic analysis of the production system over a period and is based on the productivity of plants on degraded and currently unusable land with poor soils that have no opportunity costs. While an estimated net internal return of 21.8 per cent can be generated per hectare of jatropha plantation, about 16 per cent internal return is expected for a small-scale biodiesel production plant with processing capacity of 2,000 tons of raw vegetable oil per year. At the same time, the cost of producing a liter of biodiesel stands at 0.50 dollars. Though the results seem to be very viable, they are not produced under the assumption of steady yields and large-scale cultivation, which however proved to be impractical under the Indian circumstances.

Domac J *et al.,* (2005) pointed that monetary gains and employment generation are viewed as the prime drivers of the present bio-energy projects. The authors ascertain that given the extreme complex nature of bioenergy and its linkages with a number of aspects, the bioenergy debate should not just be focused on the net return and employment, but, in effect, look into the various other aspects which include social, cultural, institutional and environmental issues. The paper clearly depicts significant contribution of bioenergy as a labor-intensive technology, having the potential of creating employment at national, regional and local levels. However, the employment depends on the different processes employed and the different stages of the conversion process. The authors also ascertain that there is a huge difference between the bioenergy sector in the developed and the developing countries given its various linkages and complexities in it. In developing countries, though bioenergy can provide positive employment and income particularly during the off-harvest season, the current practices employed would make it unsustainable and hence, there is a need for modernizing traditional practices.

Larson (2006), summarizes the results of literature published on LCA studies of liquid biofuels in the transport sector. The review chiefly focuses on the impacts that the production and use of biofuels might have on emissions of GHGs relative to conventional petroleum-based fuels. The study highlights the drawback of lack of proper LCA analysis in the developing countries. He notes that almost all biofuel LCA studies have been undertaken in the European or North American context, while only one good study was available for Brazil and India (both based on ethanol produced from sugarcane). The author rightly observes that though the European and North American context studies provide indicative results, given the context-specific variability and uncertainty around the input parameter values in the LCA analysis, country-or at least region-specific studies are needed for providing quantitatively more meaningful results. The review also highlights the wide range of results in terms of net energy balances and the net greenhouse gas emissions (expressed in terms of equivalent CO_2) reported for a given biofuel and originating biomass.

Quirin *et al.*, (2004) suggest that the results for any single biofuel pathway span a large range in the per-km savings relative to the use of fossil fuels. The authors note that it is difficult to arrive at unequivocal conclusions regarding the precise quantity of energy and environmental benefits given the diversity of the LCA results. They ascertain that in order to understand the diversity there is a need to examine the details of each study regarding analytical boundaries, numerical input assumptions, and methodologies used to generate the results. They conclude that higher GHG savings with biofuels are likely to be achieved only when there are high and ecologically sustainable biomass yields.

Muller *et al.,* (2007) perceive that the food vs fuel debate regarding biofuels is unwarranted as there is no imminent global shortage of land and water to grow a substantial amount of biomass both for food as well as bio-energy production. Though the growing demand for bioenergy will have a negative effect on food as higher food prices increase food insecurity among the poor; on the positive side higher prices and more marketable production can stimulate the agriculture sector by creating better employment opportunities. However, the authors agree that uneven distribution of natural resources, resulting in regional differences would continue to have negative consequences unless trade-related areas are addressed.

Rajagopal (2007) highlights the drawbacks in India's biofuel policy given the fact dependence of rural poor on wastelands for diverse purposes. The national biofuel mission emphasizes cultivation of biofuel crops on wastelands; however, majority of these lands are classified as Common Property Resources (CPR), meaning that the community owns the resources collectively. Quoting Haripriya Gundimeda (2005), the author establishes that the CPRs contribute between 12 - 25 per cent of the poor household income, and the poorer the household the greater the dependence on CPRs. The study also highlights the loopholes in the categorization of land as wasteland in India, given the change in parameters according to the regions and crops grown. The author states that conflicts are bound to exist if appropriation of wastelands happens without involving of the local communities in decision making, in addition to the problems of the lack of prior experience and absence of minimum support prices for biofuel crops. The author suggests cultivation of multi-purpose short duration crops that can simultaneously yield food/fodder fuel in rotation with food crops as an alternative approach such that even small private farmers can benefit from the opportunities that come from biofuel crops.

Sunil Kumar *et al.*, (2008) in their study on "Economic sustainability of jatropha biodiesel in India", assess the feasibility of bio-fuel production in terms of cost factors. They highlight the necessity of biofuel with reference to fuel shortages and international crude price fluctuations that frequently affect the country. The study also assesses the productive opportunities that are supposed to be created by the bio-fuel industry with reference to employment generation, and reclamation of waste and degraded land. It is estimated that crops such as sunflower, rapeseed, and tree-borne oil seeds such as *Jatropha Curcas* provide rich biomass and nutrients to the soil and check degradation of land - a major problem affecting nearly 65 million hectares in the country. Quoting the Planning Commission's report, they estimate that out of 130 million hectares of wasteland in India, about 33 million are available for reclamation through tree plantation. An economic analysis of feasibility of biofuels in the country done using both primary and secondary data from Bhopal industry shows that while the cost of bio-diesel (specific gravity of 0.85) per liter stood at Rs.30.91, while the retail price stood at Rs.37.81, which is much lesser than the international crude prices. Considering the economics, the authors concludes that jatropha bio-diesel can be more economical than petroleum diesel in the Indian scenario. However, they are of the opinion that though biofuel blending is the need of the hour, nobody in the country is in favor of the implementation of high-tech agrarian methods that need maximum inputs to deliver bumper crops.

Pradip Kumar Biswas *et al.*, (2010) in their research article, "Biodiesel from Jatropha: Can India meet the 20 per cent blending target?" attempt to make an assessment of the state of India's biofuel programme and to identify the hurdles that policy makers need to overcome to achieve the goal of 20 per cent blending. Due to the non-feasibility of using edible oils in India - as the domestic consumption demand often exceeds domestic production, jatropha presents a viable option given its shrubby nature and short gestation period that makes harvesting easier. Added to this, seed collection of jatropha does not coincide with the rainy season when most agricultural activities take place, thus making it possible for people to generate additional income in the lean season, not to forget the general advantage of the plant vis-à-vis pest resistance and ability to survive on less fertile land. The authors discuss the important question of availability of land for jatropha cultivation and the methods to bring land under it. While addressing the bottlenecks of biofuel programme and as a conclusion, the authors present the state of commercial production of biodiesel in the country. The first important bottleneck with reference to large-scale production of biodiesel using Jatropha is the different and divergent opinions about the identification and estimation of wastelands/fallow lands in the country. In order to meet the Planning Commission estimated target of 20 per cent blending by 2016-17, the authors project that the need of the hour as economies of scale or large-scale production that reduces prices. The Planning Commission estimates that 20 per cent blending requires 17 million tons of biodiesel that has to be cultivated over 14 mha. However, availability of wastelands, issue of ownership, capital investment, long gestation period, risk of mono-culture, yield fluctuations in different climatic zones, handicaps in terms of extraction technology and most importantly the issue of price fluctuations, large-scale production of biofuel using jatropha is not feasible in the country. Referring to the approach paper to the mid-term appraisal by TERI (2005) they note that in both forest and government owned wastelands, local communities are not willing to participate unless land ownership is given to them. The authors conclude that the success of the biofuel programme in India depends on solving various problems ranging from land identification, identification of farmers, diffusion of high-yielding crops, and scale of processing plants, prices and subsidies to provide incentives to various stakeholders.

Giovanni Sorda *et al.*, (2010) review the national strategy plans of the world's leading producers over the last decade, with particular attention to blending targets, support schemes, and feedstock use. The article aims to identify the driving forces behind the recent growth of biofuel production, while also focusing on the agricultural products that are directly affected by local support schemes. The authors note that the last ten years (2000-2009) witnessed an increase of fuel ethanol output from 16.9 billion liters to 72 billion liters, while that of biodiesel grew from 0.8 to 14.7 billion liters. This is chiefly driven by government interventions such as mandatory blending targets, tax exemptions, and subsidies. In addition to production and consumption-driven interventions, the government has also intervened on the production chain by supporting intermediate inputs (feed stock crops), and subsidizing value-adding factors including capital and labor, not to forget the import tariffs that protect the domestic industries.

The authors note that without government intervention, production is unprofitable and needs to be driven by external incentives in the form of tax exemptions, subsidies, or any other form of financial incentives. In addition to these strongly distorting policies and criticism on food security, the biofuel lifecycle assessment highlighted a negative net contribution to a reduction in GHG emissions. Hence, the need for second generation of fuel crops is necessitated, which focuses on non-food crops. Given these new challenges and concerns, many countries are adopting new legislations. While the US and EU now require substantial reduction in GHG lifecycle emission, the impact on bio-ethanol and biodiesel production on indirect land use has also been taken into consideration as manufactures now have to certify the origin of the feedstock. Germany, on the other hand, has set its future biofuel targets in terms of GHG reductions rather than output volumes. However, the authors note that it would be a demanding task to couple capacity expansion with environmentally substantial production, while at the same time limiting biofuel burden on the state budgets.

The study by Pere Ariza Montobbio and Sharachandra Lele (2010) on "Jatropha Plantations for biodiesel in Tamil Nadu, India: Viability, Livelihood Trade-offs and Latent Conflict", focuses on the dimensions of productivity, economic viability, and distribution and latent conflict of biodiesel plantations both at the farm level as well as the household level. They also studied how these observations vary across different socio-economic classes. They argue that integrated assessment of large-scale biofuel production has a 'very low energy return on investment compared to fossil fuels, while at the same time imposing heavy demand on land, water and labour per net GJ delivered. They observe that the government's promotion of cultivation on private lands using state-supported and corporate-supported contract farming approaches in regions of poverty, agrarian distress, and water scarcity have the potential to spark unanticipated conflicts. Citing Fargione *et al.,* 2008, they say that the claimed positive GHG emissions balance will be compromised by the "biofuel carbon debt" of converting forest or shrub ecosystems to energy crops.

The results of the primary study conducted in Tamil Nadu found that the yields are much lower than expected and its cultivation is currently unviable and even its potential viability is strongly determined by water access. Rather than alleviating poverty, the crop impoverishes farmers particularly the poorer and backward sections and also promotes conflict between state and farmer and between different socio-economic classes. Agronomic assessment found that jatropha requires at least three years to start giving consistent economic yields. Though survival rates are high, they differed between rain-fed and irrigated areas, with plots in the irrigated areas reporting better survival. In accordance to the existing literature, the study found that jatropha has high water footprint, as per unit consumption of this plant is 1.5 times more than soya bean and 5 times more than sugarcane/maize. The highest yield in a three-year old plantation ranged from 450 kg/ha in rain-fed areas to 750 kg/ha in irrigated areas while the globally reported yields show high variability ranging from 0.4 to 12 tonnes/ha.

The economic viability of the plantations studied under three different scenarios of plots - irrigated with electric pumpset, plots irrigated with diesel pumpsets, and rain-fed crops, showed that considering current yields, the net returns are always going to be negative even for irrigated farmers, when assumed that the best case results are at three-year plant maturity (which however is not the reality). When the economic viability of jatropha is compared taking into consideration the opportunity cost of cultivating groundnut, it yielded unprofitable scenarios even under the assumptions of generating experimental level yields and non-factoring of interest burden. Given these poor agro-economic performances close to 30 per cent of the plantations were removed and the other 50 per cent were kept without maintenance.

The impact on livelihoods has also been assessed considering the changes in the items that are valued outside formal markets. It has been noticed that even when the cultivation becomes economically viable, it benefits only large landholders and not people from the lower sections of the society. Crop choice has complex implications for labour demand. Many of the activities in the livelihood portfolio are complementary and address different needs of the household; hence they cannot be conceptually aggregated into a single measure of income. The study also found a significant negative impact on food security as 82 per cent of the respondents were cultivating food crops in the plots which have been now shifted to jatropha and 50 per cent of the total landholding of household converted to this cultivation. A negative tradeoff has been noticed when the opportunity cost of not cultivating groundnut is taken into consideration - an additional Rs.3500 per year per household is incurred with regard to expenses for food (cooking oil), wage labour, and fodder (from biomass of ground; one acre of groundnut or paddy yields cart load of paddy feed bullocks for two months).

Martin Banse *et al.*, (2010) in their research article, "Impact of EU biofuel policies on world agriculture production and land use", discuss the impact of policies by extending the global general equilibrium model Global Trade Analysis Project (GTAP) by including biofuel crops into the analysis. Though the extension does not present biofuels as separate products for final consumption, it enables analysis of the impact of targeted policies such as tax exemptions and obligatory blending for the petrol sector for individual regions and countries. The authors say that though biofuels provide additional income for farmers in an otherwise saturated market, there are also concerns as they tend to increase the volatility of agricultural world prices by linking them with crude oil prices.

The results of the analysis show that enhanced demand for biofuel crops under the EU mandate has strong impact both at the global as well as regional level. The long term trend of declining real world prices of agricultural products slow down or may even be reversed for the feedstock used for biofuels. At the same time, increased incentive to produce also tends to increase land prices in many regions, especially in the South and Central Americas. However, the results depend on the fluctuations of global crude oil prices on the higher side - the higher the crude oil prices, the more competitive the biofuel crops become. The analysis also establishes that the projected changes in production of biofuels would have environmental side effects. As biofuel crops are dependent on scarce resources such as land, water, and other agricultural inputs, they tend to effect the CO2 balance, soil erosion, and biodiversity. Furthermore, long run investments in R&D, higher yield varieties, better conversion technologies, coupled with strong government intervention are needed for the industry to be competitive. The study also ascertains the need for spatially explicit analysis at the regional level to measure the actual effect of biofuel crop cultivation.

The study by Findalter and Kandilkar (2011) about second generation biofuel stocks in Rajasthan observed the specific local impact of rapid Jatropha plantation development on both government and private lands on rural livelihoods. The study is based in Jhadol Tehsil of Rajasthan, a predominately semi-arid district and a demography dominated by Scheduled Tribes. Jatropha grows naturally in this Tehsil and the villagers have traditionally planted it as a protective fence, while at the same time using its seeds to make soap. Given the relative abundance of wasteland, prior association of the plant to this region, a plantation boom was observed after the launching of the National Mission for Biodiesel in 2003, making this tehsil a frontrunner in the national biodiesel programme.

In Rajasthan, most of the wastelands to be leased in jatropha development are either government-owned or common land previously accessible to farmers and villagers for grazing, forage collection and resource gathering. The study observes that since the poorest villagers typically have the smallest landholdings if any, the disappearance of common grazing land affects them disapportionately, as the use of accessible common land for plantation development may have unintended local consequences by displacing grazing and forage collection. The study also found that the yields have been much lesser than anticipated and they have been handicapped in making use of public or private land, due to the reduction of grass levels on jatropha planted land. The most severely impacted farmers and villagers are those with the smallest landholdings - typically the poorest as they tend to be more heavily dependent on public land for forage. None of the participants reported substantial income from the selling of seeds. Added to this there is an additional burden on them as all the villagers indicated that they had to buy additional fodder in years of low rainfall.

The study by Peter Karacsony et al., (2011) examined the extent to which EU biofuel production and utilization can contribute to sustainable development of environment while at the same time producing long term socio-economic effects. The study notes that to achieve the EU agreement dated 2007, which specifies a 10 per cent component of biofuel mix for 2020 within total fuel consumption, the basic ingredients will have to be cultivated on 38 per cent of the EU soil area with the remaining shared between plant cultivation for food and fodder purposes. The study notes that food supply, biofuel industry, and environmental protection influence each other tightly, with safe supply of food being the most important. In the above connected system, the three factors namely, food, energy and environment compete with each other. Citing the Gallagher Report, they opine that biofuel production impacts safe supply of food which is already skewed due to the imbalance in the distribution of resources in the world. Added to the pressure on land, increase in cereal prices due to biofuels will have a direct impact on developing countries, while in developed countries where higher added animal meat is consumed, there is an indirect impact. The study also notes that the decrease of CO_2 and other GHGs by using biofuel depends on the raw materials, and the applied agricultural and production technologies. Citing IEA report on biofuels for Transport's Lifecycle Assessment, the study notes that the best result was reached by the cellulose-based second generation bioethanol (60-100 per cent GHG saving compared to conventional fuel), compared to 80-90 per cent of first generation sugarcane based ones.

Dan Van der Horst and SaskiaVermeylen (2011) in their article "Spatial Scale and Social Impacts of Biofuel Production", provides a critical examination of the impact of biofuel policies within the framework of social impact assessment for both developed and developing countries. The paper explores how the social impacts of biofuel production may be at odds with the push to increase the production of liquid biofuels as global commodities. The authors also attempt to find out when and why negative social impacts are likely to occur and under what circumstances more positive impacts might be expected. The authors note that though biomass energy has the potential to fulfill multiple objectives of environmental, social, developmental/economic, and supply security, in practice, the choice of specific policy designs and project types often privileges the achievement of one policy objective at the expense of another. They argue that policies that are designed for a narrowly-defined purpose of security of supply cannot be realistically expected to yield high social or environmental benefits. The production and use of biofuels is never carbon neutral, and at best it is less carbon-intensive than the petroleum products it displaces. Hence, the justification of promoting biofuels hinges to a large extent on the question of how to avoid these negative social impacts and how to obtain positive social impacts.

The authors assess the social impact of biofuels in relation to the Inter-Organizatcional Committee on Guidelines and Principles for Social Impact Assessment (IOCGP), which define social impact as the "consequences to human populations of any public or private actions that alter the way in which people live, work, play, relate to one-another, organize to meet their needs and generally cope as members of the society. They maintain that SIA guidelines can be more easily implemented in a more participatory process, leading to no negative social impacts, even though when a project causes social impacts beyond national boundaries, which tends to have negative impacts. The article highlights the social impacts of large-scale biofuel among developing countries under three heads namely, land used for increased production, distribution of the different benefits among different sections of society, and the impact of large scale cash crops on rural livelihoods. The authors conclude that none of them have a positive social impact.

The authors rightly note that the displacement effect is also not included in the LCA analysis of liquid biofuels, given that they require a much more interdisciplinary and multi-method approach. The study envisages that the involvement of rural communities in the production of liquid biofuels cannot be evaluated through simplistic proxies such as the number of jobs on the plantation or the average pay per worker. What is required is a much more detailed analysis of how the livelihood strategies and outcomes of rural communities and individuals are transformed by changes in land ownership, land management, and land use associated with the switch towards production of biofuel. The major finding of the study that though production of transport biofuels could bring positive social impacts, these are very unlikely to emerge as automatic by-products of the large-scale production of bioethanol or biodiesel, without strict regulation of the entire supply chain. Large scale and globalized production models are much more likely to result in negative social impacts, caused or exacerbated by the geographical, cultural and power divided between the governments and large companies that are driving this agenda forward and the individuals and communities affected on the ground.

Umesh Babu and Sunil Nautiyal (2012), in their study on "Socio-economic and Ecological Consequences of Biofuel Development in India", highlight that biofuels and their production have failed to address challenges such as the supply of water and food security for the growing population in India as well as many other developing countries in the world. Added to shortcomings such as food security and lack of market linkages, the article notes that biofuels which are made from crops require enormous amounts of water which is already getting scarce. Bioenergy is definitely an alternative for fossil fuels, but it will compete with water, which is required for food production. Referring to the report by Stockholm International Water Institute (SIWI), the authors note that by 2050, the amount of additional water needed for bioenergy production could be equivalent to the amount required by the agricultural sector. Hence, the biofuels are not 'the' solution but one of the solutions, and its production could be a great competitor to food production.

Meyer P. M *et al.,* (2013) assessed the Brazilian renewable sector which is considered as a pioneer not only in biofuel (sugar-based ethanol) production but also in the use of ethanol as motor fuel. While highlighting that ethanol substitutes for a little over half of all the gasoline that would otherwise be consumed in Brazil, they assessed how the bioethanol industry has affected livestock and agriculture production as well as environmental and socio-economic issues. They note that the success of Brazil's biofuel programme is due to greater consolidation as the gasoline contains 25 per cent of ethanol and its availability at all gas stations. Added to this, about 50 per cent and 90 per cent of the existing and new car fleet are "flex fuel" (dual fuel, running on any proportion of ethanol and gasoline). The authors argue that the lack of structural regulations created greater instability in the production and consumption of alternative fuels leading to cycles of fuel substitution with negative effects to all stakeholders. For example, the sector which grew at the rate of 10 per cent per year between 2000 and 2008, slowed down to 3 per cent after the financial crisis, creating supply constraints for ethanol-based cars.

Comparing different studies based on the regional scenarios of both ethanol and cattle industry in Brazil between 1997 to 2006, the authors conclude that the pressure exerted by the sugar-ethanol industry on livestock is negative, given the appreciation of land prices especially in the areas with high agricultural potential characterized by fertile and well-drained soils and flat topography. In addition to this, the bias of the sugar-ethanol industry to large urban centers further aggravates the problem and leads to shifting of lands from cattle cultivation to sugarcane cultivation. As of a result, livestock activity and the people who depended on this experienced three different situations: i) local migration where the farmers abandoned livestock rearing due to inadequate knowledge of sugarcane cultivation, thereby leasing out their lands. This phenomenon of rural exodus is more observed among small and medium farmers in the southeast region who migrated mostly to Sao Paulo. ii) Regional migration, which motsly affected medium farmers who exchanged their farms in the southeast region for extensive areas at the agricultural frontier in the midwest and northern regions, resulted in clearing of native forest areas to move cattle to untouched areas. iii) Technological migration - the pressure exerted by the bioethanol industry on livestock by rising land prices resulted in technological migration as it led to change from an extensive production system to an intensive production system that requires highly-specialized techniques.

Summary of review indicates that liquid fuels from biomass have already entered commercial markets in many countries especially as blends with gasoline and diesel. Though India has scope for developing biofuels for substituting conventional fuels and achieving energy security due to availability of raw material, a review of the existing literature points out that R&D, suitable policy support, and most importantly the global market balances are required for avoiding negative externalities. Given that a vast majority of the population and livelihoods are interlinked to the agriculture and its surrounding environmental balances, a fine blend of policy decisions and technological breakthroughs are the need of the hour for achieving positive social impacts or at least to do away with the negative social impacts. Achieving energy security for the country through alternate methods is an important area being focused by the Indian policy makers. However, any attempt to promote the use of major staple food crops such as Jowar and Bajra for biofuels production has a long-lasting impact on the food, fodder and nutritional security of millions of people and livestock in India. Cultivation of high biomass jowar and bajra varieties on a large scale could pose a serious threat to the existing rich diversity in these crops. Hence, even for trying out these crops at the research level, it is very essential to have a dialogue with the farmers of the dry lands, where these two crops are predominantly grown. The voice of small and marginal farmers and women should be heard before moving further into utilizing these crops for biofuel production. More importantly, we should learn from our earlier experiences of jatropha cultivation. Large-scale biofuel production is not an alternative to the current use of oil and is not even an advisable option to cover a significant fraction of it (Giampietro *et al.,* 1997). The production of feed stocks for biofuels would put additional pressure on agricultural resources such as land and water. Therefore, it is quite important that policies, plans and strategies for energy security do not conflict with other aspects of critical national importance like food security.

The review projects a mixed picture about the economic, environmental and social viability of biofuels. Except for the experiences related to jatropha, no literature is available with reference to biofuel production from food-based crops in India. Experiences from Europe and other South American countries however provide learning opportunities with regard to policy, technology barriers especially in terms of conversion, problems associated with trade linkages, and most importantly long-run economic viability. A strong synergy of rationales such as the prospect of reduction in external dependence, better environment and creation of additional employment opportunities make a strong case for promotion of biofuels in India. However, reviews suggest that it is difficult to achieve all of the objectives simultaneously and it would be a demanding task to couple capacity expansion with environmentally substantial production, while at the same time limiting biofuel burden on the state budgets. The outlook for biofuels is also highly sensitive to possible changes in government subsidies and blending mandates, which remain the main stimulus for biofuels use. Over the past year, much uncertainty has developed about how biofuel policies in several key markets will evolve (IEA, 2013).

