Biobased Economy – Sustainable Use of Agricultural Resources

S. Kulshreshtha[1], B. G. McConkey[2], T. T. Liu[2],
J. A. Dyer[3], X. P. C. Vergé[4] and R. L. Desjardins[5]
[1]*University of Saskatchewan, Saskatoon,*
[2]*Agriculture & Agri-Food Canada, Swift Current,*
[3]*Agro-environmental Consultant, Cambridge, Ontario,*
[4]*Consultant to AAFC, Ottawa, Ontario,*
[5]*Agriculture & Agri-Food Ottawa, Ontario*
Canada

1. Introduction

The biobased economy can be to the 21st century what the fossil-based economy was to the 20th century. Agriculture has the potential to be central to this economy, providing source materials for commodity items such as liquid fuels and value-added products (chemicals and materials). At the same time, agriculture will continue to provide food and feed that are healthful and safe, which may give rise to some situations of trade-offs.

The use of agricultural raw material in a biobased economy is not new. However, now agriculture has to compete with alternative land uses in order to claim the status of socially responsible entrepreneurship. Conservation of valuable landscapes, habitats, biodiversity have come to the forefront of some policy makers' agenda. The public-good benefits that could accrue from the biobased economy are compelling. They include increased security in some countries (such as USA), economic advantages to farmers, industry, rural communities, and society, environmental benefits at the global, regional, and local levels, and other benefits to society in terms of human health and safety.

How should this economy develop so that whatever is done is done well? This question requires examining some of the issues related to sustainability of this economy. Such an investigation has not taken place and thus, there is a need to explore this aspect of the biobased economy. In this chapter, opportunities and challenges facing the bioeconomy are introduced, primarily through a review of the literature. Major concentration of this study is on the agricultural feedstocks for use in the production of liquid transportation fuels, and related products. Some attention is also paid to production of biogas for electricity and heating purposes.

2. Definition of biobased economy

As an alternative, researchers working in the agriculture, forestry, and fisheries sectors recognize the use of biobased products for competing with the fossil-based industry (CARC, 2003), commonly referred to as the 'biobased economy'. This economy uses renewable bioresources, biological tools, eco-efficient processes that contribute to GHG emission reductions to produce sustainable bioproducts for medical treatments, diagnostics, and more-nutritional foods, energy, chemicals and materials while improving the quality of the environment and standard of living (OECD, 2001). Biobased resources are materials derived from a range of plant systems, and may include starch, sugar, wood, cellulose, lignin, proteins etc. These resources are produced from different sources such as, biomass, crop residue, dedicated crops and crop processing by-product.

The major commodity produced in the biobased economy is energy, in the form of liquid fuels (ethanol and biodiesel) and biogas (Hardy, 2002). The types of energy generated from these products include uses in transportation, heating, electric appliances etc. Agricultural and forest products are generally used in the production of the above biofuels.

Generally, agricultural activity generates a variety of feedstocks for the production of bio-products, particularly bioenergy. Main feedstocks of agricultural activity are from crop biomass including crop residues and livestock waste. Canada, possessing about 67.5 M ha of agricultural farmland, has the potential to offer feedstocks for bioenergy (including biofuels). Of this area, 31.87 M ha are planted each year to grow starch (wheat, barley, corn and oat), oil (rapeseed, soybean and flaxseed) and forage crops (Rye, fodder corn and tame hay), with a total carbon content of about 33.5 Mt C/yr, and an energy content of about 2 exajoules (EJ) yr^{-1} or 2 times 10^{18} J yr^{-1} (Wood & Layzel, 2003). Additionally, agricultural crop residues were estimated to contain about 56 Mt C/year. Although some of this residue may be incorporated into the soil to maintain soil fertility and carbon content, the recoverable portion contains 14.6 Mt C/yr and has an energy potential of 0.52 EJ/yr. To this estimate, one can add livestock wastes in Canada, which could produce over 3 billion m^3 of biogas which is equivalent to energy of 0.065 EJ/yr (Wood & Layzel, 2003).