The production and use of biofuels is never carbon-neutral, and at best it is less carbon-intensive than the petroleum products it displaces. There is also a huge difference between the bioenergy sector in the developed and the developing countries given its various linkages and complexities. In developing countries, though bioenergy can provide positive employment and income particularly during the off-harvest season, the current practices employed would make it unsustainable and hence there is a need for modernizing traditional practices. Most of the alternative energy policies are designed for a narrowly-defined purpose of supply security and cannot be realistically expected to yield high social or environmental benefits. Hence, the justification of promoting biofuels hinges to a large extent on the question of how to avoid these negative social impacts and how to obtain positive social impacts. The important barriers for successful implementation of biofuels come from the farmers - the chief stakeholders, and given the fact that India's majority livelihoods are linked and re-linked to agriculture, caution must be exercised in promoting biofuel production from food-based crops. Review reveals that there is limited work on this aspect in India and hence CESS has done in-depth research on "Socio-economic aspects and Life Cycle Analysis of biofuel production with reference to India.

CHAPTER - 3
Drivers and Barriers in Cultivating Biofuel Crops for the Production of Ethanol in India

3.1 Introduction

It is now an established fact that India is one of the fastest growing economies in the world. India's economy is growing at rapid pace and so are its demands. Rising per capita income, urbanisation, and infrastructure development has led to increased vehicle density, and consequently, increased demand for gasoline. A growing economy naturally means higher energy consumption which is critical to its social as well as economic development. According to the Energy Information Administration (EIA) website, India was the fourth-largest consumer of crude oil and petroleum products in the world in 2015 after the United States, China, and Japan. Most of India's demand for energy is met by the import of crude oil from the Middle East countries. Higher import of petroleum products leads to a strain on the economy by causing a trade deficit. Of all the sectors, the transport sector is the largest consumer of petroleum with more than fifty percent consumption and is also responsible for the emission of harmful Greenhouse Gases. Thus, there is pressure on India to look for alternative and environmentally benign sources that can fulfil its energy requirements in a sustainable manner as well as enhance its energy security. The Government, in order to promote biofuels, gives out various incentives and subsidies. The Government also necessitates that the biofuel crops be cultivated only on degraded 'or wastelands' that are not useful for the production of food grains so that there is no conflict between food security and fuel security. Despite all the encouragement, India has not been able to meet the demand for biofuels for various reasons. In this chapter, the main drivers and barriers of cultivating biofuel crops to produce ethanol are discussed.

3.2 India's National Policy on Biofuels

The Ministry of Petroleum and Natural Gas (MoPNG) under the Government of India first in 2002 issued a notification making it mandatory for 9 major sugarcane states and 4 Union Territories to implement 5% Ethanol blending in petrol compulsory from the year 2003 onwards. In 2003, the Planning Commission called for a phase wise implementation of biofuel blending across the country. Due to a shortage in the supply of ethanol, blending was made optional during the year 2004. It was resumed again in

October 2006 in 20 states. In 2007, 5% blending was again made mandatory across the country except J&K, the north eastern region and the islands. In 2008, the Government of India gave out the National Policy on Biofuels.

According to the policy the blending of bio ethanol with petrol was made mandatory from October 2008. An indicative target of 20% blending of both bio ethanol and bio diesel was set to be achieved by the year 2017. A new biofuel policy was approved by the cabinet in December 2009. These figures would be moderated based on the availability of biofuels from time to time. This policy also proposed to set up a National Biofuel Coordination Committee (NBCC). A Minimum Purchase Price (MPP) was also proposed where this minimum price of was to be based on the actual cost of production and import price of bio ethanol. This Minimum Purchase Price would be determined by a Biofuel steering committee. If ever the price of bio ethanol fell below the minimum price, it was the responsibility of the Government to compensate the Oil Marketing Companies (OMCs). The policy also supports biofuels by way of exemptions and concessions. Bio ethanol has a 16% concession of excise duty and bio diesel is exempted from excise duty. The policy also ensures that the biofuels that are produced indigenously are not costlier than the fuels that are imported. Further, farmers would be encouraged to undertake plantations of feedstock required for bio ethanol and bio diesel. The biofuel policy in India is different from that of other countries. In India, the production of biofuels would be based on the utilization of wastelands i.e. those lands which are not suitable for cultivating food crops. This ensures that there is no conflict between food security and fuel security. There would also be focus on the research and development on the production of biofuels so as to increase the efficiency of these fuels. With this policy framework on biofuels, the government of India embarked on a future towards a seemingly cleaner, efficient and economically rewarding energy policy.

3.3 Ethanol demand in India

India is the world's second largest sugarcane producer and a major manufacturer of molasses-derived ethanol (Biofuel Roadmap for India, 2008). According to the Ministry of Agriculture, in 2010-11 alone the four states of Uttar Pradesh, Maharashtra, Karnataka and Tamil Nadu contribute to more than 80 per cent of the country's total sugarcane production (MoA, 2012). Ethanol in India is primarily produced by the fermentation of molasses. It is estimated that 85-100 kg of sugar (8.5-10%) and 35-45 kg (3.5-4.5%) of molasses can be obtained from 1 tonne of sugarcane, whereas the recovery of ethanol from molasses is 22-25%, as per Indian standards. This means that, if the entire sugarcane crop (342.4 Mt in 2010- 11) is used for sugar production, estimated molasses production is 15.4 Mt, and the associated estimated ethanol yield is 3.6 billion litres (Purohit and Fischer, 2014). In reality, 70 to 80 per cent of sugarcane produced in India is used for sugar production, and the remaining 20 to 30 per cent is used for alternative sweeteners (jaggery and khandsari) and seeds (Raju *et al.,* 2009). Moreover, 32.5 per cent of the available molasses is used in alcoholic beverages, 25 per cent by industry, and 3.5 per cent for other applications. The surplus available alcohol is diverted for blending with transportation fuel.

3.4 Ethanol Production in India

In India it is ensured that biofuels are deliberately produced only based on non-food feedstocks. Hence bio-ethanol is produced mainly from molasses, a by-product of the sugar industry. It is produced from the fermentation of sugarcane molasses and sugar beet. It is also produced from starch containing crops such as corn and sorghum. But the ethanol production in India is mainly sugarcane centric. This is to ensure that a food vs fuel conflict does not arise as a result of growing non-food feedstocks on lands where food crops are grown. But there has been criticism that ethanol produces from sugarcane molasses alone will not be sufficient to cater to the present blending levels. Restricting ethanol production only to sugarcane molasses is neither sustainable nor economically viable. To increase the availability of ethanol and reduce over supply of sugar, the sugar industry has been permitted by the government to produce ethanol directly from sugarcane juice. But Ethanol production in India continues to face a lot of challenges. In what follows, the main drivers and barriers in the cultivation of bioethanol crops in India are discussed.

3.5 Drivers for Bioethanol production in India

There are several reasons for which biofuel production in general and ethanol production in particular are being encouraged not only in India but across the world. The following reasons are considered as the main drivers in the production of Ethanol. (Background Paper for the World Bank Group Energy Sector Strategy, March 2010)

(i) First is the notion of **energy security**. As mentioned earlier, growing population and its demands naturally require higher amounts of energy. The conventional fuels such as fossil fuels on which the world is majorly dependent are fast depleting. There is, hence, an immediate need to look for alternative fuels. Hence biofuels, which are derivatives of biomass are not only renewable but also help in decreasing the net import of oils from other countries. So energy security is a catchall term to mean increased reliance on domestically produced fuels so as to be insulated from the high volatility of oil prices by switching to bio fuels. Diversification of fuels means that even if the price of one type of fuel increases, it would not drastically affect the economy. Biofuels will be price takers as long as they comprise a small share of total fuel supply, but they can still influence world petroleum prices if they can contribute to sufficient additional supply.

(ii) Second, if a good market for ethanol is developed, growing ethanol crops such as corn or sugarcane more extensively will be profitable and result in higher revenues, making farmers well off, thus contributing to **rural development**. It also contributes to job creation and acts as a support to the agricultural economy. The entire biofuel industry can create a lot of jobs, especially in the rural areas. The production of biofuels is spread across various sectors. This includes growing the crops, construction of the refinery which takes at least two years thus creating temporary jobs; transportation of biomass to the plant also creates jobs and finally the operation of the bio-refinery also creates employment. This employment generation in turn simulates economic development. Expansion of biofuels has been seen as a way to increase demand for agricultural commodities, create jobs in more impoverished rural areas, and otherwise enhance rural development. This has been one of the main drivers in all countries promoting domestic production of biofuels through government support

(iii) Thirdly and finally, **environmental sustainability** is also an important driver in the production of biofuel crops. Biomass fuels such as ethanol are seen as better than fossil fuels for two reasons: i) they are renewable and hence contribute to sustainable development and ii) they are seen as a means of reducing GHG emissions. Reducing GHG emissions through the use of renewable fuel is frequently cited as an important reason to support biofuels. Researchers differ on the magnitude of the prospective reduction in GHG emissions as a result of greater biofuel use. The extent of GHG reduction depends on the entire cycle of biofuel production, from the cultivation of feedstock and the biofuels production process to transport of biofuels to markets. Estimates of gains vary, depending on the type of feedstock and production process used, with ethanol from established sugarcane fields ranking among the highest in net GHG emission reduction and ethanol from maize among the lowest because of the high energy-intensity of its production. With these drivers in mind, the next section delineates on the barriers in the production of bioethanol.

3.6 Barriers in the Production of Bioethanol in India

The National Policy on Biofuels mandates a 20% blending of ethanol in petrol by the year 2017. However, as of July 2014, oil companies have only been able to reach 1.37% blending of ethanol in petrol. According to a Report of Expert Committee on *Auto Fuel*

Vision and Policy 2025, the average blending rate of ethanol is only 2% and that ethanol blends are available only in 13 states in the entire country (GoI, 2014). The ethanol blending programme (EBP) can be a reality only when there is an adequate supply of ethanol. One of the main reasons for the lack of adequate supply of ethanol is due to a deficiency in growing biofuel crops in India. As mentioned earlier, the main source of ethanol production in India is sugarcane. Even though there exist alternative crops such as sugar beet, corn, sorghum etc. for the production of bio ethanol, India cannot fully make use of them. This is because of the unique way in which the biofuel policy in India is formulated.

The National Policy on Biofuels states that ?the Indian approach to biofuels, in particular, is somewhat different to the current international approaches which could lead to conflict with food security. It is based solely on non-food feedstocks to be raised on degraded or wastelands that are not suited to agriculture, thus avoiding a possible conflict of fuel vs. food security. Now there are some problems with this particular regulation. Due to this constraint, India has not been able to look beyond crops other than sugarcane for the production of ethanol. Although crops like jatropha, used for producing bio diesel can be produced on wastelands, there is no concrete evidence that crops such as sugar beet or sorghum can be grown on such wastelands. Even if they were, India does not have the technology or the infrastructure to convert cellulosic material in these crops into sugar and consequently into ethanol.

Another problem is the term wastelands itself. How can one demarcate between wastelands/ marginal lands and lands which are fit for production of food crops? Most of the poor rural populations depend on these so called marginal lands for their living. Those lands that are declared as wastelands by the Government in reality are probably used by poor farmers for grazing their livestock or for growing food crops for their sustenance. So allotting these lands for biofuel crops may lead to dispossessing poor farmers of their lands. Also, if a market for the biofuel crops were to develop, in order to reduce costs and increase yield, farmers may switch to higher quality/fertile lands to cultivate these crops in order to make higher profits. Biofuel crop production, in case of ever increasing demand and prospect of huge profits would no longer be restricted to marginal lands. This would lead to displacement of food crops from the fertile lands and eventually lead to a threat to food security.

Another problem with growing biofuel crops, especially sugarcane in India may actually be a bane instead of a boon. This is because growing sugarcane crop requires large quantities of water given the changing climate. Sugarcane requires about 20,000- 30,000 m3/ha/

crop of water (TERI Brief, 2015). Many parts in India already suffer a shortage in water and drought like conditions persist in a lot of regions during summers. So production of sugarcane on a large scale results in the consumption of a significant amount of water. Biofuels can also impact the quality of water in many ways. For example, the agro chemicals used in the processing of ethanol may be released into water bodies or ground water. So increasing demand for biofuels also increases the demand for water. With water already being scarce in many parts of the nation, biofuel crops may actually be a bane. The fluctuations in the sugarcane crop output makes it difficult for the formulation of policies uncertain and thus the mandated blending rates are rarely achieved to the fullest. Other barriers in the non-realization of bioethanol blending in petrol in general include the battle between alcohol sector, medicinal sector and fuel sector for ethanol. Of the total amount of available ethanol, a maximum of 45% goes to the alcohol industry.

About 40% is used in chemical industries and the rest of it is used in blending with petrol or as a fuel in itself. Pricing issues such as fixing a very low price for ethanol also discourages its production. Hence the Government, in December 2014 fixed price ranges for ethanol depending upon the distance of the OMC depot from the distillery. The prices of ethanol range from ?48.5/litre to ?49.5/litre (Damodaran, 2014). Also the impact of biofuels on the environment is not clear. Although Biofuels are considered as cleaner because of less Green House gas emissions, the net impact of biofuels, right from the production of crops to their transportation to the refinery and the fuel consumption at the refinery may in fact exceed the emissions from conventional fuels.

In India, it may be possible to produce a large quantities of biofuels using advanced technologies, especially those that can be grown on a relatively small area of land (e.g., micro algae), or from agricultural residues so as to avoid the problem of food security. But application of advanced biofuel technologies is affected by a number of barriers which include low conversion efficiency from biomass to fuel, limits on supply of key enzymes used in conversion, large energy requirements for operation etc. Hence, in spite of huge future potential, large scale use of advanced biofuel technologies is not very likely in the near future, unless further research and development can lead to a lowering, if not elimination of these barriers.

3.7 Conclusion

Rapid growth of liquid biofuel production and consumption has had negative unintended consequences. Questions are being raised about possible competition for land and water resources even in growing energy crops for second-generation biofuels. In this uncertain situation, use of wastes, residues, and under-utilized by products will continue to receive priority. The pace of technological progress will influence the future potential of liquid biofuels. A large number of companies and research groups are directing efforts at developing new pathways for producing liquid fuels. According to the National Policy on Biofuels, substantial research thrust in the development of second and third generation feedstock is needed to address the country's future energy needs, particularly in regards to future transport fuel needs.

Achieving the 20% blending of ethanol with petrol by 2017 as mandated by the National Policy on Biofuels is very difficult given the restriction of ethanol production only to sugarcane molasses. Another way of increasing ethanol production is by producing ethanol directly from sugarcane juice. This in turn may cause adverse effects on sugar prices and thus is not a very viable option. Another problem with sugarcane is, as seen earlier, that sugarcane cultivation is cyclical. To achieve the given blending rates, a constant supply of sugarcane is required.

The need of the hour is thus to look beyond production of ethanol from sugarcane molasses and move to second generation ethanol. The second generation ethanol is produced from biomass which involves converting cellulosic material into sugars. If the technology required for doing this is made available in India, alternative sources of sugar such as sugar beet, sorghum etc. can be used in the production of ethanol. Second-generation biofuels can also be produced from crop residues given the cellulosic ethanol production technology. But this has its own drawbacks. This is because crop residue acts not only as a fodder source and nesting place for animals, but is also a source of organic material for the next crop. Thus the excessive removal of crop residues may cause changes in biodiversity by altering the fertility of the land.

In conclusion, biofuels, either conventional or advanced should not be blindly encouraged without a comprehensive outlook on the overall impact the will ultimately have on the society, environment or on the countries energy security. Efforts should be made towards encouragement of research and development in the field as well as in formulating a comprehensive and effective biofuel policy.

CHAPTER - 4
Socio-Economic Analysis of the Sample Households: Findings of Base line Survey

In this chapter an attempt is made to understand the socio-economic profile of sample farmers and the issues related to sorghum and pearl millet cultivation. The demographic features of the sample villages and livelihood patterns seen in the selected villages are discussed. The socio-economic features, age group, literacy level, livestock population, market distance, farming experience, social participation, caste composition, landholding, net income and borrowings, awareness on biofuels cultivation, use of jowar crop for biofuel production and its impact on food and fodder are some of the important issues discussed in the latter part of this chapter. This analysis is expected to provide information about the representativeness of the sample villages and help in getting an insight into the issues of jowar crop cultivation for biofuel production. The following sections present the empirical findings of the baseline study conducted during the year 2013-14 in Madhya Pradesh state with respect to different socio-economic aspects related to sample farmers. The sample was drawn in such fashion that it reflects the socio-demographic structure of the village and that would reflect the impact of cultivation of bio-fuels across different social structures after the implementation of the project in the study area.

4.1 Caste

In order to understand the social and economic dynamics of the sample villages, one has to look into the social system, which largely determines people's perceptions, values and knowledge. Caste is also synonymous with occupation and livelihood in the rural context.

While majority of the districts observed in the state have a substantial OBC (Other Backward Castes) population, there is also a substantial presence of Scheduled Castes (SCs) and Scheduled Tribes (STs) - the most vulnerable households - in the study villages (see table 4.1). It has to be noted that the Rupkheda Village in Khargone District has 100% tribal households which allows a study of the impact dynamics among them. Among the total sample households, 58 per cent belonged to other Backward Communities (OBCs) followed by Other Castes (OCs) 17.40 per cent, SCs 15.3 per cent and STs 9.33 per cent.

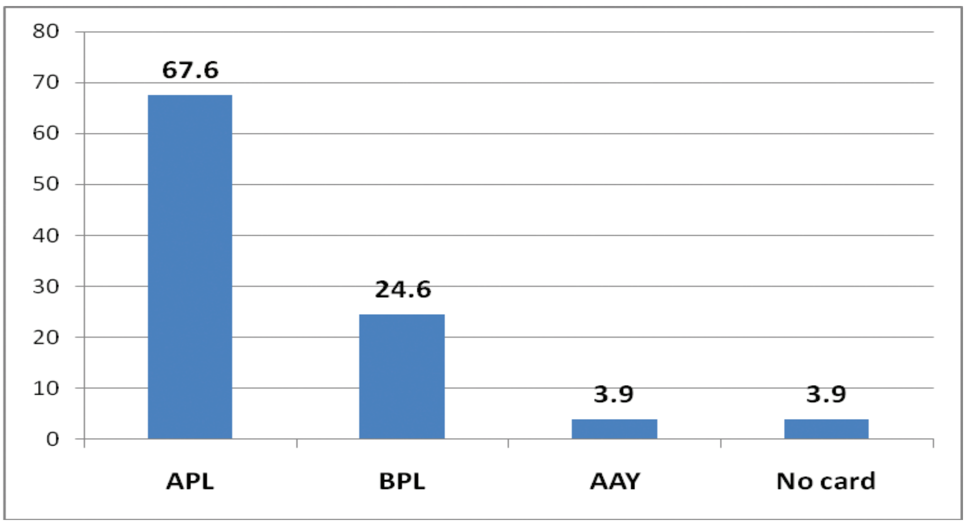
Table 4.1: Distribution of respondents according to their social category in study villages of Madhya Pradesh during 2012-13

District Name	Village Name	SC	ST	OBC	Others	Total
DEVAS	Nagada	5.9 (1)	5.9 (1)	47.1 (8)	41.2 (70)	100.0 (17)
	Chinvani Mahankal	0.0(0)	5.6 (1)	94.4 (17)	0.0(0)	100.0 (18)
Khargone	Nagziri	0.0(0)	13.0 (7)	77.8 (42)	9.3 (5)	100.0 (54)
	Rupkheda	0.0(0)	100.0 (15)	0.0(0)	0.0(0)	100.0 (15)
Bhind	Baraha	11.1 (6)	1.9 (1)	64.8 (35)	22.2 (12)	100.0 (54)
Gwalior	Bijoli	27.3 (6)	13.6 (3)	45.5 (10)	13.6 (3)	100.0 (22)
	Daheli	35.3 (6)	0.0(0)	58.8 (10)	5.9 (1)	100.0 (17)
	Jakara	36.5 (19)	3.8 (2)	53.8 (28)	5.8 (3)	100.0 (52)
Morena	Nahar Donki	13.6 (3)	0.0(0)	50.0 (11)	36.4 (8)	100.0 (22)
	Ummed garh	16.1 (10)	1.6 (1)	51.6 (32)	30.6 (19)	100.0 (62)
	Total	15.3 (51)	9.3 (31)	58.0 (193)	17.4 (58)	100.0 (333)

Source: Field Survey

Note : The figures in the parenthesis are actual number of households.

Fig.4.1: Distribution of sample households according to the ownership of ration cards in the study area during 2013-14



Source: Field Survey

Note: APY: Above poverty line; BPL: Below poverty line; AAY: Antodya Yojana

It is clear from the figure 4.1 that the majority (67.6 per cent) of the sample households are Above Poverty Line (APL), followed by 24.6 per cent Below Povert Line (BPL). Furthermore, households having Anthyodaya (AAY) cards are 3.9 per cent and the same percentage of households have no cards.

4.2 Literacy

Education is operationalised as the number of years of formal schooling attended by the sample farmer. For the purpose of distribution of farmers, six categories were identified-not literate, literate but did not complete primary school, primary, upper primary, SSC, Intermediate, Graduation, and above.

It is presumed that literacy generally equips an individual with an analytical outlook towards a problem and rational behavior, in general, as compared to the illiterate. Even regarding soil fertility management, this holds good. There is a general feeling that an average Indian farmer can be more effective if he is educated, and it is presumed that if a farmer is educated he can be made aware of better methods of farming. More importantly, it would be relatively easier for the extension agencies to communicate information regarding recent advances in crop husbandry to a literate farmer. Hence, an attempt has been made to enquire into the educational background of the respondents and the percentage of farmers in various educational levels in the respective size class; the total number of sample households was also calculated.

It is evident from table 4.2 that among the total sample farmers, 29.10 per cent were not literate, followed by upper primary (23.10 percent), and SSC (15.90 per cent). This could be due to lack of proper educational infrastructure in these villages. Another reason could be financial constraints and the need to work for the sustenance of their families. Only 2.1 per cent of the sample farmers were graduates. Among the study villages, the literacy level was better in case of Ummedgarh Village. Contrastingly, among the sample farmers of Rupheda Village, 80 per cent of them were not literates. This might be due to lack of better educational facilities, coupled with the presence of ST families, who were traditionally lagging behind in the literacy level due to lack of awareness about the importance of education.

Table 4.2: Distribution of respondents according to their education level in the study area of Madhya Pradesh during the year 2012-13

District Name	Village Name	Illiterate	Literate but didn't complete PS	Primary	Upper Primary	SSC	Inter	Graduation	Total
DEVAS	Nagada	11.8 (2)	58.8 (10)	11.8 (2)	11.8 (2)	5.9 (1)	0.0(0)	0.0(0)	100.0 (17)
	Chinvani Mahankal	16.7 (3)	22.2 (4)	11.1 (2)	22.2 (4)	22.2 (4)	5.6 (1)	0.0(0)	100.0 (18)
Khargone	Nagziri	25.9 (14)	11.1 (6)	16.7 (9)	24.1 (13)	11.1 (6)	9.3 (5)	1.9 (1)	100.0 (54)
	Rupkheda	80.0 (12)	20.0 (3)	0.0(0)	0.0(0)	0.0(0)	0.0(0)	0.0(0)	100.0 (15)
Bhind	Baraha	46.3 (25)	3.7 (2)	13.0 (7)	22.2 (12)	7.4 (4)	3.7 (2)	3.7 (2)	100.0 (54)
Gwalior	Bijoli	18.2 (4)	0.0(0)	0.0(0)	27.3 (6)	40.9 (9)	13.6 (3)	0.0(0)	100.0 (22)
	Daheli	41.2 (7)	11.8 (2)	29.4 (5)	11.8 (2)	5.9 (1)	0.0(0)	0.0(0)	100.0 (17)
	Jakara	28.8 (15)	5.8 (3)	7.7 (4)	26.9 (14)	21.2 (11)	5.8 (3)	3.8 (2)	100.0 (52)
Morena	Nahar Donki	22.7 (5)	0.0(0)	18.2 (4)	22.7 (5)	27.3 (6)	9.1 (2)	0.0(0)	100.0 (22)
	Ummed garh	16.1 (10)	6.5 (4)	11.3 (7)	30.6 (19)	17.7 (11)	14.5 (9)	3.2 (2)	100.0 (62)
	Total	**29.1 (97)**	**10.2 (34)**	**12.0 (40)**	**23.1 (77)**	**15.9 (53)**	**7.5 (25)**	**2.1 (7)**	**100.0 (333)**

Source: Field Survey, *Note:* The figures in the parenthesis are actual number of households.

4.3 Family Size

This refers to the total number of people in the sample farmers' families, usually consisting of husband, wife, children and other dependent members. Majority (63.1 per cent) of the sample households in the study area live in joint family system which is quite contrary to the emergence of nuclear family system in other parts of India (see table 4.3). This will enable the better availability of family labour in farming in general and biofuel production in particular.

Table 4.3: Distribution of Sampled Households according to their family size during the year 2012-13

District	Village Name	Joint Family	Nuclear Family	Total
DEVAS	Nagada	94.1 (16)	5.9 (1)	100.0 (17)
	Chinvani Mahankal	83.3 (15)	16.7 (3)	100.0 (18)
Khargone	Nagziri	35.2 (19)	64.8 (35)	100.0 (54)
	Rupkheda	(5) 33.3	66.7 (10)	100.0 (15)
Bhind	Baraha	90.7 (49)	9.3 (5)	100.0 (54)
Gwalior	Bijoli	86.4 (19)	13.6 (3)	100.0 (22)
	Daheli	94.1 (16)	5.9 (1)	100.0 (17)
	Jakara	86.5 (45)	13.5 (7)	100.0 (52)
Morena	Nahar Donki	31.8 (7)	68.2 (15)	100.0 (22)
	Ummed garh	30.6 (19)	69.4 (43)	100.0 (62)
	Total	**63.1 (210)**	**36.9 (123)**	**100.0 (333)**

Source: Field Survey

Note: The figures in the parenthesis are actual number of households.

Table 4.4: Distribution of sampled households according to their occupation (percentage)

Occupation	Primary Occupation	Secondary Occupation
Agriculture	87.38 (291)	9.41 (24)
Agril. casual labour	4.50 (15)	17.25 (44)
Salaried agriculture worker	0.30 (1)	0.0 (0)
Own business	1.80 (6)	3.92 (10)
Self-employed in household industry	0.90 (3)	0.78 (2)
Non-agril casual labour	1.20 (4)	9.80 (25)
Salaried work	1.50(5)	1.17 (3)
Common property resources	0.30 (1)	0.0 (0)
Livestock management	2.10 (7)	57.64 (147)
Total	100.0 (333)	100.0 (255)

Source: Field Survey

Note : The figures in the parenthesis are actual number of households.

It is evident from table 4.4 that primary occupation in the study area was farming followed by agricultural casual labour. Similarly, livestock was predominantly secondary occupation for many sample households. Own business, self employment and salaried work were other occupations taken up as primary and secondary occupations by some households. Dependence on Common Property Resources (CPRs) for their occupation was negligible in the study sites.

Table 4.5: Area under fallow (in acres) in the study area during the year 2012-13

Village	Current Fallows	Permanent Fallows	Total
Nagada	1.5	1	2.5
Sunvani Mahankal	11.5	0.5	12
Nagziri	108.75	18	126.75
Rupkheda	26	3	29
Baraha	0	0	0
Bijoli	0	0	0
Daheli	0	0	0
Jakara	0	0	0
Nahar Donki	0	0	0
Ummed garh	0	0	0
Grand Total	147.75	22.50	170.25

Source: Field Survey

Current fallows are observed only in Nagziri. Villages such as Baraha, Bijoli, Daheli, Jakara, Nahar Donki, and Ummed Garh have no area under both current as well as permanent fallows. Thus, table 4.5 offers little hope of utilizing current or permanent fallows for biofuel production due to less area under these categories.

4.4 Availability of Marginal Lands in Madhya Pradesh

One of the major objectives of the project is to utilize the existing wastelands in Madhya Pradesh to cultivate high biomass producing jowar and bajra varieties. It can be seen from table 4.6 that only 3.93 per cent of the land (1.2 million hectares) is culturable waste in Madhya Pradesh. Out of this, how much land can be brought under cultivation is a question which can be answered only in future; and this depends on whether the fertility level of these soils is capable enough to support the cultivation of high biomass producing varieties which are generally input-intensive. If we do not aim at these lands and instead promote high biomass jowar and bajra varieties in the existing cultivated lands, it will affect the food and fodder security of the farming households of the region when the project is upscaled.

Table 4.6: Land use details of India and Madhya Pradesh State during the year 2011-12 (000'hectares)

Particulars	India	Madhya Pradesh
Geographical area	328726	30825
Forests	70015 (21.29)	8681 (28.16)
Area under non-agriculture uses	26294 (8.19)	1890 (6.13)
Barren and uncultivated land	17227 (5.24)	1417(4.60)
Permanent pastures	10296 (3.13)	1394 (4.52)
Land under miscellaneous tree crops and groves	3164 (0.96)	19 (0.06)
Culturable waste land	12636 (3.84)	1213 (3.93)
Fallow lands other than current fallows	10666(3.24)	626(2.03)
Current fallows	14715 (4.48)	997(3.23)
Net area sown	140801(42.83)	14518 (47.09)
Total cropped area	195246 (59.39)	18078(58.64)
Area sown more than once	54444(16.56)	3560 (11.55)

Source: Directorate of Economics and Statistics, Department of Agriculture and cooperation of Ministry of Agriculture, GOI and Ministry of Statistics and Programme Implementation.
Note: Figures in the parenthesis are percentages to total geographical area.

According to Ministry of Rural Development (MoRD), there is 13.01 per cent of wasteland in the state as compared to the total geographical area in the state (see table 4.7). Similarly, according to the Waste Lands Atlas of India, 2011, the area of waste lands in Madhya Pradesh is 4.01 million hectares. Furthermore, even at the national level there is a huge difference in the areas reported under waste land by different agencies (Reddy et al., 2014). For example, according to the Ministry of Rural development, the area of waste lands in 2010 is 47.3 million hectares as against the Waste Land Atlas data of 63.85 million hectares for the same year. Given the lack of clarity on the exact waste land area available, the argument for promoting sorghum and pearl millet production in these waste lands in future is a questionable proposition.

Table 4.7 : Total area under waste lands in Madhya Pradesh state and India during 2008-09

(00'hecatres)

State	Total Geographical areas	Total waste land	Percentage of waste land to total geographical area
Madhya Pradesh	308252	40113.27	13.01
India	3166414	467021.16	14.75

Source: Ministry of Rural Development, Govt of India and Compendium of Environmental Statistics, Govt. of India

4.5 Soil Fertility

The present research tried to assess the level of soil fertility of sample plots according to farmers' own perception. For this purpose, all the 691 plots owned by sample households were compared with the best fertile plot in the respective village (based on FGDs). The soils of the farmers were evaluated on a scale of continuum consisting of very bad, bad, average and good. Table 4.8 indicates that the majority (53 per cent) of the sampled plots are having a depth of more than 4.1 feet followed by 2.1 to 3 feet. However, a majority (48.6 per cent) are interestingly having average soil quality as perceived by farmers and 25.3 per cent of the sample plots are of good quality (see figure 4.2). This has implication for high biomass jowar cultivation as soil fertility will directly affect crop yield. Plots with bad soil quality were 22 per cent and very bad were 4.1 per cent. The low fertility status could be due to gradual decline in organic manure application and intensive cultivation. The study by Reddy (2010) reported that 37.13 per cent of the plots were perceived to be of average fertility status and only 10.25 per cent had good soil fertility.

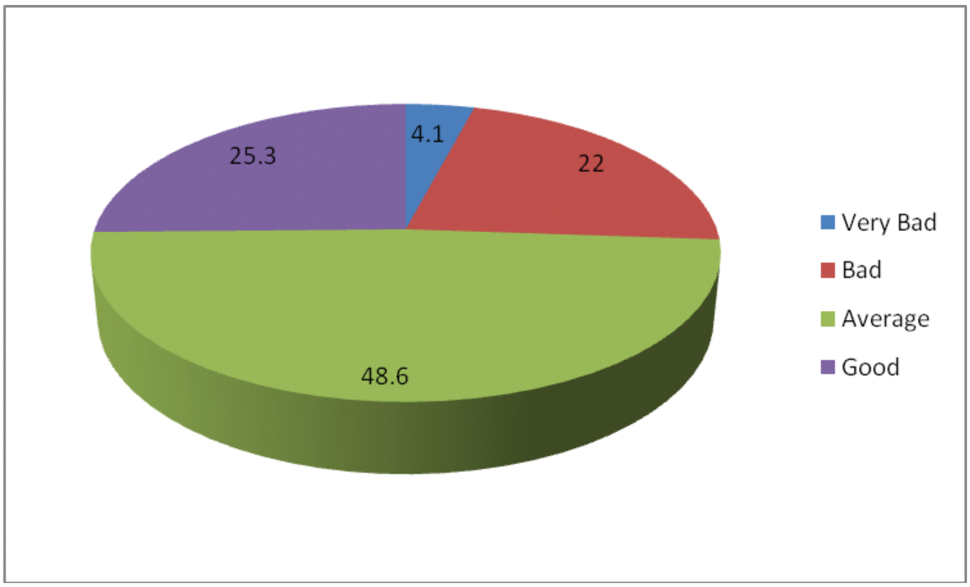
Table 4.8: Distribution of Sample plots according to their soil depth during the year 2012-13

Village	Soil Depth					Total (N=691)
	Upto 1 feet (Very Shallow)	1.1 to 2 feet (Shallow)	2.1 -3 feet (Medium)	3.1-4 feet (Deep)	4.1 feet and above (Very Deep)	
Nagada	22.2 (6)	18.5 (5)	22.2 (6)	11.1 (3)	25.9 (7)	100.0 (27)
Chinvani	11.4 (4)	2.9 (1)	8.6 (3)	17.1 (6)	60.0 (21)	100.0 (35)
Nagziri	36.1 (44)	52.5 (64)	11.5 (14)	0.0 (0)	0.0 (0)	100.0 (122)
Rupkheda	54.2 (13)	33.3 (8)	8.3 (2)	4.2 (1)	0.0 (0)	100.0 (24)
Baraha	0.0 (0)	26.7 (20)	52.0 (39)	6.7 (5)	14.7 (11)	100.0 (75)
Bijoli	0.0 (0)	2.7 (1)	35.1 (13)	5.4 (2)	56.8 (21)	100.0 (37)
Daheli	0.0 (0)	5.0 (2)	5.0 (2)	2.5 (1)	87.5 (35)	100.0 (40)
Jakara	0.0 (0)	4.8 (5)	33.3 (35)	5.7 (6)	56.2 (59)	100.0 (105)
Nahar Donki	0.0 (0)	8.6 (6)	0.0 (0)	0.0 (0)	91.4 (64)	100.0 (70)
Ummed garh	0.0 (0)	3.8 (6)	0.6 (1)	0.0 (0)	95.5 (149)	100.0 (156)
Total	9.7 (67)	17.1 (118)	16.6 (115)	3.5 (24)	53.1 (367)	100.0 (691)

Source: Field Survey,

Note : The figures in the parenthesis are actual number of households.

Figure 4.2: Respondents perception about soil quality of sample plots

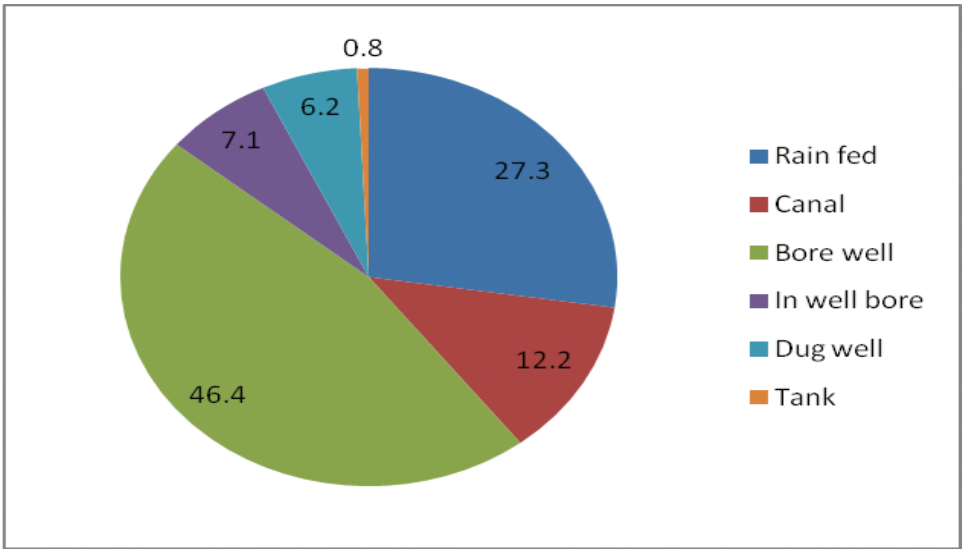


Source: Field Survey,

4.6 Source of Irrigation

The study area has diverse sources of irrigation including rainwater for crop cultivation. Figure 4.3 indicates that borewell is the major source of irrigation (46.4 per cent), followed by rainfall (27.3 per cent), and canal irrigation. Additionally, in-well bores, dug-wells and tank irrigation were other sources of irrigation. Among methods of irrigation, flooding was predominant, followed by drip and sprinkler. Better irrigation access to farmers in the study area could help them to take advantage of the encouragement given in the project to high biomass cultivation.

Figure 4.3: Area under different sources of irrigation for sampled plots in the study area during 2013 (in acres)

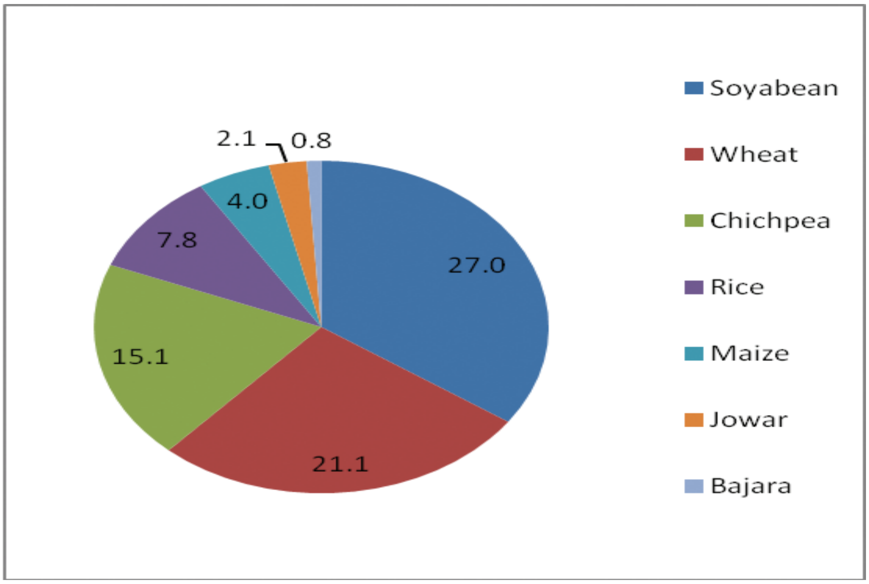


Source: Field Survey,

4.7 Cropping Pattern in Madhya Pradesh

Gross cropping area of various crops in Madhya Pradesh clearly indicate that jowar and bajra occupy 2.1 per cent and 0.8 per cent respectively (see figure 4.4). Soya bean (27 per cent) occupies the major area, followed by wheat (21.1per cent) and chick pea (15.1per cent). Contrary to the state-level picture, the study sites of this baseline survey has considerable area under sorghum and pearl millet and interestingly, soya bean did not spread in the study villages.

Figure 4.4: Percentage of area under cultivation of major crops to the gross cropped area in MP in 2010



Source: Field Survey,

4.8 Cropping System

Farmers of drylands have developed diversified cropping systems to ensure that the most essential natural elements such as sunlight, wind, rainfall and soil are optimally utilised throughout the year. Crops that were developed over centuries were specifically bred to suit the changes in the rainfall pattern from year to year. The short and long duration varieties, water tolerant and drought resistant varieties, etc., that were developed were the result of this careful planning over centuries by farming communities. Inter cropping, mixed cropping, relay cropping and multi-tiered cropping were the strategies adopted by the sample farmers and were highly relevant. By doing so, the farmers have balanced food and cash crops, along with the fodder needs of their animals and simultaneously managed the fertility of their marginal soils. An effort was made to find out the cropping pattern in the study area.

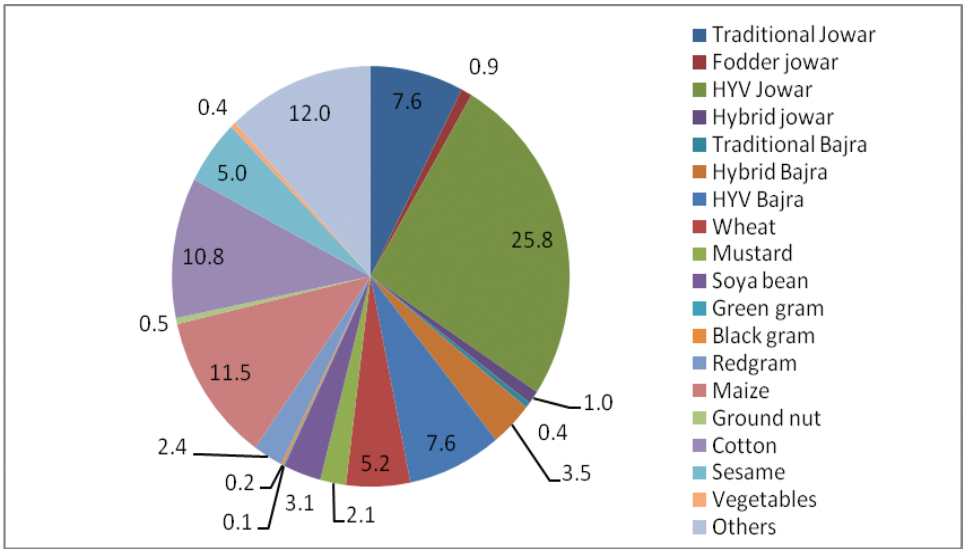
It can be seen from table 4.9 that monocropping is predominant in the sample plots with an area of 2483.50 acres, followed by intercropping (269 acres). Mixed cropping is observed to be negligible (9 acres). This could be due to the rigorous campaign by the agricultural universities, private companies, and agricultural extension systems regarding the advocating of monocropping. One of the reasons for monocropping was to facilitate easy application of inorganic fertilisers, pesticides and weedicides. Another reason for the reduction in agro-biodiversity was the lack of easy access to labour during different times of a season, when these diverse crops get ready for harvest; and also market influence. A large number of farmers, especially the women, have been nurturing the agro-biodiversity and soil fertility without any support from the government (Reddy, 2009).

Table 4.9: Distribution of area under various cropping systems in sample plots during 2012-13 (in acres)

Village name	Mono cropping	Intercropping	Mixed cropping	Grand Total
Nagada	313.0	0.0	0.0	313.0
Sunvani Mahankal	123.0	150.0	6.0	279.0
Nagziri	526.75	29.75	0.0	556.50
Rupheda	98.5	57.5	0.0	156.0
Baraha	313.5	0.0	0.0	313.50
Bijoli	144.58	0.0	0.0	144.58
Daheli	112.0	0.0	0.0	112.0
Jakara	353.50	0.0	0.0	353.50
Nahar Donki	164.8	24.5	3.0	192.30
Ummed garh	334.12	7.25	0.0	341.37
Grand Total	2483.75	269.0	9.0	2761.75

Source: Field Survey

Figure4.5: Distribution of sampled household lands under various crops in the study area during Kharif 2012-13



Source: Field Survey,

Figure 4.5 shows that jowar (around 35%) accounts for the largest share of crop that is being cultivated among the respondent households, followed by bajra (11.5%). Even among these crops, it is the high-yielding varieties that occupy the largest share among the respondent households. This depicts the importance of these two crops in the study villages and more so importantly among the households in them.

Table 4.10 indicates that the area cultivated by the sample farmers is more during kharif (1164.45 acres) followed by rabi (626.23 acres) and summer (26.5 acres). The major crops cultivated in rabi are wheat and mustard.

Table 4.10: Total cultivated area of sample households in different seasons during the year 2012-13

(Percent)

Village name	Kharif area	Rabi area	Summer area	Total land in acres
Nagada	12.88(150)	16.53(103.5)	13.20(3.5)	14.14(257)
Sunvani Mahankal	4.25 (49.5)	11.74(73.5)	86.80(23)	8.03(146)
Nagziri	23.64 (275.25)	0.64(4)	0.0(0)	15.37(279.25)
Rupheda	5.15(60)	1.44(9)	0.0(0)	3.80(69)
Baraha	16.14(188)	6.23(39)	0.0(0)	12.50(227)
Bijoli	6.14(71.5)	8.70(54.5)	0.0(0)	6.93(126)
Daheli	2.83(33)	8.62 (54)	0.0(0)	4.79(87)
Jakara	18.55(216)	24.27(152)	0.0(0)	20.25(368)
Nahar Donki	3.91(45.5)	5.98(37.5)	0.0(0)	4.57(83)
Ummed garh	6.50(75.7)	15.84(99.23)	0.0(0)	9.62(174.93)
Grand Total	**100.00(1164.45)**	**100.00(626.23)**	**100.00(26.5)**	**100.00(1817.18)**

Source: Field Survey

Note: Figures in the parentheses are the actual number of acres

It can be seen from tables 4.11 and 4.12 that varietal diversity exists in the case of both jowar and bajra. High-yielding varieties occupy a major area in case of both crops. During kharif (see table 4.11), the major area of the sampled households was under HYV jowar (253.12 acres) followed by maize (112.75 acres) and cotton (106 acres). Interestingly, the height of some of the traditional sorghum varieties grown by farmers is at least 12 feet and the price it fetches in the open market is Rs.2500 per quintal. Farmers perceive that traditional white sorghum fetches a better market price. Interestingly, unlike the state's scenario, soya bean is cultivated in a very less area, indicating that it has still not replaced the cultivation of sorghum and pearl millet in the sample villages. This is due to the fodder requirement of the region due to its strong milk economy. Similar to the kharif season, crop diversity is observed to be prevalent during the rabi season too (see table 4.12). However, it is observed to be dominated by wheat (325.27 acres) and mustard (153.07 acres).