3. Definition of sustainability

3.1 What is sustainability?

Sustainability is inherently about durability and endurance. The World Commission on Environment and Development defines it as “the capacity to meet the needs of the present without compromising the ability of future generations to meet their own needs” (UNGA, 1987). It emphasizes strategies that promote economic and social development to meet human needs in ways that avoid environmental degradation, overexploitation or pollution (Khanna et al., 2009). At the 2005 World Summit it was noted that this requires the reconciliation of economic, environmental and social demands - the "three pillars" of sustainability (UNGA, 2005). The concept of sustainability is shown in Fig. 1.

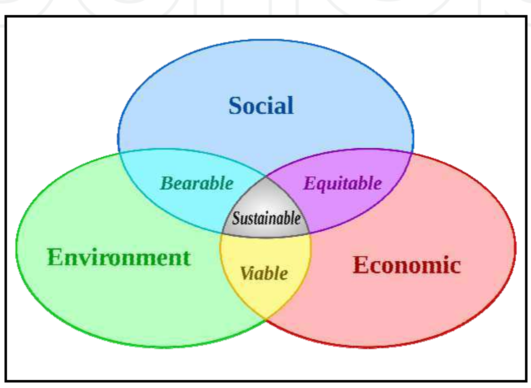

Fig. 1. Framework for Assessment of Sustainability

Figure 1 shows that an economy would be sustainable if it is: (1) Economically viable (uses natural, financial and human capital to create value, wealth and profits); (2) Environmentally compatible (uses cleaner, more eco-efficient products and processes to prevent pollution, depletion of natural resources as well as loss of biodiversity and wildlife habitat), and minimizes damage to the ecosystem services that provide many ecological goods and services to the society; and (3) Socially responsible (behaves in an ethical manner and manages the various impacts of its production through initiatives).

3.2 Sustainability in the context of biobased economy

The biobased economy can contribute to a more sustainable society, not only because it leads to an economy no longer primarily dependent on fossil fuels for energy and industrial raw materials, but also by generating less waste, by a lower energy consumption and by using less water. In addition, the biobased economy provides also for the established industries the opportunity for further growth in a sustainable way (Albrecht et al., 2010). However, does it mean that the production and use of bioenergy is intrinsically sustainable? The Environmental Audit Committee (EAC) found that although biofuels can reduce GHG emissions from road transport, most first generation biofuels have a detrimental impact on the environment overall. In addition, most biofuels are often not an effective use of bioenergy resources, in terms either of cutting GHG emissions or value-for-money (EAC, 2008). Stoeglehner & Narodoslawsky (2009) answered this question from an ecological footprint perspective. They found, by comparing different technologies, that biofuels are considerably more sustainable than fossil options presently in use. Yet, to what extent biofuel use is sustainable remains open as this can only be answered in a regional context taking other land use demands, visions and values into account (Stoeglehner & Narodoslawsky, 2009).

Major utilitarian frameworks define and identify sustainable choices as those that maximize per capita utility subject to an ethical constraint that per capita utility will not decline over time. The utilitarian framework can be applied to derive sustainable outcomes in the context of biofuels, and in particular to identify which biofuels to produce and to what extent, by assuming that utility is derived from the consumption of food, fuel (fossil fuel and biofuel) and other private goods and is maximized subject to budget constraints, land availability and various sustainability constraints. Biofuels would be considered a sustainable substitute if they can compete with fossil fuels in a free market setting at prices that internalize all environmental costs of production, minimize damages to the environment and allow food and other goods and services to be available such that overall utility is non-decreasing over time (Khanna et al., 2009). The production of any type of biofuel is likely to involve trade-offs among these multi-dimensional aspects of sustainability. The degree to which biofuels can accommodate the three pillars of sustainability, taking account of potential tradeoffs among these pillars, needs to be evaluated