Table 4.11: Village-wise distribution of sample household lands under various crops in the study area during Kharif 2012-13 (In acres)

Crop name	Nagada	Chinvani	Nagziri	Rupkheda	Baraha	Bijoli	Daheli	Jakhara	Nahar Donki	Ummedgad	Crop-wise Total area
Traditional Jowar	2	18	21	4	0	3.5	7.5	17	1.25	0	74.25
Fodder jowar	0	1	3	4	0	0	0	0	0	0.75	8.75
HYV Jowar	54.5	11.5	70.5	0	3.5	27.5	2.5	74	4.85	4.27	253.12
Hybrid jowar	0	0	0	0	1	0	5	1.5	0	2.5	10
Traditional Bajra	0	0	0	0	0	0	1	2.5	0	0.75	4.25
Hybrid Bajra	0	0	0	0	24	2.25	6.5	0	1.25	0.0	34
HYV Bajra	0	0	0	0	2.5	0	4.5	4.25	30.37	33.25	74.87
Wheat	34.5	16.5	0	0	0	0	0	0	0	0	51
Mustard	0	0	0	0	0	2.5	0	0	0	18	20.5
Soya bean	14	2	9	0	5	0	0	0	0	0	30
Green gram	0	0	1	0	0	0	0	0	0	0	1
Black gram	0	0	0	0	0	0	0	0	2	0	2
Redgram	0	0	3	0	0	1.5	0	0	9.62	9.6	23.72
Maize	0	0.5	82.75	26	3.5	0	0	0	0	0	112.75
Groundnut	0	0	4	0	0	0	0	0	0.5	0	4.5
Cotton	0	0	76.5	26	3.5	0	0	0	0	0	106
Sesame	0	0	0	0	41.5	7.5	0	0	0	0	49
Vegetables	0	0	1	0	0	0	0	0	0	3.25	4.25
Others	0	0	2	0	41.5	14	15	0	34.2	10.6	117.3
Village wise total area.	**105**	**49.5**	**273.75**	**60**	**126**	**58.75**	**42**	**99.25**	**84.04**	**82.97**	**981.26**

Source: Field Survey

4.9 Livestock:

Livestock and farming are inseparable. Cattle provide draught power for agricultural operations and organic manure for maintaining soil fertility. Livestock also provide cash to many resource-poor farmers during critical times, for meeting their health and food needs. Farm yard manure provided by the livestock has always been one of the principal means of replenishing soil losses in dryland regions. This manure is a major source of food for diverse soil biota which plays a key role in soil productivity. The depletion of soil organic matter leads to deterioration in soil structure, reduced capacity to retain soil moisture and nutrients, and reduced microbiological activity (Reddy, 2011). Table 4.13

indicates that though the study villages are predominantly agrarian in nature cultivating mainly wheat, jowar, bajra, soya bean and mustard, a substantial amount of their economy is also dependent on the rearing of livestock. Without livestock, dryland farming would not be possible. It is observed that most of the sample households own buffaloes followed by cows and bullocks. Especially, the bullock population is coming down more with large farmers. The reasons are reduced farm size, increased mechanization, declining area under common lands, and changing patterns in labour availability (Conroy et al. 2001). Another reason is that earlier children from SC and BC communities, who worked for the landlords, are now going to school due to the awareness created by voluntary organizations and the emphasis given by the government on primary education.

Table 4.12: Village-wise distribution of sample household lands under various crops in the study area during rabi 2012-13 (In acres)

Crop name	Nagada	Chinvani	Nagziri	Rupkheda	Baraha	Bijoli	Daheli	Jakhara	Nahar Donki	Ummedgad	Crop-wise Total area
Traditional Jowar	27	13.5	1	0	0	0	0	0	0	0.75	42.25
Fodder Jowar	0	0.5	3	0	0	0	0	0	0	0	3.5
HYV Jowar	22.50	2	0	0	0	1	0	0	0	0	25.5
Hybrid Jowar	0	0	0	0	0	0	0	0	0	3	1.5
Traditional Bajra	0	0	0	0	0	0	0	5	0	0	5
Hybrid Bajra	0	0	0	0	0	0	0	0	1.25	0	1.25
Wheat	46	47	0.75	6.5	16.5	32.5	26	63.5	28.25	58.27	325.27
Mustard	0	0	0	0	9	11	29.5	60	12	31.57	153.07
Soya bean	4	8	0	0	0	0	0	0	0	0	12
Redgram	4	2.5	0	0	0	0	0	0	0	0	6.5
Chick pea	0	0	0	2.5	0	10	15.5	1	0	0	29
Vegetables	0	0	3.75	0	0	7.5	12	0	1	3.12	27.37
Others	0	0	0	0	0	0	0	0	0	4.5	4.5
Village wise total area	**103.5**	**73.5**	**8.5**	**9**	**25.5**	**62**	**83**	**129.5**	**42.5**	**101.21**	**636.71**

Source: Field Survey

Table 4.13: Total number of livestock owned by sample households in the study villages during 2012 -13

Village name	Buffalo	Bullock	Cow	Goat	Others	Grand Total
Nagada	19	1	8	0	6	34
Sunvani Mahankal	33	5	34	0	36	108
Nagziri	19	50	33	0	0	102
Rupheda	6	24	11	0	0	41
Baraha	54	0	0	0	0	54
Bijoli	89	0	7	12	0	108
Daheli	71	1	3	0	0	75
Jakara	123	0	4	0	2	129
Nahar Donki	57	0	2	2	0	61
Ummed garh	114	0	13	1	0	128
Grand Total	**585**	**81**	**115**	**15**	**44**	**840**

Source: Field survey

The livestock not only assists the households in the traditional agricultural activities but also provides a substantial amount of income source as the villagers supply milk to the nearby towns. It is important to note here that the traditional cultivation of bajra and jowar, the two main crops intended for bio-fuels in our study, are traditionally the major fodder sources for the livestock in the villages. It is in this context that we need to look at the viability of cultivation of food/fodder crops for large scale bio-fuel in the context of traditional and agrarian-based economies like India in general and in MP in particular.

An effort was made to understand the dependence of livestock-owning sampled households on various kinds of grazing areas for meeting the fodder requirements of their livestock. It was evident from table 4.14 that the animals are predominantly grazed in lands owned by the households (42.5%), followed by stall feeding (36%). It is also observed that access to forest (4.5%) and CPRs (4.5%) has come down as compared to earlier times.

It can be seen from figure 4.6 that the sample households derived their major income (80.4%) from buffaloes, followed by cows (16.9%) indicating that the study area has strong milk economy. Hence is the observed predominance of jowar and bajra in the region as they take care of the fodder needs of the milch animals. As seen from table 4.13, bullocks were present in only three villages Sunvani Mahankal, Nagzari and Rupheda and hence lesser income from them in the study area.

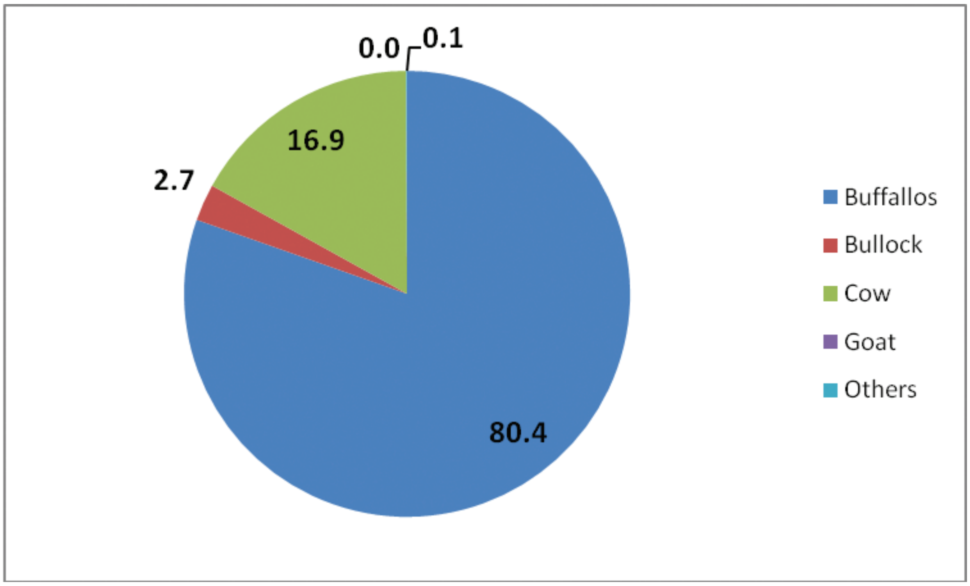
Table 4.14: Details of animal grazing areas used by sample households during 2012-13 in the study area

Village name	Stall feeding	Own lands	Private lands	Forest area	CPRs	Others	Total (N=247)
Nagada	57.1 (8)	21.4 (3)	7.1 (1)	14.3 (2)	0.0(0)	0.0(0)	100.0 (14)
Sunvani Mahankal	31.2 (5)	43.8 (70)	18.8 (3)	0.0(0)	0.0(0)	6.2 (1)	100.0 (16)
Nagziri	0.0(0)	48.5 (16)	27.3 (9)	9.1 (3)	0.0(0)	15.2 (5)	100.0 (33)
Rupheda	28.6 (4)	57.1(8)	7.1 (1)	7.1 (1)	0.0(0)	0.0(0)	100.0 (14)
Baraha	25.0 (5)	25.0 (5)	0.0(0)	5.0 (1)	45.0 (9)	0.0(0)	100.0 (20)
Bijoli	33.3 (7)	47.6 (10)	9.5(2)	0.0(0)	9.5 (2)	0.0(0)	100.0 (21)
Daheli	35.3 (6)	58.8 (10)	0.0(0)	5.9 (1)	0.0(0)	0.0(0)	100.0 (17)
Jakara	21.6 (8)	67.6 (25)	2.7 (1)	5.4 (2)	0.0(0)	2.7 (1)	100.0 (37)
Nahar Donki	63.6 (14)	9.1 (2)	27.3 (6)	0.0(0)	0.0(0)	0.0(0)	100.0 (22)
Ummed garh	60.4 (32)	35.8 (19)	0.0(0)	1.9 (1)	0.0(0)	1.9 (1)	100.0 (53)
Total	36.0 (89)	42.5(105)	9.3 (23)	4.5 (11)	4.5 (11)	3.2 (8)	100.0 (247)

Source: Field Survey

Note: The figures in the parentheses are actual number of households.

Fig. 4.6: Total income derived from the livestock in sample villages (INR)



Source: Field Survey

4.10 Indebtedness

This variable was operationalized as the amount of outstanding loan of a farmer from the loan taken from various sources during the years 2011-12 and 2012-13. They were categorized into 5 groups as indebtedness ranging between less than Rs.30000, between Rs.30001-50000, Rs.50001 to 70000, and indebtedness above Rs.70001.

From table 4.15, it is evident that among the total sample farmers, the majority (58.6%) had not taken any loan. This is followed by indebtedness above Rs70000 and loans ranging between Rs.50001-70000. Among those who accessed loans, the primary purpose of loan is observed to be for the purchase of agricultural inputs (21.9%) followed by 6.9 percent for consumption purpose and irrigation (6%). It is observed that increase in costs of inputs and decrease in profits from farming is pushing farmers towards debt. It is a good sign to see that majority did not access any credit for farming (see table 4.16). It is interesting to observe that majority of the sample households (23.1%) are taking credit from fertiliser and pesticide dealers, followed by money lenders (11.7%). A large number of fertiliser and pesticide dealers are unaware of the basics of agriculture and are mostly driven by commercial interests. Since farmers are procuring these fertiliser and pesticide products from private dealers, by the end of the season, there would be a large

Table 4.15: Distribution of sample households according to their indebtedness (percentage) in 2012-13

Village name	Less than Rs.30000	Rs.30001-50000	Rs.50001-70000	Above Rs.70001	Not Taken any loan	Total (N=333)
Nagada	11.8(2)	0.0(0)	23.5(4)	64.7(11)	0.0(0)	100.0(17)
Chinvani	27.8(5)	0.0(0)	22.2(4)	38.9(7)	11.1(2)	100.0(18)
Nagaziri	11.1(6)	1.9(1)	25.9(14)	27.8(15)	33.3(18)	100.0(54)
Rupkheda	20.0(3)	6.7(1)	40.0(6)	33.3(5)	0.0(0)	100.0(15)
Baraha	0.0(0)	0.0(0)	0.0(0)	0.0(0)	100.0(54)	100.0(54)
Bijoli	9.1(2)	0.0(0)	0.0(0)	0.0(0)	90.9(20)	100.0(22)
Daheli	17.6(3)	0.0(0)	0.0(0)	0.0(0)	82.4(14)	100.0(17)
Jakara	0.0(0)	0.0(0)	0.0(0)	0.0(0)	100.0(52)	100.0(52)
Nahar Donki	18.2(4)	4.5(1)	18.2(4)	13.6(3)	45.5(10)	100.0(22)
Ummed Garh	37.1(23)	4.8(3)	4.8(3)	12.9(8)	40.3(25)	100.0(62)
Total	**14.4(48)**	**1.8(6)**	**10.5(35)**	**14.7(49)**	**58.6(195)**	**100.0(333)**

Source: Field survey

amount of money due to the dealer. Hence, quite often, they are forced to sell off their produce to the very same dealer at a much cheaper rate than the existing market price. Financial exclusion in terms of access to credit from formal institutions is high for small and marginal farmers and some social groups (Dev, 2006). It is clear from table 4.16 that majority of the households used personal trust (17.7%) to access loans, followed by mortgage of patta pass books (15.3%). Nearly 15 per cent of the farmers are observed to access loans at a monthly interest rate of Rupees three , followed by 14.4 per cent at the rate of one rupee. It is also seen that out of the 138 households accessing loans only 20 households (14.4%) could repay the loan that they have taken.

Table 4.16: Credit details of sampled households during 2011-12 and 2012-13

Source of Loan						**(N=333)**
Not taken any loan	**Commercial bank**	**Co-operative bank**	**Money lender**	**Fertilizer dealer**	**Other**	**Grand Total**
58.6(195)	3.3(11)	2.4(8)	11.7(39)	23.1(77)	0.9(3)	100.0(333)
Purpose of Loan						
Agricultural inputs	Consumption	Irrigation	Health	Others	Not taken any loan	Total
21.9(73)	6.9(23)	.6(2)	5.4(18)	6.37(22)	58.6(195)	100.0(333)
Mortgaged Item						
	Patta pass book	Gold	Trust	Promisory note	Not taken any loan	Total
	15.3(51)	3.3(11)	17.7(59)	4.8(16)	58.6(195)	100.0(333)
Interest Rate per Rs100 as loan/Month						
	Not taken any loan	Rs1	Rs.2	Rs.3	Rs.4 and above	Total
	58.6(195)	14.4(48)	6.9(23)	15.0(5)	5.1(17)	100.0(333)
Loan Outstanding						
	Less than Rs.30000	Rs.30001-50000	Rs.50001-70000	Above Rs.70001	Not taken any loan	Total
	19.5(65)	3.0(10)	4.2(14)	8.7(29)	64.6(215)	100.0(333)

Source: Field Survey

4.11 Cost of Cultivation:

Table 4.17 presents the crop economics that are prevalent in the study area of Madhya Pradesh. It could be seen from the table that traditional jowar and high-yielding varieties of jowar were doing well in the year 2012-13, as compared with hybrid jowar. During the years of lesser rainfall the hybrids do not perform well as can be seen in the table 4.17. Moreover, hybrid jowar attracts certain pests and diseases, thereby affecting the yield and income. Interestingly, in the case of bajra, the hybrid variety was doing extremely well with per acre net income (Rs.10748), followed by traditional bajra (Rs.3644). Furthermore, hybrid jowar and HYV bajra showed a negative income during the year 2012-13. Though there was lesser area of soya bean, it was doing very well interms of income with a per acre income of Rs.15724. Despite being cultivated in a major area during rabi, wheat is observed to give a moderate income of Rs.4618/acre to the sample households. As seen from table 4.17, cultivation of mustard during rabi gave rich returns to the sample farmers. Similarly, red gram, chick pea and groundnut also give a good per acre net return. On the other hand, green gram's net returns are observed to be negative as the crop had badly suffered due to less rain during the initial stages of the crop season. Similarly, cultivation of cotton crop also led to losses due to heavy input costs and lesser yields due to pest incidence and poor performance of bt cotton under unfavourable climatic conditions.

Table 4.17: Average cost of cultivation of major crops in the study area during the year 2012-13 (in Rupees/Acre)

Crop	Total Cost	Total Income	Net Income
Traditional Jowar	14504	18791	4287
Fodder Jowar	13438	15616	2178
HYV Jowar	12070	18745	6675
Hybrid Jowar	12846	10137	-2709
Traditional Bajra	12216	15860	3644
HYV Bajra	12248	12105	-143
Hybrid Bajra	14074	25452	10748
Wheat	23242	27860	4618
Mustard	14020	34228	20208
Soya bean	26962	42686	15724
Green gram	14366	7000	-7366
Red gram	9066	23941	14875
Chick pea	16670	33106	16436
Maize	14648	20358	5710
Ground nut	19234	32548	13314
Cotton	37616	31395	-6221
Til	8328	7974	-354

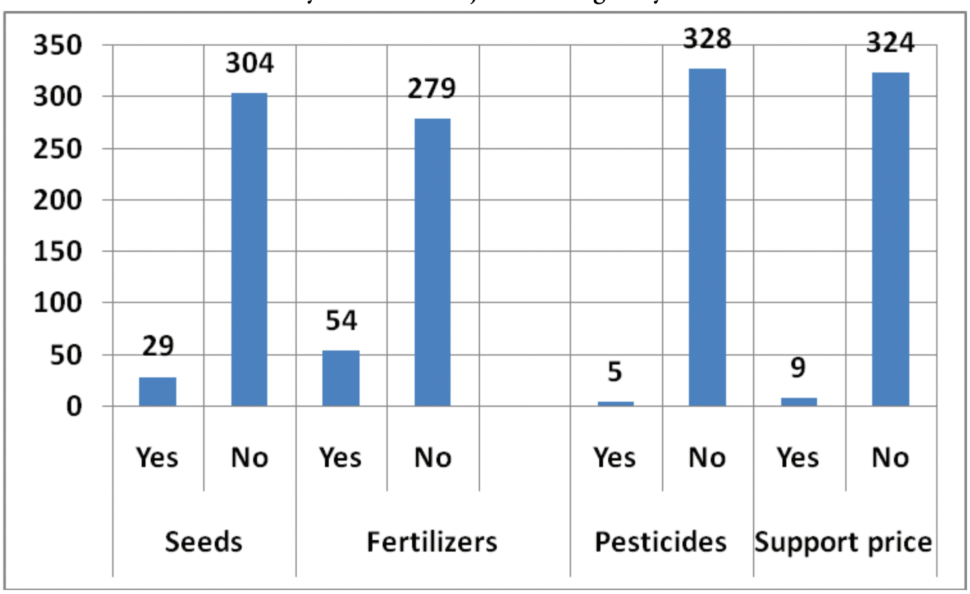
Source: Field Survey

Table 4.17 clearly indicates that the high biomass jowar and bajra varieties being promoted in the Indo-US JCERDC biofuel project should be more fetching than the existing cultivars of these staple food crops; they should also have a comparative advantage simultaneously with other crops such as the soya bean, wheat and mustard. Otherwise, the farmers might not be inclined to adopt these varieties for biofuels production.

4.12 Sorghum (Jowar) / Pearl Millet (Bajra) Crops and their Subsidy

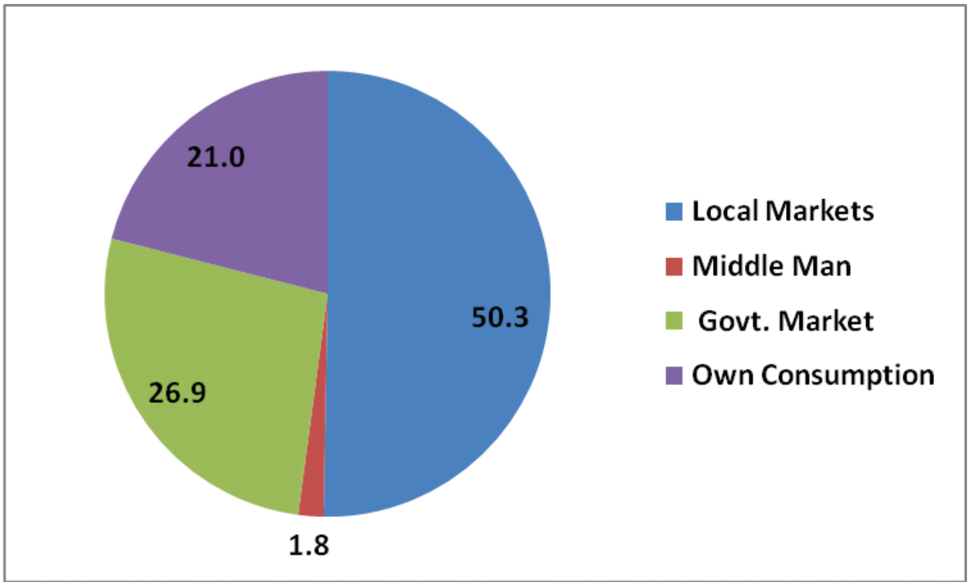
The present study also tried to understand the kind of subsidy the staple food crops get in the region. Responses of the sample households were taken to understand the satisfaction regarding the subsidy support they get for components such as seed fertilizers and pesticides. Their responses regarding the satisfaction for the Minimum Support Price (MSP) for jowar and bajra were also elicited. It can be observed from figure 4.7 that very less subsidy was available for the cultivation of these food crops with regard to seeds and fertilizers and negligible support for pesticides. Similarly, a very negligible percentage of the sample households was happy with the kind of Minimum Support Price (MSP) given by the government for these staple food crops. It is crucial for the sorghum and millet sector to be supported by strong government policies and programmes for food, fodder and better nutrition through value addition and demand creation (Nagarj *et al.*, 2013).

Fig.4.7: Distribution of households according to their responses regarding subsidy availability and MSP for jowar during the year 2013



Source: Field Survey

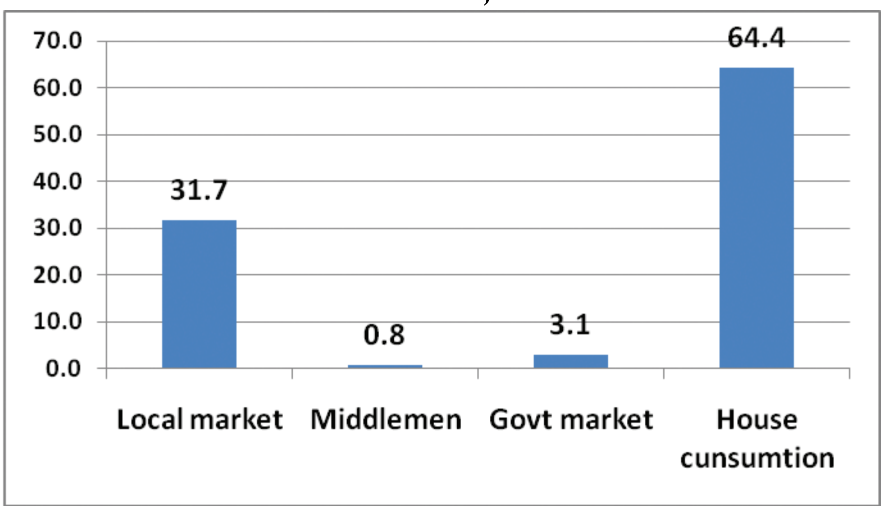
Fig.4.8: Distribution of households according to their response of marketing channels used for jowar grain



Source: Field Survey

An effort was also made to understand both jowar and bajra grain and fodder markets in order to assess the role of these crops in future biofuel markets. Farmers responses were taken about the nearest local market, middle men, government market yards and their

Fig. 4.9: Distribution of households according to their response regarding marketing channels used for jowar fodder



Source: Field Survey

own consumption. It is observed from figure 4.8 that with regards to grain market, 50.3 per cent of the farmers sold their crop in the local market while 21 per cent have used it for self consumption. When it comes to fodder market, figure 4.9 clearly reveals that 64.4 per cent was used for self consumption, followed by local markets (31.7%). This clearly indicates how important these two crops are for the sample households from the fodder point of view.

4.13 Water Pollution:

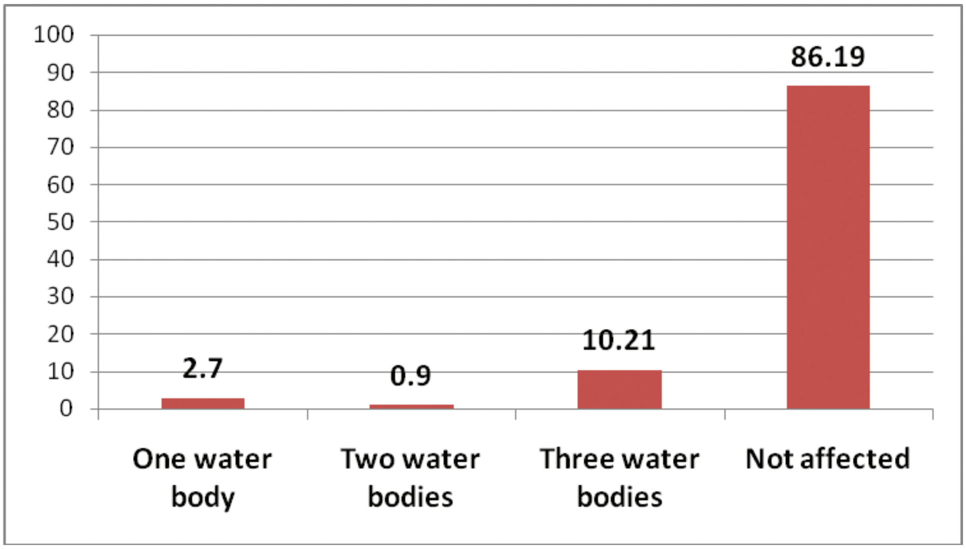
The study also looked at the farmers perception regarding the environmental pollution caused by the use of pesticides and fertilizers in general and cultivation of jowar and bajra in particular. Table 4.18 indicates that only 13.81 per cent of the households reported that there was pollution of water bodies due to usage of fertilizers and pesticides in crop cultivation while 86.19 per cent reported no pollution. In Sunvani Mahankal Village, all the sampled households reported pollution due to usage of fertilizers and pesticides whereas in Rupheda and Bahara villages, none of the sample households reported pollution. A further enquiry was conducted to understand the number of bodies that are being affected in the study villages. Figure 4.10 shows that nearly 10.21 per cent of the sample households reported pollution of three water bodies in their village.

Table 4.18: Response of sample households with respect to water pollution due to pesticide and fertilizer applications

Village name	Yes	No	Grand Total
Nagada	82.35(14)	17.65(3)	100.00(17)
Sunvani Mahankal	100.00(18)	0.00(0)	100.00(18)
Nagziri	1.85(1)	98.15(53)	100.00(54)
Rupheda	0.00(0)	100.00(15)	100.00(15)
Baraha	0.00(0)	100.00(54)	100.00(54)
Bijoli	9.09(2)	90.91(20)	100.00(22)
Daheli	5.88(1)	94.12(16)	100.00(17)
Jakara	3.85(2)	96.15(50)	100.00(52)
Nahar Donki	18.18(4)	81.82(18)	100.00(22)
Ummed garh	6.45(4)	93.55(58)	100.00(62)
Grand Total	13.81(46)	86.19(287)	100.00(333)

Source: Field survey

Fig 4.10: Response of sample households regarding the number of water bodies polluted due to pesticide and fertilizer applications



Source: Field Survey

4.14 Awareness on Biofuels:

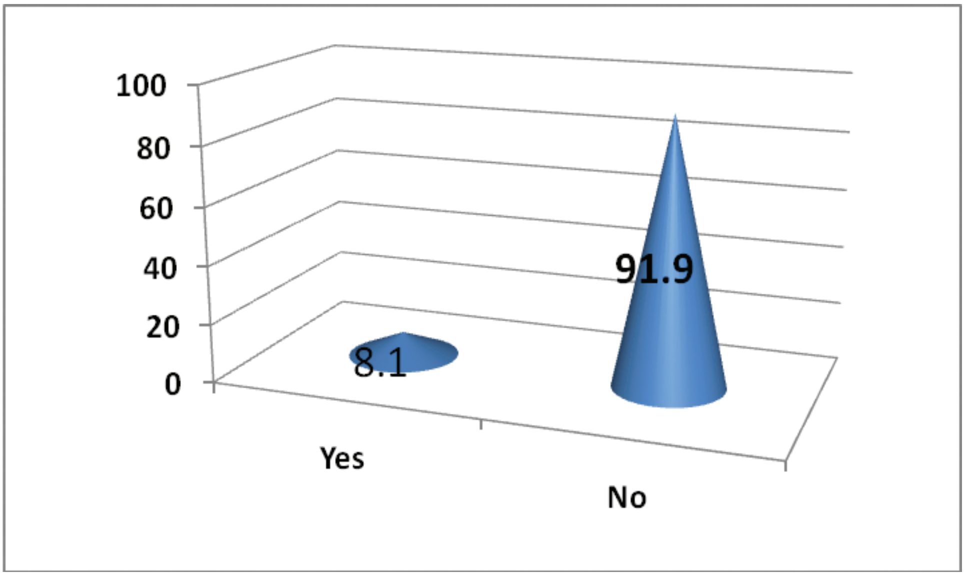
As noted in the literature, the lifecycle of biofuel production from the cultivation of biofuel crops to the final consumption is a highly complex and complicated process with high inter-linkages between different sections of the economy. Hence, a proper understanding of the process is necessary. However, the initial analysis of our primary study shows that awareness among farm households is almost negligible, which might further complicate the large scale production of these crops.

Farmers' perception regarding biofuels and their cultivation was also assessed in the present study. Figure 4.11 indicates that 91.9 percent of the sample households did not have any awareness about the biofuels. Continuing the probe further, farmers were asked whether they have any idea about the production of biofuels from agricultural crops such as jowar and bajra to which they responded negatively-nearly 95 per cent of the farmers had no idea about this. Further, they were asked whether this kind of biofuel production from jowar and bajra is desirable. Responding to this, 79.88 per cent said yes and 20.12 per cent said no.

4.15 Impact on Food Security

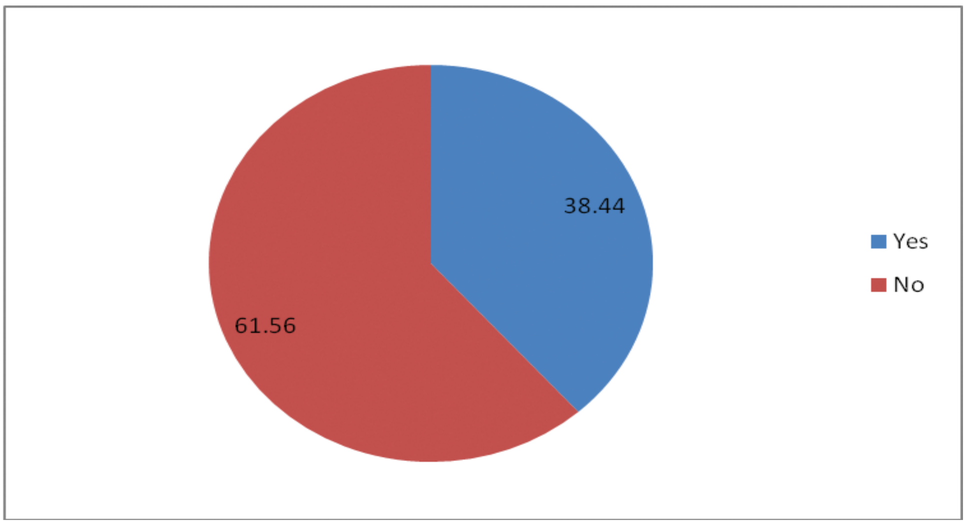
Information was elicited regarding possible shortage of food grains due to diversion of jowar and bajra for biofuel cultivation. As the probing got deeper, it was interesting to observe that 38.44 per cent of the households agreed that it will result in shortage of food grains while 61.56 per cent did not percieve a reduction in the food supply.

Fig 4.11: Awareness of sample households with respect to biofuels



Source: Field Survey

Fig. 4.12: Farmers perception of possible shortage of food grains due to diversion of jowar and bajra for biofuel cultivation



Source: Field Survey

Majority of the respondents felt that there would not be any impact on food security, citing the reason that they would supplement jowar/bajra either by procuring from fair price shops or from retail markets. Out of the 128 households which felt that there will be a reduction in food grains, 66.40 per cent felt that such reduction in grains will impact the household food security, while 33.60 per cent did not agree. Development of biofuels to meet the requirements of the transport sector can bring about changes in the land use pattern of the country and could threaten food security and other agrarian supplies (Singhal and Sengupta, 2012).

4.16 Impact on Fodder Security

The potential diversion or displacement of food crops is also considered to be a serious problem. Though the initial analysis of our field shows that the impact might not be much regarding food grain security, there is a considerable amount of apprehension on its potential impact on fodder security. It is evident from table 4.19 that even before the cultivation of these crops for biofuels production, a majority of the households (51.96%) believe that use of these crops will affect the fodder security of their animals.

Table 4.19: Village-wise response of farmers regarding the impact of use of jowar/bajra for biofuel production on fodder security

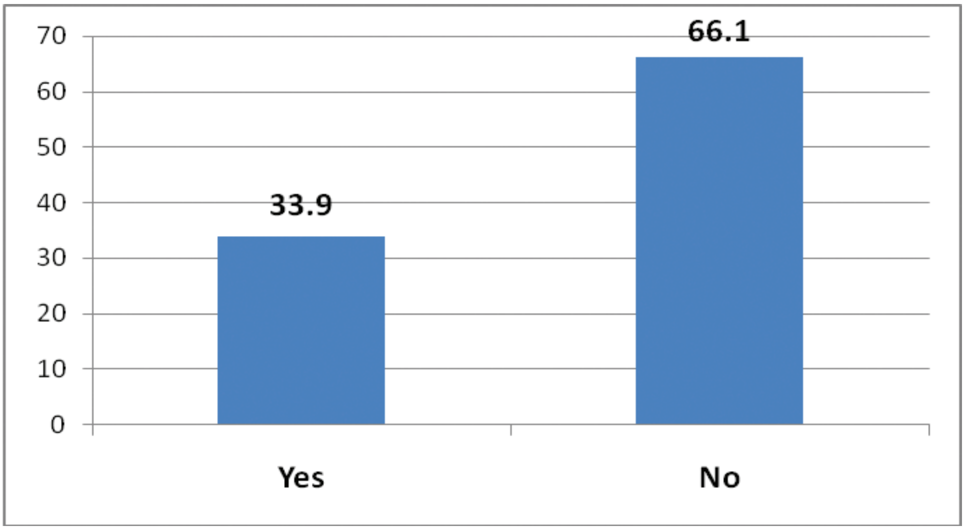
Village name	Yes	No	Total
Nagada	47.06 (8)	52.94(9)	100.0(17)
Chinvani	55.6(10)	44.4(8)	100.0(18)
Nagaziri	61.1(33)	38.9(21)	100.0(54)
Rupkheda	46.7(7)	53.3(8)	100.0(15)
Baraha	37.03(20)	62.96(34)	100.0(54)
Bijoli	31.8(7)	68.2(15)	100.0(22)
Dahel	52.9(9)	47.1(8)	100.0(17)
Jakara	19.2(10)	80.8(42)	100.0(52)
Nahar Donki	100.0(22)	0.0(0)	100.0(22)
Ummed Garh	75.8(47)	24.2(15)	100.0(62)
Total	51.96(173)	48.04(160)	100.0(333)

Source: Field Survey

On the other hand, 48.04 per cent of the sample households perceived that there won't be any impact on fodder security. It was very interesting to see that across all study villages of the five districts, there were a few households which did perceive that there would be fodder insecurity in the event of cultivation of these crops for biofuels production (see table 4.19).

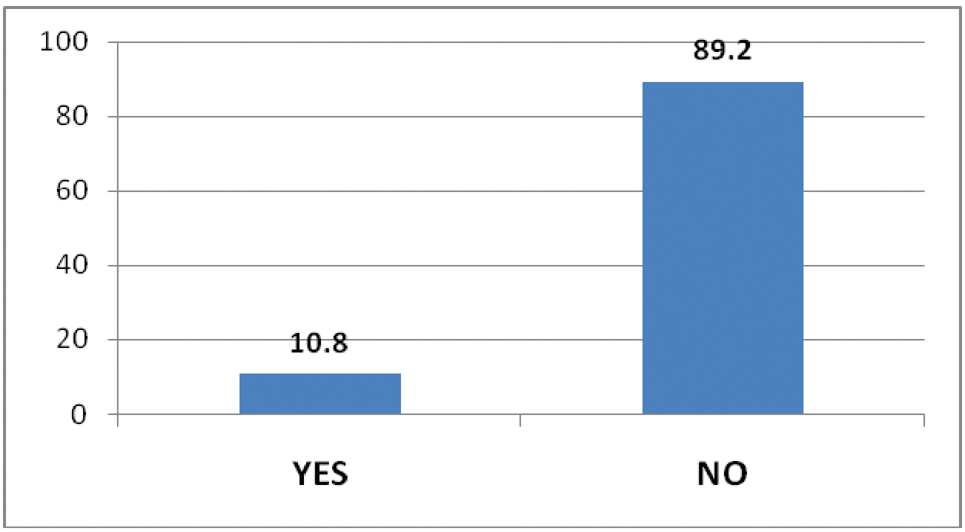
A further investigation was conducted to understand whether the diversion of fodder/ biomass for biofuel production will affect the milk economy of the region. Nearly 33.9 per cent of the samples households perceived that it will affect the milk economy, whereas 66.1 per cent responded negatively (see fig.4.13).

Fig.4.13: Impact of diversion of fodder for biofuel production on milk economy



Source: Field Survey

Fig. 4.14: Response of sampled households regarding migration of family members during 2013



Source: Field Survey

4.17 Migration:

Migration was another important issue that the baseline study observed in the study areas. It was interesting to note that during 2013-13 only 10.8 per cent of the sample households reported migration of their family members every year while 89.2 per cent did not migrate at all (see fig 4.14). Those who migrated usually went to the nearest towns for a couple of months in a year. Due to the vibrant agrarian and milk economy, MANY people found work in their respective villages. Moreover, households with livestock cannot easily migrate, ignoring the fodder and drinking water needs of their livestock.

5. Conclusion

Any attempt to promote the use of major staple food crops such as jowar and bajra for biofuel production has a long-lasting impact on the food and fodder security of both human beings and livestock in India. Hence, even for trying out these crops at research level, it is essential to have a dialogue with the farmers of drylands where these two crops are predominantly grown. More importantly, we should learn from our earlier experiences of jatropoha cultivation (Montobio and Lele, 2010; Singhal and Sengupta, 2012). Large-scale biofuel production is not an alternative to the current use of oil and is not even an advisable option to cover a significant fraction of it (Giampietro et al., 1997). Therefore, it is quite important that policies, plans and strategies for energy security do not conflict with other aspects of critical national importance such as food and fodder security.

CHAPTER - 5

Multi-locational Trials in Farmers Fields: An Empirical Analysis

5.1 Introduction

As a part of this project, work package 1 group led by International Crops Research Institute for Semi-Arid Tropics (ICRISAT) has taken up cultivation of High Biomass Varieties(HBV) of Jowar and Bajra, developed by them in the farmers' fields at different locations of Indore and Gwalior region of Madhya Pradesh with the assistance of scientists of Rajmata Vijayaraje Scindia Krishi Vishwa vidyalay(RVSKVV). These HBV varieties were meant for use as feed stocks for biofuel production. Along with the Baseline Survey in 2013-14, Centre for Economic and Social Studies(CESS) has also conducted household Survey of farmers (in Gwalior and Indore region) in whose field Multi location Trials of Jowar and Bajra were conducted. These surveys were done in two rounds i.e in the year 2014-15 Kharif and 2015-16 Kharif. The surveys tried to address the suitability of High Biomass Varieties (HBVs) of Jowar and Bajra feedstock's with regard to crop economics, socio-economic dynamics, potential up-scaling, issues with regard to use of wasteland, and finally the carbon neutrality.

5.2 Objectives of the 2014-15 and 2015-16 Kharif studies

- Re assess the socioeconomic conditions of the jowar- and bajra-cultivating households of MLT trials,
- Assess the economies of new bio mass variety of jowar and bajra with regard to the prevailing varieties that are being cultivated in the region,
- Identify the potential possibilities and hurdles for large scale upscaling of these new varieties.

Farmers of Gwalior, Khargone, Dewas and Morena districts, who had taken up the varieties for high biomass production developed by ICRISAT and IIMR (Indian Institute of Millets Research, Hyderabad) in their lands (multi location trails) were surveyed during 2014-15 Kharif. Focussed Group Discussions(FGD) have also been conducted by CESS team in Gwalior and Indore region with MLT farmers during the years 2015 and 2016. RVSKVV Scientists were part of these FGDs

Farmers of Gwalior, Khargone, Dewas and Morena districts, who had taken up the varieties for high biomass production developed by ICRISAT and IIMR (Indian Institute of Millets Research, Hyderabad) in their lands (multi location trails) were surveyed.

5.1 Study villages and the samples selected in Madhya Pradesh state during the third round of survey in 2015-16 Kharif

	Jowar Varieties			Bajra Varieties						
District name	RV ICSSH 28	CSV 93046	Total	Bajra 1	Bajra 2	Bajra 3	Bajra 4	Bajra 5	Bajra 6	Total
Dewas	13 (100.0)	0 (0.0)	13 (100.0)	- -	-	-	-	-	-	
Gwalior	25 (78.1)	7 (21.9)	32 (100.0)	- -	-	-	-	-	-	
Khargone	18	0 (100.0)	18 (0.0)	- (100.0)	-	-	-	-	-	-
Moraina	0 (0.0)	0 (0.0)	0 (0.0)	2 (8.7)	1 (4.3)	1 (4.3)	9 (39.1)	5 (21.7)	5 (21.7)	23 (100.0)
Total	**56 (88.9)**	**7 (11.1)**	**63 (100.0)**	**2 (8.7)**	**1 (4.3)**	**1 (4.3)**	**9 (39.1)**	**5 (21.7)**	**5 (21.7)**	**23 (100.0)**

Source: Field Survey

Note: Bajra 1 to Bajra 6 are the varieties developed for high Biomass by ICRISAT.

In 2016, the Project Monitoring Committee (PMC), with regards to Jowar crop has advised to focus only on RV1CSH 28, ICSV-25333 and CSH 22SS. In 2015 Kharif field trials, Indian Institute of Millet Research(IIMR) variety CSH 22SS and ICSV-25333 were not a part of trials (see table 5.1). Similarly, in the case of Bajra crop, ICMV-05222, 05777 and IP-61072 were finalized. However in 2016 trials 6 varieties are being used with series 1-6. Data of 2015 and 2016 field trials shows that there is inconsistency in the varieties being used in trials vis-à-vis the varieties that are being used in treatment analysis by Work Package 2.

With regards to Jowar, in 2014 Kharif six varieties were used in trials(see table 5.2). In 2015 only two varieties were cultivated. Interestingly, according to the data given by RVSKVV, the Jowar varieties(ICSV-25333 and IIMR variety CSH -22 SS) that were finalized in the PMC meeting in Delhi were not cultivated with farmers either in 2014 Kharif or 2015 Kharif. In the case of Bajra, ICMV-05222, 05777 and IP-61072 were finalized. However in 2014 and 2015 kharif trials 6 varieties are being used with series

1-6. Major finding of the 2014 Kharif trials was that the average income collectively from both grain and fodder yield was relatively lower for the new variety than compared to the ones being cultivated in the previous year.

5.2 Study villages and the samples selected in Madhya Pradesh state during the second round of survey in 2014-15 Kharif.

	Jowar varieties							Bajra						
District name	**ICSSH 28**	**ICSV 93046**	**CSH -24**	**CSH -1r3**	**IS-27206**	**IS-18542**	**TOTAL**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**TOTAL**
Dewas	1	3	1	-	1	1	7	-	-	-	-	-	-	-
Gwalior	3	11	-	13	-	-	27	-	-	-	-	-	-	-
Khargone	2	3	1	4	-	1	11	-	-	-	-	-	-	-
Moraina	-	-	1	-	4	-	5	2	5	4	5	9	3	28
Total	6	17	3	17	5	2	50	2	5	4	5	9	3	28

Source: Feidl Survey

5.3 Distribution of Households Cultivating High Bio-mass Variety(HBV) in Study Districts of Madhya pradesh state during the year 2015-16 Kharif

HBV Name	Dewas	Gwalior	Khargone	Morena	Total
BAJRA					
IP 13150	0 (0.0)	0 (0.0)	0(0.0)	2(100.0)	2(100.0)
ICMV 05222	0 (0.0)	0 (0.0)	0(0.0)	2(100.0)	2(100.0)
ICMV 05777	0 (0.0)	0 (0.0)	0(0.0)	9 (100.0)	9 (100.0)
IP 22269	0 (0.0)	0 (0.0)	0(0.0)	5 (100.0)	5 (100.0)
IP 61072	0 (0.0)	0 (0.0)	0(0.0)	5 (100.0)	5 (100.0)
SORGHUM					
ICSSH 28	13 (23.2)	25 (44.6)	18 (32.1)	0 (0.0)	56 (100.0)
ICSV93046	0 (0.0)	7 (100.0)	0 (0.0)	0 (0.0)	7 (100.0)
Total	**13 (15.1)**	**32 (37.2)**	**18 (20.9)**	**23 (26.7)**	**86 (100.0)**

Source: Field Survey 2016

In the PMC meeting during 2016 at Delhi, in the case of Bajra crop, ICMV-05222, 05777 and IP-61072 were finalized. However, in 2015-16 trials, three more varieties were also used in MLTs in addition to suggested varieties (see table 5.3). However, with respect to Jowar the decision was taken to focus only on ICSSH 28, ICSV-25333 and CSH 22SS. In 2015-16 Kharif field trials IIMR variety CSH 22SS and ICSV-25333 were not a part of trials. Surprisingly, the variety ICSV-25333 which is being used for analysis by Work package 2 group is not a part of the MLTs and its performance could not be assessed.

5.4 Table :Jowar and Bajra crops and Their Year-Wise Grain and Fodder Yeilds

Region	Year	Village	Crop	Variety	Avg.Grain Yeild in Quintols /acre	Avg.Grain Value in Rs/ Quintol	Dry Fodder yield in Kgs/ acre	Value of Fodder in Rs/Kg
Indore	2015-16	Nagzari	Jowar	Existing varieties (Hybrids)	10-12	1300-1500	1600-2000	2
	2015-16		Bajra	Existing varieties	4	1300-1400	700-800	2 -2.5
	2014-15		Jowar	HBV	4.5 to 5	Consumed	400	-
	2015-16		Jowar	HBV	1	Consumed	350	-
	2015-16	Nagdha	Jowar	Existing varieties (Hybrids)	14	1200- 1300	1000-1250	2
			Jowar	HBV	14	Consumed	1000	2
	2015-16	Palnagar	Jowar	HBV	1-1.4	Consumed	2800	2
Gwalior	2015-16	Nahardonki	Bajra	HBV	Nil	-	6000	Own Use
			Bajra	Existing Varieties (Mostly hybrids)	12	1200	2000	5
	2014-15		Bajra	Existing Varieties	12	900-1000	1000	3
	2013-14		Bajra	Existing Varieties	12	1100	1000	2
	2015-16	Bijoli	Jowar	Hybrids	12	1000-1200	1600-2000	1
				Peeli Jowar	8	2000-2500	3200	1.5 to 2
				Desi Safed Jowar	8	4500	3200	1.5 to 2
				HBV	4	Consumed	3200-4000	1.8 to 2
			Bajra	Existing varieties	8-10	-	1600-2000	1
Baseline Survey	2013-14	Average of all villages	Jowar	Traditional Jowar	12.06	-	950	1.5 to 2
				Hybrid Jowar	11.41	-	890	1 to 1.5
		Average of all villages	Bajra	Traditional Bajra	10.50	-	1000	1.5-2.0
				Hybrid	22		925	1-1.25

Source: FGD with sampled farmers of Indore and Gwalior region during 2014-15 and 2015-16 and Baseline survey of 2013-14.