3.2.1 Economic sustainability

The economic sustainability of biofuels depends on the costs of production and market price of supply. The sustainability of the corn ethanol industry depends on its ability to deal with volatility in both gasoline and corn prices. Variability in the price of corn could lead to cycles of boom and bust for the biofuel industry with the impact of supply shocks being exacerbated when inventories are low (Hochman et al., 2008). The oil price, commercially viable technology to produce cellulosic biofuels, and trade barriers also affect economic viability of the biofuel industry. The rising oil price has contributed to higher corn prices because of increased cost of production of corn, in addition to its demand. Besides the supply-side considerations, the demand for ethanol and the availability of infrastructure to deliver the ethanol produced to the blenders are the driving forces behind the biofuel industry sustain expansion.

3.2.2 Environmental sustainability

Biofuels are occasionally claimed as being carbon neutral and fossil-fuel free, but serious concerns about the carbon benefits of current biofuels have been raised. Actually, biofuels consume a significant amount of energy that is derived from fossil fuels. Equally important is the fact that production of biofuels has other environmental impacts, such as soil erosion due to tilling, eutrophication due to fertilizer runoffs, impacts of exposure to pesticides, habitat, and biodiversity loss due to land-use change, etc., which have not received the same attention as GHG emissions (Rajagopal & Zilberman, 2007). Conversely, the grain used for ethanol feedstock production is often the poor quality, impure grains which are mostly unsuitable for either human or livestock, and which also do not require as much pesticide (Dyer et al., 2011). In contrast to grain-based ethanol, cellulosic biofuels from perennial grasses (such as switchgrass) have the potential to produce more biofuel per hectare of land and thus have smaller indirect land use effects. While, the environmental benefits of cellulosic biofuels depend on the mix of feedstocks use, the location and management practices used to grow them are equally important. There might also be some trade-offs between environmental benefits and most profitable methods of producing cellulosic feedstocks (Khanna et al., 2009).

3.2.3 Social sustainability

Khanna et al. (2009) consider that the social sustainability of biofuel depends on the distribution of biofuel costs and benefits across countries, income groups, and rural and urban areas. One should keep in mind that human rights, health and equity are also important issues that are related to social sustainability. Higher crop prices in response to increased demand of biofuel will improve farm incomes. However, the higher commodity price may be capitalized into land rent and prices of inputs, which will reduce the future benefit to farmers. Cost of food to consumers may also increase, which may create a heavy burden on the urban poors. The development of biofuel production may also bring to the forefront equity and gender-related issues, such as labour conditions on plantations, constraints faced by small holders and the disadvantaged position of female farmers (FAO, 2008). All of these could affect the welfare of the society and sustainability.

3.3 The criteria and indicators for assessing the sustainability of bioenergy development

An indicator can be used to quantify a specific impact of bioenergy production (e.g. the rate of soil erosion) (Smeets, 2008). Ideally, to evaluate the sustainability of bioenergy use, the impacts of bioenergy production, conversion and trade must be analysed using an integrated approach, taking account of the three dimensions of sustainable development: people (social well-being; the social impacts), planet (maintaining environmental quality; the environmental impact), and profit (economic viability of bioenergy production and its welfare impacts; and other economic impacts). The production and use of bioenergy can only be deemed sustainable if the net impact is positive (Smeets, 2008). Practically applicable criteria and/or indicators are required to monitor and assess the sustainability of bioenergy production and use.

Various ongoing initiatives aim to ensure the sustainability of bioenergy production and use through certification, a form of communication that assures the buyer of bioenergy that the supplier complies with specific sustainability criteria. The European Union and several individual countries, most notably the UK and The Netherlands, are currently developing certification systems. Other countries, for example Brazil, are linking biofuel certification with tax reductions and other incentives to stimulate sustainable bioenergy use. Also, various non-governmental organisations are formulating sustainability criteria.