5.3 Reasons for low/high or fluctuating Grain and Fodder Yeilds

The HBV jowar grain yield(2015-16 Kharif) in Nagzari was less due to less rains and some of it was eaten by birds and the fodder yield too was less. The reason for high HBV Jowar yield (Kharif 2015-16) in Nagdha are fertile soils and one supplemental irrigation in September month (in the event of no rains). As grain yield was high, there was reduction in fodder yield. Reason for less HBV Jowar yields in Palnagar is due to excess rains and failure of seed to germinate and the farmers had to go for second sowing which led to delay in sowing period and eventual low yields. In Nahardonki HBV crop height was very good but no grains were harvested due to multiple cuttings for fodder purpose. In Bijoli (Gwalior region) during 2015-16 Kharif, there was very less rain and it was almost like a drought and hence low yields in HBV Jowar. However Hybrids and Traditional Jowar varieties did reasonably well. In Palnagar and Bijoli, HBV jowar yielded a fodder quantity of around 3000Kgs. In Nahardonki village of Morena District (Gwalior region), despite zero grain yield in HBV Bajra crop, the fodder yield was highest with 6000Kgs/acre. The value of Jowar dry fodder changed from village to village (see table 5.5). However, it generally ranged between Rs1 to 2 rupees/Kg. In the case of Bajra crop fodder, there was wide range during 2015-16 Kharif as it varied between Rs 1 per Kg in Bijoli to Rs 5/Kg in Nahardonki of Gwalior region. The cost of fodder has implications for biofuel production as it is this material that is used a raw material. The lower the fodder price the more economical will be the biofuel production from these crops.

5.5 Market Price of Jowar and Bajra during 2014, 2015 and 2016 in Study Districts of Madhya Pradesh (in Rupees/Quintol)

JOWAR				
Village	**Variety**	**2014**	**2015**	**2016**
Nagzari (Indore)	Existing varieties	900-1200	1300-1400	1300-1500
Nagdha (Indore)	Existing varieties	800-1000	1500	1500
Bijoli (Gwalior)	Hybrid	900	1500-1600	2000
	Peeli Jowar	1000	2000	2000-2500
	Safed Jowar	1100	2000	4500
BAJRA				
Nahardonki	Existing varieties	1100	900-1000	1200

Source: Focused Group Discussions

Note: MSP of Jowar was Rs 1550 in 2015 and would become Rs1600 in 2016. However, Traders are buying the Jowar produce much below the MSP price in Indore region.

From last two years, there is huge increase in market price of Safed Jowar(traditional variety of the region) due to its utility for some industrial purpose(see table 5.5). Hence, farmers are increasing the area under this crop in Gwalior region and there is a growing demand for the seed of this crop.

Table 5.6 : Details of Grain and Fodder yields of High Biomass Varieties vis-à-vis Existing Varieties during the year 2015-16 Kharif.

Particulars	Bajra Crop						Jowar Crop		
	2015-ICFPM-7	2015-ICFPM-1	ICMV 05222	ICMV 05777	IP 6107	Existing Varieties	ICSSH 28	ICSV 93046	Existing Varieties
Grain yield in Qtls	4.00	-	4.66	6.66	4.00	12	7.82	-	10
Fodder yield in Kgs	1260	3000	1740	1460	1410	2000	2924	2550	2000
Fodder income in Rs	3150	7500	4350	3650	3525	6000	5263	4590	3000
Grain value in Rs.	4800	-	5592	7992	4800	14440	9384	-	12000
Cost of cultivation in Rs.	1180	1610	2095	1816	1498	10,000	6046	1986	6000
Gross income in Rs.	7950	7500	9942	11642	8325	20400	14647	4590	15000
Net income in Rs.	6770	5890	7847	9826	6827	10400	8601	2604	9000

Source: Field Survey 2016.

The HBV varieties were taken up in less than quarter acre and the values were imputed per acre. However the values of existing varieties are based on the results from actual acreage. In the case of both Bajra and Jowar crops, with regards to overall per acre income existing varieties were doing slightly better than ICMV 05777 and ICSSH-28 respectively and far better than other HBV varieties used in MLTs in farmers field during Kharif 2015-16 (see table 5.6). When it comes to biomass yield, 2015-ICFPM-1 (This is not in the PMC finalised list) of Bajra crop and ICSSH-28 and ICSV 93046 (not present in the PMC finalised list) were performing much better than existing varieties in 2015-16 Kharif.

5.4 Conclusion :

The empirical analysis of MLTs has clearly indicated that the varieties that were finalized by the project management committee of the JCERD-SLABs programmes were not seen in the multilocational trials conducted by work package I group. Contrary, they have included some other varieties. This has implication for the work package 2 group which is doing chemical analysis of feed stocks. They have used a feedstock for analysis which was not a part of MLTs for example ICSV-25333 and its performance could not be assessed. Such things reduce the significance of MLTs and there by learnings from these trials may not be of much use for taking decisions regarding upscaling the cultivation of these two feed stocks.

CHAPTER - 6
Life Cycle Assessment of Second Generation Bioethanol from Sorghum and Pearl Millet Feedstocks

6.1 Introduction

Depletion of fossil fuels at an alarming rate has attracted increasing attention to blending bio-fuels worldwide. With self-sufficiency levels in crude oil becoming a distant dream, there is growing interest to look out for alternative fuels and the biofuels are an important option for policy makers in India (Reddy et al, 2015). National Biofuel Policy promoted blending 20% bio-ethanol and bio-diesel by 2017 and gave thrust for the development of second generation biofuels and other new feedstocks for production of bio-fuels (Ministry of Renewable Energy, 2009). Attempts are being made to identify new feedstocks for ethanol production. These include the use of straw from food crops such as paddy, wheat, sorghum and pearl millet. The straw contains 35-40% of cellulose, 17-25% of hemicellulose and 10-20% of lignin apart from significant amount of extractives and silica. The cellulose and hemicellulose can be hydrolysed to glucose, xylose using chemicals and enzymes. These hydrolysed sugars can be further converted into ethanol upon fermentation using yeast. Ethanol produced upon denaturing, can be used as a blending fuel for Internal Combustion Engines. The objective of this chapter is to assess the performance of Sorghum and Pearl millet feed stocks for bioethanol production in India using a Life Cycle Assessment (LCA) approach.

6.2 Life Cycle Assessment Methodology

Cradle to Grave approach of Life Cycle Assessment designed excel based model was used to assess the renewability potential of the bioethanol feedstocks. This model was designed based on the ISO 14040-Life Cycle Assessment standard(International Organisation of Standards, 2006)to design the system boundaries for a functional unit of 1 Tonne per Day (TPD) of dry biomass feedstock plant. These system boundaries included feedstock farming, transportation of feedstock, ethanol production, ethanol transportation, ethanol blending and fuel combustion. Along with the baseline survey data (of 2013) collected for feedstock with 333 farmers covering five districts of Madhya Pradesh state of India, empirical data from the 66 multi-locational trials of sorghum and pearl millet conducted during the years 2014-15 and 2015-16 in farmers fields was used to conduct the LCA analysis. Data from secondary sources was also used to conduct the analysis.

Life Cycle Assessment as per the ISO-14040 has multiple steps. They are i) to define the goal and scope of the work ii) inventory analysis iii) impact assessment which demands clear distinction and definition of all the unit processes and their impact separately iv) interpretation phase which validates the study and provides concluding remarks for the product under study.

6.3 Approach

To carry out a LCA for sorghum and pearl millet stalks as feedstock and identifying their viability for biofuel production is the main goal of this approach. As per the LCA methodology, it is important to design a system boundary. The first step to any process design is to develop a set of process flow diagrams (PFDs).

Figure 6.1 contains the PFDs used for this study. A typical ethanol production requires separate saccharification of pentose and hexose sugars. In this study, simultaneous saccharification and co-fermentation is considered. Farming data was collected from the field surveys conducted by Centre for Economic and Social Studies (CESS) and the data from agro-India. High Biomass Variety (HBV) was considered for this study and the data on these hybrids were taken from International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and Indian Institute of Millet Research. In the present model analysis was carried out for both rain fed and irrigated crops. Lignocellulosic feedstock considered in this study are a high biomass variety crops which yield high fodder and are grown specifically for meeting bioethanol blending target. This feedstock gives fodder which is considered as an additional market value gained and hence it is important to analyse its life cycle inventory from the farming stage for a better comparison and allocation. Certain inventory input values were either calculated for Madhya Pradesh region or collected from secondary data sources. The model considers mass and energy balances associated within the processes.

6.4 Process Overview

Processes included in this study and their significance is explained in this section;

- Farming: The feedstock is cultivated, harvested and dried in this process.
- Feedstock handling and storage: The feedstock is handled and stored at the farm and transported using a tractor or truck
- Size reduction: Size reduction is through a knife mill
- Pre-treatment: This process is carried out to separate lignin from the cellulose and hemicellulose.
- Simultaneous Saccharification and co-fermentation: Hydrolysis and fermentation is carried out to convert the glucose and xylose to ethanol.

- Distillation: Steam distillation is employed to purify ethanol
- Product purification: the product ethanol is purified using a second distillation column to refine the ethanol and then the ethanol is denatured
- Product storage: Ethanol produced is directly shipped to the nearest blending stations instead of storing
- Waste water treatment: water is treated and the lignin is separated from the waste water
- Lignin Combustion: Lignin combustion to produce process steam and excess steam to produce electricity.
- Ethanol transportation to the blending station
- Ethanol blending at the blending station
- Ethanol blended fuel combustion

Process overview is indicated in the Process flow diagram shown in figure 6.1

6.5 Life Cycle Assessment System

Life Cycle Assessment is an analysis to assess the impacts associated in all the stages of the product formation from the raw materials.

6.5.1 Farming and transportation of the feedstock

Farming includes soil preparation, sowing, cultivation and harvesting. Soil preparation involves ploughing and levelling which can also be mechanised. Water will be provided for the crop based on the irrigation requirement and number of irrigations. Crop duration is 120 days and on attaining maturity the crop is harvested by cutting down the stem and allowing the remaining plant to fertilise the soil.

Basis: As per ISO standards, Functional Unit=1 Tonne per Day (TPD) of dry biomass feedstock

6.5.2 Land requirement

Land required for growing feedstock for a plant capacity of one Tonne per day (TPD). It is calculated based on the dry biomass yield(Stakeholder, 2015)

Equation 1

$$Land\ requirement(hectare) = \frac{Plant\ Capacity\ (TPD)}{Dry\ biomass\ yield\ (\frac{Tonne}{hectare})}$$

Figure 6.1: System Boundary

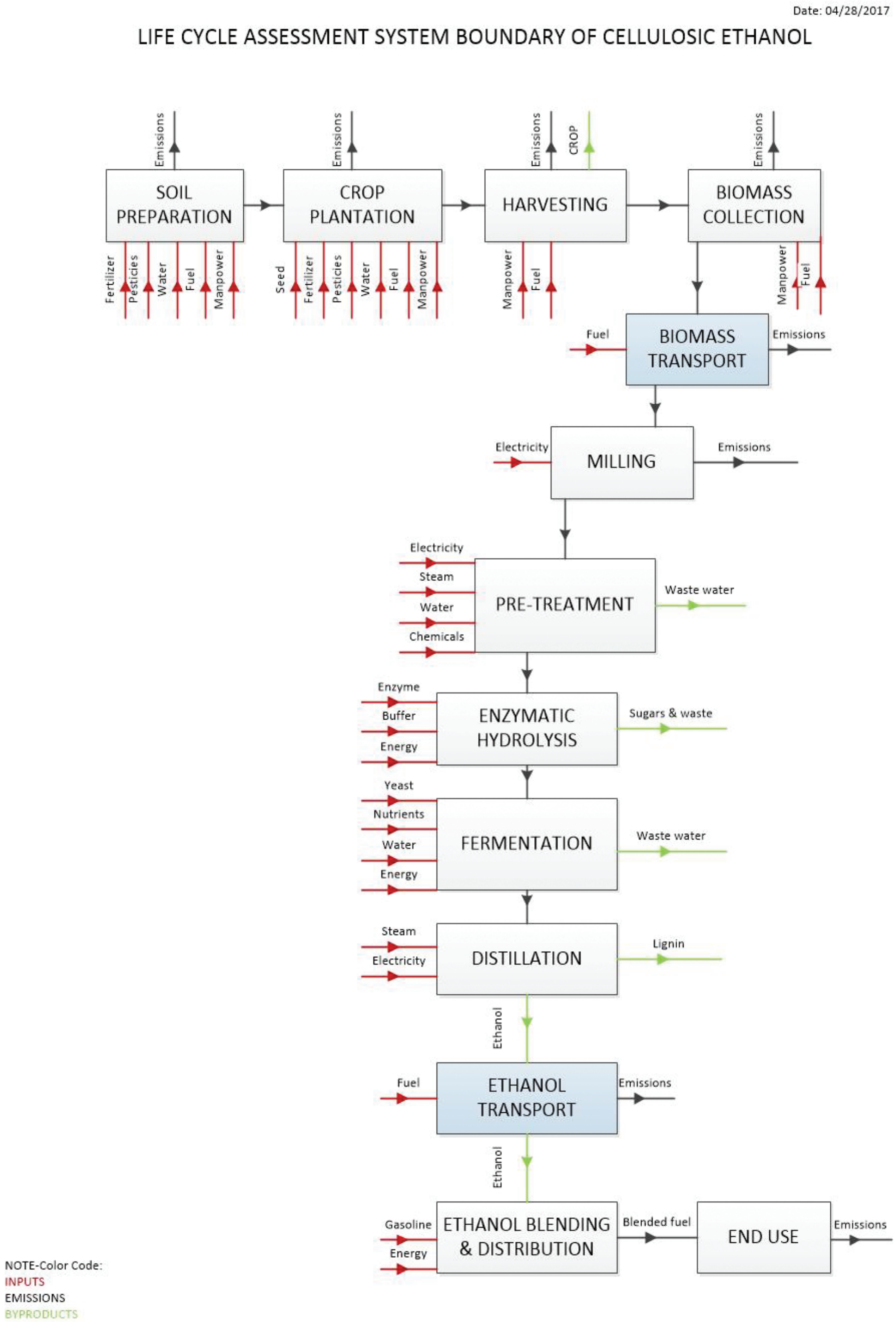


Table 6. 1: Feed stock or Biomass yield and land requirement

Feedstock	Dry fodder yield (kg/acre)	Land requirement (ha)
Sorghum stalk	4000	0.10
Pearl millet Stalk	2000	0.20

6.5.3 Water requirement

Sorghum and Pearl millet are usually rain fed crops. To estimate the impact caused if the crop was irrigated, water requirement becomes an important parameter. Water requirement for crops are given in terms of depth of irrigation and number of irrigations. Average values for kharif and rabi crops are considered for irrigation depths(Gangaiah, 2012). The crop is irrigated at the flower primordial initiation and flowering stages i.e 70-80 days after cultivation.

Equation 2: water requirement

$$Water\ requirement\ (kL) = water\ depth(mm) \times Area(ha) \times No\ of\ irrigations$$

Table 6. 2: Water requirement

Feedstock	Water depth (mm) (kl/hectare)	One irrigation water requirement[a]	No of irrigations	Water requirement (kl)
Sorghum stalk	550	5500	1-2	550
Pearl millet Stalk	300	3000	1-2	300

A depth of water (mm) requirement is converted to mm3/ha

6.5.4 Chemicals required

Chemical inventory was based on the empirical data collected by CESS from farmers of Madhya pradesh state (see table 6.3). Fertiliser and pesticide usage for sorghum and pearl millet crops was based on farmer's survey in Madhya Pradesh.

Table 6.3 : Fertilizer /pesticides requirement for Sorghum and Pearl millet crops

Feedstock	Urea (kg/acre)	Di-ammonium phosphate (DAP) (kg/acre)	Potash (kg/acre)	Complex (kg/acre)	Herbicides (L/acre)	Pesticides (L/acre)
Sorghum stalk	71.3	60.1	41.3	117.8	1.0	1.5
Pearl millet Stalk	45.2	20.0	6.0	0.0	1.0	1.5

Area converted from bigha to acre. 1 acre=2.49 bigha(Easy Calculations.com, 2017)

6.5.5 Diesel requirement

Land preparation is a one crop time activity where the ploughing is done well in early showers. It is done using a cart or a tractor.By a stake holder interaction with a farmer, diesel requirement for land preparation is 4-7 litres per acre.

6.5.6 Electricity requirement

3 HP electric pump for irrigation is used in case of water drawn from bore well. In case of rain fed crops, electricity requirement become nil in case of irrigation purpose. This pump has a Total Dynamic Head (TDH) of 20-22 m(Pumpkart, 2017)

Equation 3: Electricity requirement

$$Electricity\ requirement(kWh) = water\ requirement\ \left(\frac{L}{ha}\right) \times power\ consumption\ \left(\frac{kWh}{L}\right) \times$$

Equation 4: Power of an electric pump

$$Power\ consumption\ of\ a\ pump = \frac{2.725 \times TDH}{\eta}$$

Where η=0.63

1 Mega litre of waterto lift to 1 metre of height uses 2.725 kilowatt-hours (kWh) of electricity(Foley, 2015)

Table 6.4 : Power consumption for irrigation

Feedstock	Power consumption (kWh)
Sorghum	52.71
Pearl millet	57.47

6.5.7 Seed requirement

Based on the literature, seed requirements are 10 kg/ha and 7 kg/ha for Sorghum and Pearl millet respectively (TNAU Agritech portal, 2017; Agropedia, 2017)

Table 6.5: Seed requirement for feedstock

Feedstock	Seed requirement (kg)
Sorghum	1.01
Pearl millet	1.42

6.5.8 Labour requirement

Labour requirement in Madhya Pradesh is 36.13 and 45.08 Man-days/ha for Sorghum and Pearl millet feedstock respectively (Jaiswal, 2009; Deshmukh, 2010). Assumption of 8 working hours is considered per day.

Table 6. 6: Labour requirement for farming

Feedstock	Labour requirement (Man-hour)
Sorghum	29.2
Pearl millet	73.0

6.5.9 Transportation of feedstock

Certain underlying assumption for making this feedstock viable and to avoid the risk due to expensive transportation, farm to plant distance is 50 km as suggested by CESS. Transportation of the feedstock is usually be by a 40 HP tractor from farm to the plant. Through farmer's survey, an average carrying capacity of a 40 HP tractor is 5 ton which consumes 4 km/L of diesel in loaded condition and 7 km/L in unloaded condition. The feedstock can be collected and transported once in five days to divide the transportation inventory.

Equation 5: Fuel consumption for transportation

$$Fuel\ consumed = (Cp \times distance)/(Ct\ \times mileage\ )$$

Where Cp is the capacity of the plant (TPD)

Ct is the capacity of the vehicle (Tonnes)

Distance in km

Mileage in km/l

7. Ethanol production

Dry biomass feedstock is fed to a knife mill where the straw is debaled and size reducedto 10 mm. The crushing capacity of a knife mill is 360 kg/h with the power consumption of 10.53 kWh/Tonne(Bitra, 2009). The crushed biomass feedstock is sent to the pre-treatment reactor through a level ground conveyor of 100 TPH capacity (power capacity of 3.75 hp) connecting 300 ft. distance(Engineering Tool Box, 2017).

Composition of dry Sorghum and Pearl millet stalk is in Table 6. 6.

Table 6. 7: Feedstock composition

Component	Sorghum stalk (%)	Pearl millet stalk (%)
Cellulose	35.9	41.0
Hemicellulose	26.0	20.9
Lignin	7.5	18.3
Ash	0.7	6.0
Moisture	15.0	10.0
Others	14.9	3.9

Production of cellulosic ethanol via biological conversion consists of three critical steps:

- Pre-treatment of biomass
- Hydrolysis of sugar polymers to sugar monomers and
- Fermentation of sugar monomers to ethanol

7.1 Pre-treatment

Recalcitrant and heterogeneous structure of the biomass poses a fundamental challenge to depolymerisation of cellulose during enzymatic hydrolysis process. Enzyme accessibility is restricted by the lignin and hemicellulose which makes enzyme irreversibly bind to lignin thus slowing down the process(Kumar, 2011). Pre-treatment methods are aimed at enhancing the susceptibility of lingo-cellulosic biomass to enzymes thereby degrading the hemicellulose and lignin. Cellulose in the form of glucan and hemicellulose in the form of xylans and converted to pentose and hexose sugars in this model for the ethanol production. Pre-treatment of both Sorghum and Pearl millet feedstocks are explained in this section.

The following are the major pre-treatment techniques used in agro-based feed stocks:

- Dilute acid
- Steam explosion
- Hot water
- Dilute alkali
- Alkali hydrogen peroxide

a. Dilute Acid (DA)

The biomass consisting of cellulose, hemicellulose and lignin is treated with 1 % w/w sulphuric acid at180°C and 11 bar in a reactor for 15 min. Sulphuric acid acts as a catalyst. High and low pressure steam is fed into the reactor for maintaining the water in liquid stage. At this stage, some of the cellulose is hydrolysed to glucose. A fraction of lignin is converted to soluble lignin. However, most of the hemicellulose gets hydrolysed in this process(Kumar, 2011).

b. Steam Explosion

Biomass is heated at high pressure of 15 bar at temperature of180°C for 15 min and is flashed into a tank where the rapid expansion of steam causes rupture of the biomass structure. This process is highly effective on feedstock with large particle sizes thereby reducing the energy requirement for size reduction(Kumar, 2011).

c. Hot water

In an auto catalysed hot water pre-treatment process, acetic acid released from hemicellulose and self-ionisation of water at elevated temperatures act as dilute acid for breaking the cellulose and hemicellulose sugars. Thus feedstock undergoes hydrolysis(Kumar, 2011).

d. Dilute alkali

In this process, alkali swells the cellulose thereby increasing the surface area promoting the separation of carbohydrates from lignin. This treatment, also removes acetyl groups of hemicellulose resulting in higher lignin removal during dilute alkali pre-treatment compared to other pre-treatments(Kumar, 2011).

e. Alkali hydrogen peroxide

It is an advanced method developed by Indian Institute of Chemical Technology (IICT)-Hyderabad and Indian Institute of Technology (IIT)-Delhi as a Work Package-2. This process is effective for higher digestibility and prevents the formation of inhibitors.1 % (w/w) of alkali and hydrogen peroxide is added to the biomass feedstock at 550C and atmospheric pressure for 4 hours. This pre-treatment method eliminates the formation of furfural and Hydroxymethy furfural (HMF) which inhibits the hydrolysis.

Reaction conditions of all the pre-treatment processes carried out in this study are in indicated Table 6. 7.

Table 6.8: Pre-treatment conditions

Conditions	Units	Dilute Acid	Steam Explosion	Hot water	Dilute alkali	Alkali hydrogen peroxide
Temperature	°C	180	180	180	180	55
Pressure	Bar	11	11	11	11	1.0135
Residence time	Min	15	15	15	15	240
Solid loading	%	20	30	20	20	20
Acid/Alkali loading	% w/w	1	0	0	1	1

Under above reaction conditions, following reaction stoichiometry is attained.

$$Glucan + 0.111\ H2O \rightarrow 1.111\ Glucose$$

$$Xylans + 0.136\ H2O \rightarrow 1.\ 136\ Glucose$$

$$Lignin \rightarrow Soluble\ Lignin$$

$$Xylose \rightarrow 0.64\ Furfural + 0.36\ H_2O$$

$$Glucose \rightarrow 0.7\ HMF + 0.3\ H_2O$$

Where, Hydroxymethylfurfural (HMF) and furfural are fermentation inhibitors.A summary of the pre-treatment reaction conversion is mentioned in the Table 6. 8(Kumar, 2011).

Table 6.9: Pre-treatment conversion

	Dilute Acid (%)	Steam Explosion (%)	Hot water (%)	Dilute alkali (%)	Alkaline hydrogen peroxide (%)
Cellulose to Glucose	13.04	5.00	0.43	0.29	50.00
Xylan to xylose	60.26	70.00	70.00	0.72	22.50
Lignin to soluble lignin	5.00	5.00	5.00	25.00	15.00
Xylose to furfural	5.00	15.00	2.50	0.01	0.00
Glucose to HMF	5.00	15.00	2.50	0.01	0.00

7.2 Simultaneous Saccharification and Co-fermentation

The pre-treated biomass was hydrolysed using the enzymes cellulase and hemicellulasefor cellulose and hemicellulose respectively. The enzyme loading of 15 Filter Paper Unit per gram (FPU/g) of cellulose was considered for dilute acid, steam explosion, dilute alkali and hot water treatment. Cellulose and hemicellulose hydrolysis can be done by Simultaneous Saccharification and Co-Fermentation (SSCoF) reactor which is proven successful in a pilot scale study(Kim, 2012; K.Réczey, 2004; Pothiraj, 2015).

Glucose is hydrolysed by Saccharomyces Cerevisiae. Zymomonasmobilis is an organism tested for co-fermentation of glucose and xylose(Thapelo Mokomele, 2005). Reaction conditions, conversions and inventories are considered by work done by Deepak Kumar(Kumar, 2011)

Table 6.10: Reaction conditions

Parameters	Units	Dilute Acid	Steam Explosion	Hot water	Dilute alkali	Alkali hydrogen peroxide
Temperature	oC	35	35	35	35	55
Enzyme loading	FPU/g cellulose	15	15	15	15	15 FPU/g biomass
Time	Day	5	5	5	0.25	

Under the above reaction conditions, following reaction stoichiometry is attained.

$$Glucan + 0.111\ H2O \rightarrow 1.111\ Glucose$$

$$Xylans + 0.136\ H2O \rightarrow 1.\ 136\ Glucose$$

$$Glucose \rightarrow 0.489\ CO_2 + 0.511\ Ethanol$$

$$Xylose \rightarrow 0.489\ CO_2 + 0.511\ Ethanol$$

Based on the stoichiometric balances, following conversions of ethanol under different pre-treatment conditions is shown in Table 6. 10 and their inventory is in Table 6.13 and Table 6.14 for Sorghum and Pearl millet stalks respectively.

Table 6.11: Conversion of ethanol from feedstock

Conversion	Dilute Acid Treatment (%)	Steam Explosion (%)	Hot water (%)	Dilute alkali(%)	Alkaline hydrogen peroxide (%)
Cellulose to Glucose	79.0	70.0	78.5	84.8	67.5
Xylan to xylose	80.0	80.0	80.0	80.0	64.1
Glucose to ethanol	95.0	95.0	95.0	95.0	80.0
Glucose to CO2	95.0	95.0	95.0	95.0	80.0
Xylose to ethanol	70.0	70.0	70.0	70.0	80.0
Xylose to CO2	70.0	70.0	70.0	70.0	80.0

Table 6. 12: Ethanol yield from different pre-treatment and feedstocks

Ethanol yield	Dilute Acid Treatment (%)	Steam Explosion (%)	Hot water (%)	Dilute alkali (%)	Alkaline hydrogen peroxide (%)
Sorghum Stalk	25.26	22.90	25.00	24.88	24.89
Pearl millet Stalk	25.62	27.86	25.26	25.55	25.89

Ethanol yield is calculated as output ethanol(kg) to that of the input dry biomass feedstock (kg)

The Life Cycle inventories are shown below. Chilled water, cooling water are used to dissipate heat during all the post heating process operations.Chemically treated water is used in processes for feedstock processing, dilutions and cleaning operations. DAP is used as a nutrient source for Z.Mobilis growth(Davis, 2013).

Table 6. 13: Life Cycle Inventory for Sorghum stalk-ethanol production

Inventory	Dilute Acid	Steam explosion	Hot water	Dilute alkali	Alkaline hydrogen peroxide
Electricity*	179.29	168.35	164.80	164.00	175.47
Steam	1892.17	1169.76	1904.67	1835.54	1836.0
Steam (High pressure)	134.47	179.96	133.10	132.46	132.5
Cooling water	160159.29	116523.16	180642.23	157850.48	157886.5
Chilled water	233.72	258.33	266.21	264.92	265.0
Chemically Treated water	28417.84	28718.62	28278.43	28081.93	28088.3
Water	1920.99	1257.71	1901.50	1892.31	1892.7
Sulphuric acid	65.95	0.00	0.00	15.45	15.5
Ca Hydroxide	32.02	0.00	0.00	0.00	0.00
DAP	0.32	0.29	0.32	0.32	0.32
Cellulase	83.88	87.66	95.71	95.25	95.27
Yeast	0.96	1.16	0.95	0.95	0.97
Sodium hydroxide	0.00	0.00	0.00	49.52	49.53
Gasoline	2.56	2.32	2.54	2.52	2.52
Hydrogen peroxide	0.00	0.00	0.00	0.00	49.53

All units in kg

* Units in kWh

Table 6.14: Life Cycle Inventory for Pearl millet stalk-ethanol production

Inventory	Dilute Acid	Steam explosion	Hot water	Dilute alkali	Alkaline hydrogen peroxide
Electricity	181.86	204.79	166.49	168.40	182.07
Steam	1919.30	1422.96	1924.19	1884.83	1909.9
Steam (High pressure)	136.40	218.92	134.47	136.02	137.8
Cooling water	162455.52	141745.27	182494.03	162089.01	164246.2
Chilled water	237.07	314.25	268.94	272.04	275.7
Chemically Treated water	28825.27	34934.93	28568.32	28835.97	29219.7
Water	1948.53	1529.95	1920.99	1943.12	1969.0
Sulphuric acid	66.90	0.00	0.00	15.87	16.1
Ca Hydroxide	32.48	0.00	0.00	0.00	0.00
DAP	0.32	0.35	0.32	0.32	0.33
Cellulase	85.09	106.63	96.69	97.80	99.11
Yeast	0.97	1.41	0.96	0.97	0.33
Sodium hydroxide	0.00	0.00	0.00	50.85	51.52
Gasoline	2.60	2.82	2.56	2.59	2.63
Hydrogen peroxide	0.00	0.00	0.00	0.00	51.52
Ethanol produced	324.76	353.09	320.16	323.85	103.75

All units in kg

* Units in kWh

7.3 Distillation and steam production

Followed by SSCoF process, the slurry is stored in a beer well for 4 hours to allow settling. Ethanol is distilled using two distillation columns D1 and D2. The ethanol vapours from the first column are enriched in the second distillation column. In the process of enriching, an azeotrope of ethanol and water is formed in the distillation column D1 is separated using a molecular sieve to produce anhydrous ethanol which upon denaturing is ready for blending with gasoline.

The bottom effluent from the first distillation D1 column has lignin and non-fermentables. The bottom effluent is passed through pneumapress that further separates solids and liquids. Lignin rich solids are combusted in Fluidised Bed Combustor (FBC) for steam generation. Liquid rich stream containing water is evaporated, the evaporated condensate is recycled as process recycle water and the concentrate is sent to FBC for combustion. Steam produced from lignin fraction is more than steam requirement of the plant. The excess steam is utilised for power generation which can be sold to the grid. The underlying assumption is that 1 kilo litre of ethanol gives 15.6 m3 of spent wash; 1 m3 of spent wash gives 35 m3 of biogas; 1 m3 of biogas gives 2.5 kWh of electricity and the same is calculated for different pre-treatments for Sorghum and Pearl millet feedstocks in Table 6.15 and Table 6.16 respectively.

Table 6.15: Ethanol production and byproduct from Sorghum feedstock

Product	Dilute Acid	Steam explosion	Hot water	Dilute alkali	Alkaline hydrogen peroxide
Ethanol (L)	320.16	290.26	316.92	315.39	315.46
Electricity (kWh)	437.03	396.21	432.59	430.50	430.60

Table 6. 16: Ethanol production and byproduct from Pearl millet feedstock

Product	Dilute Acid	Steam explosion	Hot water	Dilute alkali	Alkaline hydrogen peroxide
Ethanol (L)	324.76	353.09	320.16	323.85	328.16
Electricity (kWh)	443.29	481.97	437.03	442.06	447.94

8. Ethanol Transportation

Bioethanol transportation from plant to blending station is by diesel driven tankers of 40 HP. The distance from the plant to the blending and distribution station is 100 km. Truck capacity is 18000 litres with loaded and unloaded mileage of 6 and 7 km/l(Soam, 2015; Hi-Tech Services, 2017).

9. Blending

Blending of E5, E10 or E15 can be carried out in the model. However, 5% blending of ethanol with gasoline by volume is considered under this report.

10. Combustion

Combustion of the ethanol blended fuel in comparison to pure gasoline in an IC engine is considered in this study.

11. Results

The results are evaluated based on the environmental impacts through the Life Cycle Assessment at 5% blending. Net Energy Ratio (NER), Net Energy Balance (NEB), Net Carbon Balance (NCB) and % Carbon reduction are essential in analysing LCA. These parameters are calculated as below.

11.1 Net Energy Ratio

It is the ratio of energy returned on energy invested. A fuel under study is considered renewable only if the NER is greater than one(Confederation of Indian Industry, 2010)

$$Net\ Energy\ Ratio = \frac{Energy\ Output\ from\ ethanol\ production}{Energy\ Input\ for\ ethanol\ production}$$

11.2 Net Energy Balance

It is the difference between the output energy to that of the input energy(Confederation of Indian Industry, 2010)

$$Net\ Energy\ Balance = Energy\ Output - Energy\ Input$$

11.3 Net Energy Balance per kilo litre of bioethanol

It is the net energy output per kilo litre of bioethanol produced(Confederation of Indian Industry, 2010)

$$Net\ Energy\ Balance\ per\ kilo\ litre\ of\ bioethanol \left(\frac{GJ}{kl}\right) = \frac{Net\ Energy\ Balance}{Quantity\ of\ ethanol}$$

11.4 Net Carbon Balance

It is the difference between the output and input carbon emissions(Confederation of Indian Industry, 2010)

$$Net\ Carbon\ Balance = Output\ Carbon\ emissions - Input\ Carbon\ Emissions$$

11.5 Net Carbon Balance per kilo litre of bioethanol

It is the net carbon emission output per kilo litre of bioethanol produced(Confederation of Indian Industry, 2010)

$$Net\ Carbon\ Balance\ per\ kilo\ litre\ of\ bioethanol \left(\frac{tCO2e}{kl}\right) = \frac{Net\ Carbon\ Balance}{Quantity\ of\ ethanol}$$

11.6 % Carbon emission reduction

It is the net quantity of Greenhouse Gas emissions avoided by using biofuel when compared to the use of fossil fuel(Confederation of Indian Industry, 2010)

$$Net\ Carbon\ Balance\ per\ kilo\ litre\ of\ bioethanol \left(\frac{tCO2e}{kl}\right) = \frac{Net\ Carbon\ Balance}{Quantity\ of\ ethanol}$$

NER, NEB, NCB without allocation for Sorghum and Pearl millet feedstocks are estimated and presented in Table 6.17, Table 6.18, Table 6.19 and Table 6.20 respectively

Table 6.17: Energy renewability indicators of Sorghum feedstock-ethanol

Pre-treatment	Net Energy Ratio		Net Energy Balance (GJPY)		Net Energy Balance per kL of ethanol (GJ/kL)	
	Rain fed	Irrigated	Rain fed	Irrigated	Rain fed	Irrigated
Dilute Acid	2.629	2.492	1853.5	1790.9	17.5	17.0
Steam Explosion	2.332	2.213	1549.1	1486.5	16.2	15.5
Hot water	2.421	2.303	1738.1	1675.5	16.6	16.0
Dilute Alkali	1.908	1.834	1402.6	1340.0	13.5	12.9
Alkaline hydrogen peroxide	1.855	1.785	1358.9	1296.3	13.1	12.5

Table 6.18: Energy renewability indicators of Pearl millet feedstock-ethanol

Pre-treatment	Net Energy Ratio		Net Energy Balance (GJPY)		Net Energy Balance per kL of ethanol (GJ/kL)	
	Rain fed	Irrigated	Rain fed	Irrigated	Rain fed	Irrigated
Dilute Acid	2.469	2.339	1805.4	1737.1	16.8	16.2
Steam Explosion	2.374	1841.3	1909.6	1841.3	16.4	15.8
Hot water	2.279	2.167	1679.1	1610.9	15.9	15.2
Dilute Alkali	1.829	1.757	1371.7	1303.5	12.8	12.2
Alkaline hydrogen peroxide	1.788	1.720	1351.8	1283.5	12.5	11.9

Table 6.19: Environmental impact of Sorghum feedstock-ethanol

Pre-treatment	Net Carbon Balance(tCO2e/year)		Net Carbon Balance per kL of bioethanol(tCO2e/kL)		% Carbon reduction	
	Rain fed	Irrigated	Rain fed	Irrigated	Rain fed	Irrigated
Dilute Acid	-80.62	-98.41	-0.76	-0.94	-42.45	-49.80
Steam Explosion	-98.88	-117.66	-1.03	-1.23	-53.57	-61.68
Hot water	-90.07	-108.86	-0.86	-1.04	-46.51	-53.93
Dilute Alkali	-111.09	-129.88	-1.07	-1.25	-55.03	-62.48
Alkaline hydrogen peroxide	-129.71	-148.49	-1.25	-1.43	-62.40	-69.86

Table 6.20: Environmental impact of Pearl millet feedstock-ethanol

Pre-treatment	Net Carbon Balance(tCO2e/year)		Net Carbon Balance per kL of bioethanol(tCO2e/kL)		% Carbon reduction	
	Rain fed	Irrigated	Rain fed	Irrigated	Rain fed	Irrigated
Dilute Acid	-103.15	-123.63	-0.96	-1.17	-50.69	-58.59
Steam Explosion	-102.28	-122.76	-0.88	-1.05	-47.19	-54.45
Hot water	-133.15	-133.63	-1.05	-1.26	-55.17	-63.18
Dilute Alkali	-133.00	-153.48	-1.24	-1.44	-62.34	-70.26
Alkaline hydrogen peroxide	-151.24	-171.72	-1.40	-1.59	-68.63	-76.44

Sorghum and Pearl millet feedstock is a rain fed crop and hence rain fed Sorghum feedstock is considered for bioethanol production with dilute acid pre-treatment in inferring the study as follows

- The net energy ratio of bioethanol production from Sorghum stalk by dilute acid pre-treatment is 2.629, which implies that the total energy output for the production of bioethanol is 2.629 times that of the input energy consumed during its production.
- The net energy balance of 1853.5 GJPY is the delivered energy after subtracting the energy required for the production of ethanol.
- 17.5 GJ/kL of ethanol is the net energy balance per kL of ethanol produced implying that the extra energy delivered per kL of ethanol produced.
- The net carbon balance per kilo litre bioethanol is -0.76 tCO2e which means that for every kilo litre of bioethanol 0.76 tCO2e of emissions would be reduced.
- The % carbon emission reduction by using bioethanol with respect to the use of petrol is -42.45% thus signifying that bioethanol is a carbon negative fuel. This inference has occurred due to the fact that the energy consumed in the farming and chemicals have played a significant role in increasing the carbon emissions. These emissions can be reduced significantly by reducing the inventory like water and acid/alkali used.

Rain fed Pearl millet feedstock for bioethanol production with dilute acid pre-treatment infers the following

- The net energy ratio of bioethanol production from Sorghum stalk by dilute acid pre-treatment is 2.47, which implies that the total energy output for the production of bioethanol is 2.47 times that of the input energy consumed during its production.

- The net energy balance of 1805.4 GJPY is the delivered energy after subtracting the energy required for the production of ethanol.
- 16.8 GJ/kL of ethanol is the net energy balance per kL of ethanol produced implying that the extra energy delivered per kL of ethanol produced.
- The net carbon balance per kilo litre bioethanol is -0.96 tCO2e which means that for every kilo litre of bioethanol 0.96 tCO2e of emissions would be reduced.
- The % carbon emission reduction by using bioethanol with respect to the use of petrol is -50.69% thus signifying that bioethanol is a carbon negative fuel. This inference has occurred due to the fact that the energy consumed in the farming and chemicals have played a significant role in increasing the carbon emissions. Pearl millet feedstock would be more promising if the inventory was reduced either in the form of chemical consumption or water consumption.

The above inferences indicate that Pearl millet feedstock is less energy intensive than Sorghum feedstock in terms of NER and NEB. The technology needs further modification aiming at reducing the chemical consumption and thereby reducing the overall emissions.

12. Comparative Analysis of second generation biofuels to first generation biofuel

A comparison of the Net Energy Ratio of first generation molasses feedstock with second generation rice straw is in Table6. 21 (Confederation of Indian Industry, 2010)

Table 6. 21: Comparison of first generation and second generation feedstocks

Feedstock	Net Energy Ratio	% Carbon reduction
Molasses	4.57	75%
Rice straw	3.32	68%
Sorghum straw	2.629	-42.45%
Pearl millet Straw	2.469	-50.69%

As seen in the Table 6.21 first generation molasses and second generation rice straw have higher per cent carbon reduction potential in comparison to current study. The LCA system boundary designed is subjected to the individual study and hence not comparative. The energy invested in the life cycle assessment is a boundary set by the assessor and is not a standard tool to compare the renewability of one feedstock with respect to another.

13.Allocation Approach

Allocation approach is given to the life cycle assessment in order to decide the exact impact of these inventories in the environment. For instance, if stalk is utilised instead of the grain which is the major output of a crop, major burden is allocated to the major produce in terms of the grain nutrient equivalent or energy equivalent. The burden in the form of allocation is distributed in the Table 6.22.

Table 6.22: Mass, Energy and market price allocation

Process	Without allocation (%)	Mass allocation (%)	Energy allocation (%)	Market price allocation (%)
Farming	100	70	70	18
Transportation	100	100	100	100
Production of ethanol	100	85	85	90
Transportation	100	100	100	100
Blending	100	100	100	100

In the farming stage, the bioethanol feedstock yield accounts to 70% of the total plantation and costs 18% of the price invested in cultivating the crops. Ethanol production considered at the standalone distillery, all of the process utilities are accounted (85% allocation) as a major constituent and the rest 15% offered for lignin and biogas as by-products not allocated in the mass and energy allocations. All the other stages of ethanol production do not have any by-products which deliver a market value for distributing the burden and reducing the overall burden of this process.

Incorporating the allocation, the results in the NER vary to a certain extent and the same are explained for Sorghum and Pearl millet stalk with dilute acid treatment as in Table 6.23and Table 6.24.

Table 6.23: Allocation for dilute acid treated Sorghum stalk ethanol production

Process	Without allocation	Mass allocation	Energy allocation	Market price allocation
Farming	545.24	381.7	381.7	98.1
Transportation	10.01	10.01	10.01	10.0
Production of ethanol	642.40	546.04	546.04	578.2
Transportation	1.64	1.64	1.64	1.6
Blending	1.31	1.31	1.31	1.3
Total Energy	1200.61	940.68	940.68	689.3
NER	2.49	3.18	3.18	4.3

All units except NER are in GJPY

Table 6.24: Allocation for dilute acid treated Pearl millet stalk ethanol production

Process	Without allocation	Mass allocation	Energy allocation	Market price allocation
Farming	632.71	442.9	442.9	113.9
Transportation	10.01	10.01	10.01	10.0
Production of ethanol	651.59	553.85	553.85	586.4
Transportation	1.67	1.67	1.67	1.7
Blending	1.33	1.33	1.33	1.3
Total Energy	1297.30	1009.75	1009.75	713.3
NER	2.34	3.01	3.01	4.3

All units except NER are in GJPY

14. Conclusion

The findings from the LCA study are indicated as below:

- Farming: Although Sorghum and Pearl Millet are rain fed crops, farming contributes to near 30% of the energy input in the ethanol production cycle. Highest contributors of GHG emissions are pesticides and fertilizers. Reduction in the use of pesticides and fertilizers has good impact on the energy savings.
- Pearl millet stalk is more energy intensive in the aspect of energy requirement in the form of manpower requirements. Reducing the manpower requirement with alternative machinery can make the process less energy intensive.
- Rained feedstocks reduced the energy consumption by 10% in comparison to irrigated crops.
- Sorghum feedstock is more energy intensive than Pearl millet feedstock due to low grain and fodder yield.
- Biomass Transportation is less energy intensive step as the biomass is dried and then sent to the ethanol plant. Also, it does not create a threat in diversion the resources for ethanol production feedstock transportation.
- Pre-treatment: Ethanol production from second generation biomass in terms of pre-treatment processes is very energy intensive because, the biomass is separately pre-treated. Dilute acid pre-treatment has higher conversion efficiency than the other pre-treatment processes. This is due to higher glucan and xylan conversion efficiencies. Dilute acid treatment is commercially used, however there is always an imbalance created by huge amounts of impurities like furfural and HMF thereby

creating a need for an alternative. Other pre-treatment processes like hot water treatment and steam explosion consume a lot of water for the processing. Also, dilute alkali treatment has huge energy impact on the overall NER due to high energy coefficients of alkali. Modified alkali hydrogen peroxide process is promising as this reduces the overall burden of energy and emission impacts.

- Simultaneous Saccharification and co-fermentation considered in this study in the absence of primary experimentally data. However, the water, chemical inventories can be intensified on experimental values. Also, the type of enzyme used can be modified as the process requirement. Enzyme has high energy impact and this can be reduced by trade-offs through reduction in water and chemical requirements.
- The overall process is carbon negative with high NER, indicating that the process can be modified to reduce the impact and shifting it to carbon positive.
- Alkali hydrogen peroxide process is more promising with comparative yields. Reduction of process water by 70-80% can reduce the environmental impact significantly.
- Second generation ethanol production can be combined with first generation ethanol plants/distilleries to reduce the energy consumption in the distillation column. In first generation ethanol production, the energy used for cultivation and farming are not accounted as ethanol produced from the by-products. Whereas, in second generation, the additional burden comes at the farming stage which can be negotiated in the ethanol production stage by intensifying the process inventories by better enzymes, advanced processes.

CHAPTER - 7
Summary and Conclusions

7.1 Introduction

Depletion of fossil fuels at an alarming rate has attracted increasing attention to blending bio-fuels worldwide. India's energy demand is growing at an annual rate of 4.2% with highest demand growth of +129% in 2017 (BP, 2017). Depletion of fossil fuels at an alarming rate coupled with ever-growing challenges due to anthropogenic induced climate change has attracted increasing attention to blending biofuels worldwide. According to the International Energy Agency, India will become the largest single source of global oil demand growth after 2020. Hence, India needs energy security along with environmental sustainability so that the eco-capacity of the conserved and environmental uncertainty arising from events such as climate change is mitigated. Of the total primary energy supplied to Indian economy in 2016, as much as 75 per cent was from commercial fuels while 25 per cent was from non-commercial fuels. Out of the total commercial energy, coal constitutes 56.76 per cent, followed by oil (29.28 per cent), natural gas (6.2 per cent) and carbon-free hydro, nuclear, and other new renewable resources (7.4 per cent) (IEA 2016). Despite coal being the country's major resource endowment, the major source of India's energy insecurity is the heavy and growing dependence on oil imports. Of late, there have been sharp rising trends in crude oil prices coupled with volatility. India's transportation fuel requirements are unique as it consumes almost six to seven times more diesel fuel than gasoline, whereas in the rest of the world, almost all the other countries use more gasoline than diesel fuel. Biofuel is a non-polluting, locally available, accessible and reliable fuel obtained from renewable sources. It is seen by many as a "clean" form of energy as the amount of CO2 released, when it is burned, is generally equivalent to the amount of CO2 captured during the growth of the crop that produced it. Since biofuels can be produced from diverse set of crops, each country can also adopt its local/regional/country-specific strategy in order to achieve comparative advantage. Globally liquid fuels are produced from plantations, agricultural residues, weeds and organic urban and industrial wastes. Despite their appeal as an alternative to fossil fuels, biofuels are also subject of considerable controversy. Biofuel production is not considered truly as carbon-neutral because the stages of production needs non-renewable energy while transporting and processing. In India, the National Policy on Biofuels (2009) has an ambitious target of mainstreaming the use of biofuels bioethanol and biodiesel by 20 per cent blending with Petrol and High Speed Diesel (HSD) by 2017. However, the policy centers around the plantations and production of Jatropha on wastelands for the achievement of this target. With self-sufficiency levels in crude oil becoming a distant dream, there is growing interest to look out for alternative fuels and the biofuels are an important option for policy makers in India (Reddy et al, 2015).