	Area of concern	Loose set of criteria	Strict set of criteria
Social-economic	Food supply	Energy crop production must not endanger the food supply.	
	Child labour	(Child labour is prohibited.)	Child labour is prohibited
	Wages	Fair wages must be paid to avoid poverty as defined by (inter)national standards.	Fair wages must be paid to avoid poverty as defined by (inter)national standards and to ensure that wages are fair compared to national average.
	Employment	Energy crop production must contribute to employment.	Energy crop production must contribute to employment, including all indirect and induced effect.
	Education	(Education must be provided for workers' children).	Education must be provided for the workers' children by the energy crop producer.
	Healthcare	(Healthcare services must be provided for the all workers' family members).	Healthcare services must be provided for all workers' family members by the energy crop producer.
Environ-mental	Deforestation	Energy crop production must not result in deforestation.	
	Soil erosion	Soil erosion rates must not exceed those due to conventional agriculture land use	Soil erosion rates must not exceed those due to conventional agricultural land use; they must be reduced to match the natural soil-regeneration capacity.
	Depletion of fresh water resources	(Energy crop production must not deplete ground water).	
	Nutrient losses and soil nutrient depletion	Soil nutrient depletion must be prevented as far as reasonably achievable.	Soil nutrient depletion and nutrient leaching must be prevented as far as reasonably achievable.
	Pollution	Agrochemical pollution must be avoided as far as reasonably achievable	
	Biodiversity	Biodiversity must be protected.	

Table 1. Areas of concern and sustainability criteria in Smeets's study, criteria in parentheses are not translated into cost

Smeets (2008) analysed to what extent implementing a sustainability certification system affects the management system (costs) of bioenergy production and availability (quantity) of land for energy plantations. The certification system takes account of twelve sustainability criteria and accompanying indicators (Table 1). However, this certification system lacks the important criterion of "GHG emissions". A project group "Sustainable Production of Biomass" was established in 2006 by the Interdepartmental Programme Management Energy Transition to develop a system for biomass sustainability criteria for the Netherlands for the production and conversion of biomass for energy, fuels and chemistry. A set of generic sustainability criteria and corresponding sustainability indicators was formulated (Table 2) (Cramer et al., 2006).

The need to secure the sustainability of biomass production and trade in a fast growing market is widely acknowledged by many stakeholder groups and setting standards and establishing certification schemes are recognized as possible strategies that help ensure sustainable biomass production and trade (Dam & Junginger, 2008). McBridge et al. (2011) have developed a selection criteria framework for bioenergy sustainability (Fig. 2).

There seems to be a general agreement that it is important to include economic, social and environmental criteria in the development of a biomass certification system. However, mutual differences are also visible in the strictness, extent and level of detail of these criteria, due to various interests and priorities (WWF, 2006) and geographic constraints. The development of biomass certification systems is still in its infancy and largely in development. Therefore, it is worthwhile to consider in this preliminary phase which ways can be followed if the strategy to be taken in the development of a reliable and efficient biomass certification system (Dam & Junginger, 2008).

4. Environmental impacts of biobased economy

Agriculture involves a large human manipulation of the biosphere that impacts the environment. For all the impacts considered, Engstrom et al., (2007) noted that agriculture affects the environment through: eutrophication of water resources, GHG emissions, and loss of biodiversity. On a life cycle analysis basis the impacts are even larger but much of that environmental harm is associated with fossil fuel use. In addition to direct fossil fuel use for agriculture, agriculture production involves further fossil fuel use for energy-intensive inputs like N fertilizers and for transportation of inputs to the farm and products from farm to market (Dyer and Desjardins, 2009).

Bioenergy production is an important existing bioeconomy initiative whose current and potential environmental impacts have been studied extensively. Bioenergy production may cause eutrophication of water, increases ecosystem and human exposure to toxins, causes loss of biodiversity, degrades air quality, and increases acidification of the ecosystem (Bai et al., 2010).