It is against this background that an Indo-US Bilateral Joint Clean Energy Research and Development Centre (JCERDC) project for Development of Sustainable Advanced Ligno-Cellulosic Biofuels Systems(SALBS) was initiated in USA and India with multiple partners in Consortium in each country. The Consortium was led by the University of Florida (UF) in America and the Indian Institute of Chemical technology (IICT) in India. The Centre for Economic and Social Studies (CESS) was associated with the work package component of Sustainability, Marketing and Policy, and looked into the socio-economic and Life Cycle Analysis of biofuels production through cultivation of Jowar and Bajra feed stocks in India. As a part of this work, CESS has conducted a baseline survey and two rounds of field survey of Multi Locational Trials (MLTs) of High Biomass Varieties of Jowar and Bajra developed by Work Package I Group (they were concerned with feed stock development for biofuels) led by ICRISAT in farmers fields in the state of Madhya Pradesh.

The literature review projects a mixed picture about the economic, environmental and social viability of biofuels. Except for the experiences related to jatropha, no literature is available with reference to biofuel production from food-based crops in India. Experiences from Europe and other South American countries, however, provide learning opportunities with regard to policy, technology barriers especially in terms of conversion, problems associated with trade linkages, and most importantly long-run economic viability. A strong synergy of rationales such as the prospect of reduction in external dependence, better environment and creation of additional employment opportunities make a strong case for promotion of biofuels in India. However, reviews suggest that it is difficult to achieve all of the objectives simultaneously and it would be a demanding task to couple capacity expansion with environmentally substantial production, while at the same time limiting biofuel burden on the state budgets. The outlook for biofuels is also highly sensitive to possible changes in government subsidies and blending mandates, which remain the main stimulus for biofuels use. Over the past year, much uncertainty has developed about how biofuel policies in several key markets will evolve (IEA, 2013). The important barriers for successful implementation of biofuels come from the farmers

- the chief stakeholders, and given the fact that India's majority livelihoods are linked and re-linked to agriculture, caution must be exercised in promoting biofuel production from food-based crops.

7.2 Objectives of the Study

CESS was involved in the Work Package -III which looked at the component of Sustainability, Marketing and Policy related to biofuels. Hence, CESS has looked into the socio-economic and Life Cycle Analysis of biofuels production through cultivation of Jowar and Bajra feed stocks in India with the following objectives:

7.2.1 Objectives of the Study

1) To know the existing scenario with reference to the proposed biofuel crops, Jowar (Sorghum) and Bajra (Pearl Millet), in the state of Madhya pradesh.
2) To understand the socio-economic aspects of sampled farmers.
3) To assess the economics of Jowar and Bajra crop cultivation of the sampled farmers.
4) To examine the drivers and barriers in cultivation of biofuel crops.
5) To understand the awareness levels of sample farmers regarding biofuel cultivation and its impact of food and fodder security.
6) To conduct Life Cycle Analysis of Sorghum and Bajra feed stocks for biofuel production.
7) To contribute to the overall policy discourse on biofuels cultivation in India.

7.3 Research Methodology

The JCERDC Project on SALBs has decided to work in the states of Madhya Pradesh and Gujarat. CESS was responsible for the work in the state of Madhya Pradesh(M.P). One of the important reasons for choosing M.P was the presence of Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalay(RVSKVV) and the strong support they extended in conducting the multi-locational trials in the research stations as well as farmers fields. CESS has undertaken the baseline study during the year by May 2013-14 and empirical studies with sample farmers of Multilocational trials, during the year 2014-15 Kharif and 2015-16 Kharif. These different rounds of studies have primarily focused on the socio-economic, ecological, food security, and livelihood dimensions of biofuels production through the food crops such as Jowar (called as Sorghum) and Bajra (also called as Pearl millet).

7.3.1 Study Area, Sample and Data Analysis

Gwalior, Khargone, Dewas, Morena and Bhind districts hosting large areas of Sorghum and Pearl millet were selected for the study. A total of ten villages were selected from five districts where the trials of high biomass feedstocks were conducted by Work Package I partners of the project. For base line survey stratified proportionate random sampling was used covering 333 farmers belonging to different size classes in 10 villages. Similarly in 2014-15 kharif, field survey was done with all the 78 farmers in whose fields multi-locational trials of High biomass varieties of Jowar and Bajra were sown. For the year 2015-16 Kharif all the 83 farmers, in whose fields MLTs were conducted, were selected for the data collection. The study used both qualitative and quantitative methods. Personal interviews were conducted with a structured interview schedule. The study used an ex post facto research design. Participatory research tool Focused Group Discussions (FGDs) helped to understand the livelihoods, food and fodder security issues of biofuels. Secondary data on land use, fertilizer use, and demographic features of the district were collected from the survey reports by the Directorate of Census, Madhya Pradesh, Fertiliser News, and Ministry of Agriculture. The data analysis was basically conducted in two ways. One was comparing between the various size classes of large, medium and small farmers. The results of the study are discussed at two levels: one at the household level and the other at the plot level. The data gathered was analysed using different statistical tools. Averages, frequency and percentages were used to analyse the various information related to jowar and bajra cultivation.

7.4 Findings of the Study :

7.4.1 Socio-Economic Analysis: Findings of baseline survey

The socio-economic features, age group, literacy level, livestock population, market distance, farming experience, social participation, caste composition, landholding, net income and borrowings, awareness on biofuels cultivation, use of jowar crop for biofuel production and its impact on food and fodder are some of the important issues discussed so as to get insight into the issues of jowar crop cultivation for biofuel production. Among the total sampled households, 58 per cent belonged to other Backward Communities (OBCs) followed by Other Castes (OCs) 17.40 per cent, SCs 15.3 per cent and STs 9.33 per cent. Out of the total sampled farmers, 29.10 per cent were not literate, followed by upper primary (23.10 percent), and SSC (15.90 per cent). This could be due to lack of proper educational infrastructure in these villages. Majority (63.1 per cent) of the sampled households in the study area live joint family system which is quite contrary to the emergence of nuclear family system in other parts of India. This will enable the better availability of family labour in farming in general and biofuel production in particular.

Primary occupation in the study area was farming followed by agricultural casual labour. Similarly, livestock was predominantly secondary occupation for many sample households. One of the major objectives of the project was to utilize the existing wastelands in Madhya Pradesh to cultivate high biomass producing jowar and bajra varieties. Nearly 1.2 million hectares of culturable waste is present Madhya Pradesh. The fertility level of these soils is very low to support the cultivation of high biomass producing varieties which are generally input-intensive. Moreover, at the national level there is a huge difference in the areas reported under waste land by different agencies. Given the lack of clarity on the exact area of waste land available in India, the argument for promoting sorghum and pearl millet production in these waste lands in future is a questionable proposition. Majority (48.6 per cent) of the sample plots are interestingly having average soil quality as perceived by farmers and 25.3 per cent of the sampled plots are of good quality. This has implication for high biomass jowar cultivation as soil fertility will directly affect crop yield. Borewell is the major source of irrigation (46.4 per cent) for sampled households, followed by rainfall (27.3 per cent), and canal irrigation. Gross cropping area of various crops in Madhya Pradesh clearly indicate that jowar and bajra occupy 2.1 per cent and 0.8 per cent respectively. However, the study sites of the baseline survey has considerable area under sorghum and pearl millet and interestingly, soya bean did not spread in the study villages. jowar (around 35%) accounts for the largest share of crop that is being cultivated among the sampled households, followed by bajra (11.5%). This is due to the fodder requirement of the region due to its strong milk economy. Varietal diversity exists in the case of both jowar and bajra crops. High-yielding varieties occupy a major area in case of both crops. During kharif 2013-14, the major area of the sample households was under High Yeilding Varieties (HYV) jowar (253.12 acres) followed by maize (112.75 acres) and cotton (106 acres). Interestingly, the height of some of the traditional sorghum varieties grown by farmers were of at least 12 feet and the price it fetches in the open market is Rs.2500 per quintal. Farmers perceive that traditional white sorghum fetches a better market price than other sorghum varieties. It is observed that most of the sample households own buffaloes followed by cows and bullocks. It is evident from the baseline study that among the total sampled farmers, the majority (58.6%) had not taken any loan and those who accessed loans, the primary purpose of loan is observed to be for the purchase of agricultural inputs (21.9%) followed by 6.9 percent for consumption purpose and irrigation (6%).

Ttraditional and high-yielding varieties of jowar were doing well in the year 2012-13, as compared with hybrid jowar. During the years of lesser rainfall the hybrids do not perform well. Moreover, hybrid jowar attracts certain pests and diseases, thereby affecting the yield and income. Baseline survey findings clearly indicated that the high biomass jowar and bajra varieties being promoted in the Indo-US JCERDC-SALBS project should be more fetching than the existing cultivars of these staple food crops; they should also have a comparative advantage simultaneously with other crops such as the soya bean, wheat and mustard. Otherwise the farmers might not be inclined to adopt these varieties for biofuels production.

Farmers perception regarding biofuels and their cultivation was also assessed in the present study. Nearly 92 percent of the sample households did not have any awareness about the biofuels and more so about the production of biofuels from agricultural crops such as jowar and bajra. As the probing got deeper, it was interesting to observe that 38.44 per cent of the households agreed that diversion of jowar and bajra for biofuel cultivation will result in shortage of food grains while 61.56 per cent did not percieve a reduction in the food supply. Similarly, majority of the households (51.96%) believed that the use of jowar and bajra crops for biofuels production will affect the fodder security of their animals.

7.4.2 Multi-Locational Trials(MLTs) of High Biomass Varieties:

MLTs were conducted during the year 2014-15 Kharif and 2015-16 Kharif. Two surveys of these MLTs were conducted with an objective of addressing the suitability of High Biomass Varieties (HBVs) of Jowar and Bajra feedstocks with regard to crop economics, socio-economic dynamics and potential up scaling, issues. Data of 2015 and 2016 MLT field trials shows that there is inconsistency in the varieties being used in trials vis-à-vis the varieties that are being used in treatment analysis by Work Package II (this group is concerned with Chemical treatment of feed stocks). Major finding of the 2014-15 Kharif trials was that the average income (includes both grain and fodder yield) was relatively lower for the HBV varieties promoted in the project as compared to the ones being cultivated in the previous year (base line survey period). The value of Jowar dry fodder changed from village to village. However, it generally ranged between Rs1 to 2 per Kg. In the case of Bajra crop fodder, there was wide difference observed during 2015-16 Kharif and it varied between Rs 1 per Kg in Bijoli to Rs 5/Kg in Nahardonki of Gwalior region. The cost of fodder has implications for biofuel production as it is this material that is used a raw material. The lower the fodder price, more will economical will be the biofuel production from these crops. From last two years(i.e from 2014-15), there is huge increase in market price(went upto Rs4500/quintols in 2016) of traditional Safed Jowar variety due to its utility for some industrial purpose. When it comes to biomass yield, 2015-ICFPM-1 of Bajra crop and ICSSH-28 and ICSV 93046 were performing much better than existing varieties in 2015-16 Kharif.

7.5 Drivers and Barriers for Bioethanol Production in India

7.5.1 Drivers

There are several reasons for which biofuel production in general and ethanol production in particular are being encouraged not only in India but across the world. First is the notion of energy security. Energy security is a catchall term to mean increased reliance on domestically produced fuels so as to be insulated from the high volatility of oil prices by switching to bio fuels. Secondly, if a good market for ethanol is developed, growing ethanol crops such as corn or sugarcane more extensively will be profitable and result in higher revenues, making farmers well off, thus contributing to rural development. It also contributes to job creation and acts as a support to the agricultural economy. Thirdly and finally, environmental sustainability is also an important driver in the production of biofuel crops. Biomass fuels such as ethanol are seen as better than fossil fuels for two reasons: i) they are renewable and hence contribute to sustainable development and ii) they are seen as a means of reducing GHG emissions.

7.5.2 Barriers

The National Policy on Biofuels mandates a 20% blending of ethanol in petrol by the year 2017. The Ethanol Blending Programme (EBP) can be a reality only when there is an adequate supply of ethanol. One of the main reasons for the lack of adequate supply of ethanol is due to a deficiency in growing biofuel crops in India. According to the National Policy on Biofuels, biofuels have to be produced without compromising the food security. It is based solely on non-food feedstocks to be raised on degraded or wastelands that are not suited to agriculture, thus avoiding a possible conflict of fuel vs. food security. Due to this constraint, India has not been able to look beyond crops other than sugarcane for the production of ethanol.

Another problem is the term wastelands? itself. Those lands that are declared as wastelands by the Government in reality are probably used by poor farmers for grazing their livestock or for growing food crops for their sustenance. So allotting these lands for biofuel crops may lead to dispossessing poor farmers of their lands. Another problem with growing biofuel crops, especially sugarcane in India may actually be a bane instead of a boon. Production of sugarcane on a large scale results in the consumption of a significant amount of water. With water already being scarce in many parts of the nation, biofuel crops may actually be a bane. Other barriers in the non-realization of bioethanol blending in petrol in general include the battle between alcohol sector, medicinal sector and fuel sector for ethanol.

7.6 Life Cycle Analysis of Jowar and Bajra Feedstocks

Cradle to Grave approach of Life Cycle Assessment designed excel-based model was used to assess the renewability potential of the bioethanol feedstocks. This model was designed based on the ISO 14040-Life Cycle Assessment standard(International Organisation of Standards, 2006)to design the system boundaries for a functional unit of 1 Tonne per Day (TPD) of dry biomass feedstock plant. Field and secondary data was used to conduct LCA analysis. Processes included in the LCA study are farming; feedstock handling and storage; size reduction; pre-treatment; simultaneous saccharification and co-fermentation; distillation; product purification; product storage; waste water treatment; lignin combustion; ethanol transportation to the blending station; ethanol blending at the blending station and ethanol blended fuel combustion. Major pre-treatment techniques used for the agro-based feed stocks are i) Dilute acid ii) Steam explosion iii) Hot water iv) Dilute alkali and v) Alkali hydrogen peroxide.

Net Energy Ratio (NER), Net Energy Balance (NEB), Net Carbon Balance (NCB) and % Carbon reduction were some of the key parameters used for analysis and the results are evaluated based on the environmental impacts through the Life Cycle Assessment at 5% blending. Findings reveal that, dilute alkali pre-treatment process is most energy intensive due to consumption of alkali consumption. Whereas dilute acid pre-treatment has higher conversion efficiency than the other pre-treatment processes which is due to higher glucan and xylan conversion efficiencies. Pearl millet feedstock is less energy intensive than sorghum feedstock in terms of Net energy ration and net energy balance. The study concludes that Sorghum feedstock is more energy intensive than pearl millet feedstock due to higher water requirement and yield. . A comparison of the net energy ratio of first generation molasses feedstock with second generation rice straw was also attempted. First generation molasses and second generation rice straw have higher per cent carbon reduction potential in comparison to jowar and bajra.

7.7 Conclusions

Achieving energy security in the country through alternate methods is an important area being focused upon by the Indian policy makers. However, any attempt to promote the use of major staple food crops such as jowar and bajra for biofuel production has a long-lasting impact on the food, fodder and nutritional security of millions of people and livestock in India. Empirical evidence from baseline survey and MLTs has clearly indicated that existing varieties cultivated by farmers were much better interms of overall yield(grain and fodder) as compared with the HBV varieties promoted by the SLABs project. Farmers clearly perceived the threat to fodder security due to diversion of jowar and bajra straw to biofuel production.Cultivation of high biomass jowar and bajra varieties on a large scale could pose a serious threat to the existing rich diversity in these crops. Hence, even for trying out these crops at research level, it is essential to have a dialogue with the farmers of drylands where these two crops are predominantly grown. The voice of small and marginal farmers and women should be heard before moving further to utilize these crops for biofuel production. More importantly, we should learn from our earlier experiences of jatropoha cultivation (Montobio and Lele, 2010; Singhal and Sengupta, 2012). The production of feed stocks for biofuels would put additional pressure on agricultural resources such as land and water.

LCA analysis revealed that though the sorghum and pearl millet are rain fed crops, farming contributes to near 30% of the energy input in the ethanol production cycle. Highest contributors of GHG emissions are pesticides and fertilizers. Reduction in the use of pesticides and fertilizers has good impact on the energy savings. Sorghum feedstock is more energy intensive than pearl millet feedstock due to low grain and fodder yield. Ethanol production from second generation biomass in terms of pre-treatment processes is very energy intensive because, the biomass is separately pre-treated. Dilute acid pre-treatment has higher conversion efficiency than the other pre-treatment processes. Alkali hydrogen peroxide process is more promising with comparative yields. Reduction of process water by 70-80% can reduce the environmental impact significantly. Second generation ethanol production can be combined with first generation ethanol plants/distilleries to reduce the energy consumption in the distillation column. In first generation ethanol production, the energy used for cultivation and farming are not accounted as ethanol produced from the by-products. Whereas, in second generation, the additional burden comes at the farming stage which can be negotiated in the ethanol production stage by intensifying the process inventories by better enzymes and advanced processes.

Biofuels, either conventional or advanced should not be blindly be encouraged without a comprehensive outlook on the overall impact that will ultimately have on the society, environment or on the countries' energy security. Efforts should be made towards encouragement of research and development in the field as well as in formulating a comprehensive and effective biofuel policy for India.

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Annexure 1 :

Conversion factors

1 bigha	= 0.4005 acre
1 hectare	= 2.47 acre
1 Tonne	= 1000 kg
1 mm3	= 10-6 litre

Abbreviation:

kL	:kilolitre
TPD	: Tonne per Day
SSCoF	: Simultaneous Saccharification & Co-fermentation
DAP	: Di-ammonium Phosphate
TDH	: Total Displacement Head
FPU	: Filter Paper Unit
GJPY	:Giga Joules per year

Energy values

1 Litre of Diesel contains 38.4 Mega Joules (MJ) of energy (Energy density)

1 kilowatt-hour (kWh) of electricity is equivalent to3.6 Mega Joules (MJ) of energy

Annexure 2:

Table 24: Energy coefficients and carbon footprints of inventories

Inventory	Units	Energy coefficient	Units	Carbon Footprint
Ethanol	MJ/L	23.4	kg CO2 eq/L	1.21
Lignin	MJ/kg	25		
Biogas	MJ/m3	18.84	kg CO2 eq/m3	0.016
Diesel	MJ/L	36.4	kg CO2 eq/litre	2.79
Gasoline	MJ/L	35	kg CO2 eq/L	2.32
Urea	MJ/kg	46.9	kg CO2 eq/kg	6.92
Diammonium Phosphate	MJ/kg	6.79	kg CO2 eq/kg	1.66
Potash	MJ/kg	6	kg CO2 eq/kg	1.47
Complex	MJ/kg	7.59	kg CO2 eq/kg	10.71
Herbicides	MJ/L	238	kg CO2 eq/kg	10.73
Pesticide	MJ/L	101.2	kg CO2 eq/kg	10.97
Man-hour	MJ/Man-hr	1.96	kg CO2 eq/Man-hour	0.196
Electricity	MJ/kWh	3.6	kg CO2/kWh	1.08
Sulphuric acid	MJ/kg	5.22	kg CO2 eq/kg	0.21
Sodium hydroxide	MJ/kg	19.87	kg CO2 eq/kg	1.19
Enzyme	MJ/kg	21.9	kg CO2 eq/kg	5.5
Lime	MJ/kg	0.1	kg CO2 eq/kg	0.975
Water	MJ/L	0.00102	kg CO2/litre	3.00E-05
Steam (Low pressure)	MJ/kg	2.6	kg CO2 eq/kg	0.24
Steam (High pressure)	MJ/kg	2.802	kg CO2 eq/kg	0.61
Yeast	MJ/kg	13	kg CO2 eq/L of ethanol	0.96
Hydrogen peroxide	MJ/kg	2.7	kg CO2 eq/kg	1.14
Machinery	MJ/hr	62.71	kg CO2 eq/MJ	4.45

Ethanol, biogas, diesel(Ocean Washington edu, 2005; Winnipeg edu, 2012); Urea, DAP, Potash(Fertiliser europe, 2008; Kool, 2012); steam (Winnipeg edu, 2012); water (Winnipeg edu, 2012), labour (Ziaei, 2015);enzyme (Olofsson, 2017; Agostinho, 2015); yeast(Dunn, 2012; Hertrampf, 2010)

About the Authors

M. Gopinath Reddy is Professor of Political Science and Public Policy at the Centre For Economic and Social Studies (CESS) Hyderabad and also Principal Coordinator for the Division For Sustainable Development Studies (DSDS) at the CESS. He was Principal Coordinator for the recently concluded Research Unit for Livelihoods and Natural Resources (RULNR), supported Jamsetji Tata Trust (JSTT, Mumbai) and brought a number of Monographs/Working Papers under Forest Ecosystem spanning across major forest states of India. He has published articles relating to forest governance and livelihoods and natural resources in the journals of Development and Change, *The Small Scale Forestry Journal, Economic and Political Weekly (EPW)* and written chapters in the Book titled "Forests, People and Power: The Political Ecology of Reform in South Asia", brought by the EARTHSCAN publishers, UK. He has written two books: "Political Economy of Watershed Management: Policies, Institutions, Implementation & Livelihoods", brought by the Rawat Publications, (co-authoring with Prof. Ratna Reddy and Prof. John Soussan) and "A Study of Redistributive Politics and its impact on PRIs: A Case of Assembly Constituency Development Programme (MLA LADS Scheme in Andhra Pradesh)". His recent book (along with Dr. Suri Babu and Prof. S. Galab) is on "Swacch India: Experience of Water and Sanitation Programmes in Three Indian States of Madhya Pradesh, Odisha and Andhra Pradesh", published by Academic Foundation, New Delhi.

B.Suresh Reddy is Associate professor in the Division for Sustainable Development Studies (DSDS) at the Centre for Economic and Social Studies (CESS), Hyderabad. He did his Ph.D in Development Studies (Sociology) from CESS, Hyderabad and M.Sc (Ag.) in Agricultural Extension from Prof.Jayashanker Agricultural University, Rajendranagar. His Major research interest is in livelihoods, sustainable agriculture, climate change, environment and participatory research. Since past two decades he has been mainly working on the issues of Ecological agriculture/dryland agriculture. He also had the opportunity of working (with dalit women) at grass root level with an internationally well know voluntary organization, Deccan Development Society's Krishi Vigyan Kendra (Farm Science Centre funded by ICAR) in Sanga Reddy district of Telangana state as an Agricultural Extension Scientist. For half a decade during the early 2000, he was also a free lance researcher/consultant and has carried out research assignments for overseas institutions such as Department of Agricultural Economics and Social Sciences, Humboldt University (Berlin), International Institute for Environment and Development, Natural Resources Institute of Greenwich University, Overseas Development Institute and School of Engineering and Environment, University of Southampton of U.K. His recent publications include i) Prospects of Organic Farming" in the edited book on "Pesticide Residue in Foods" published by Springer international, Newyork (in 2017) ii) an article on "Soil Fertility Management in Semi-Arid Regions: The Socio-Cultural, Economic and Livelihood Dimensions of Farmers' Practices-A Case of Andhra Pradesh" published (in 2016) by Springer iii) another Springer publication in 2015 (Jointly) on "Biofuels production through food and fodder crops: Is it a viable option for sustainable energy security?". He has to his credit more than 50 national and international publications.