Informed decisions by society require comparative studies of environmental impact of alternatives. For agriculture, the most useful information for decision–makers is not the damage from agriculture to the environment but the comparative measures of environmental harm between food types, production practices, and/or geographical situations. This information facilitates making choices that best balance food need with acceptable environment damage (Brentrup et al., 2004). A similar situation exists for bioenergy. The comparative values of environmental impact between energy sources are required to make sound choices in bionergy (de Vries et al., 2010). Thus, the problem becomes a multi-objective, albeit limited, optimization across the considered alternate energy sources or across considered alternative ways to provide energy-related functions, such as km of passenger travel (European Environment Agency, 2008).

Criterion	Level	Indicator/procedure
1. GHG balance	Net emission reduction ≥50%.	• Testing with the aid of calculation methods. • Use of standard values for different steps in standard chains.
For all the themes below a dialogue with local and national stakeholders is required		
2.Competition with food, local energy supply, medicines and building material	Availability of biomass for food, local energy supply, building materials or medicines must not decrease.	• Comply with minimum requirements testable by means of performance indicators[a].
3. Biodiversity	No deterioration of protected areas or valuable ecosystems. Insight into active protection of the local ecosystem.	• Comply with minimum requirements testable by means of performance indicators[a]. • Reporting obligation on a "management plan for active protection of the local ecosystem".
4. Economic prosperity	No negative effects on the local and regional economy. Insight into the active contribution to the increase of local prosperity.	• Comply with minimum requirements testable by means of performance indicators[a]. • Reporting obligation on the way in which active contribution is made to local prosperity.
5. Well-being 5a Working conditions of workers 5b Human Rights 5c Property rights and rights of use	No negative effects on the social well-being of the workers and local population Insight into the active contribution to improvement of	• Comply with Social Accountability 8000 and with the Tripartite Declaration of Principles concerning Multinational Enterprises and Social Policy compiled by the International Labour Organisation. • Comply with the Universal Declaration of Human Rights (concerning: non-discrimination; freedom of association; child labor; forced and compulsory labor; disciplinary practices; security practices and indigenous rights). • Comply with the following requirements: • No land use without the consent of sufficiently informed original users. Land use is carefully described and officially laid down.

5d Insight into the social circumstances of local population 5e Integrity	social circumstances of local population.	• Official property and use, and customary law of the indigenous population is recognized and respected. • Comply with minimum requirements testable by means of performance indicators[a]. • Reporting obligation in which is described how an active contribution to the social circumstances of the local population is made. Here an open and transparent communication is expected with and, in consultation with, the local population. • Companies in the supply chain comply with the Business Principles for Countering Bribery.
6. The environment (6a) Waste Management (6b) Use of agro-chemicals. (6c) Prevention of erosion and soil exhaustion (6d) Insight into the conservation of quality and quantity of surface and ground water. (6e) Emission to air	No negative effects on the environment.	• Comply with local and national legislation and regulations. • Apply Good Agricultural Practice guidelines on integrated crop management. • Comply with the strictest local, international and EU rules and regulations • Comply with minimum requirements testable by means of performance indicators[a]. • Comply with EU regulations.

Note: [a] These have been developed on the basis of obligatory reports from period 2007-2010.

Table 2. Criteria and indicators for sustainable biomass production for 2011 (Cramer et al., 2006)

4.1 Greenhouse gas emissions

Reducing GHG emissions compared to fossil-fuel alternative is often considered the environmental value of biofuels. Several standards require that biofuels provides GHG emission reductions at least 60% (Zahniser, 2010) lower than those for competing fossil fuel. The estimated GHG benefits of bioenergy are complex, variable, and controversial. Most biofuel production systems provide GHG benefits, typically at least 30% less than fossil fuels (Scharlemann & Laurance, 2008). Some favourable systems such as biodiesel from palm oil and ethanol from sugarcane in Brazil can achieve life-cycle reduction of 50% to 90% (FAO, 2008). Second generation biofuels using biomass crops and crop residues have been estimated to achieve GHG reductions greater than 50%. (Bai et al., 2010) However, some studies argue that the GHG emissions associated with bioenergy production are underestimated and that there is no net GHG savings for many biofuels (Crutzen et al., 2008).

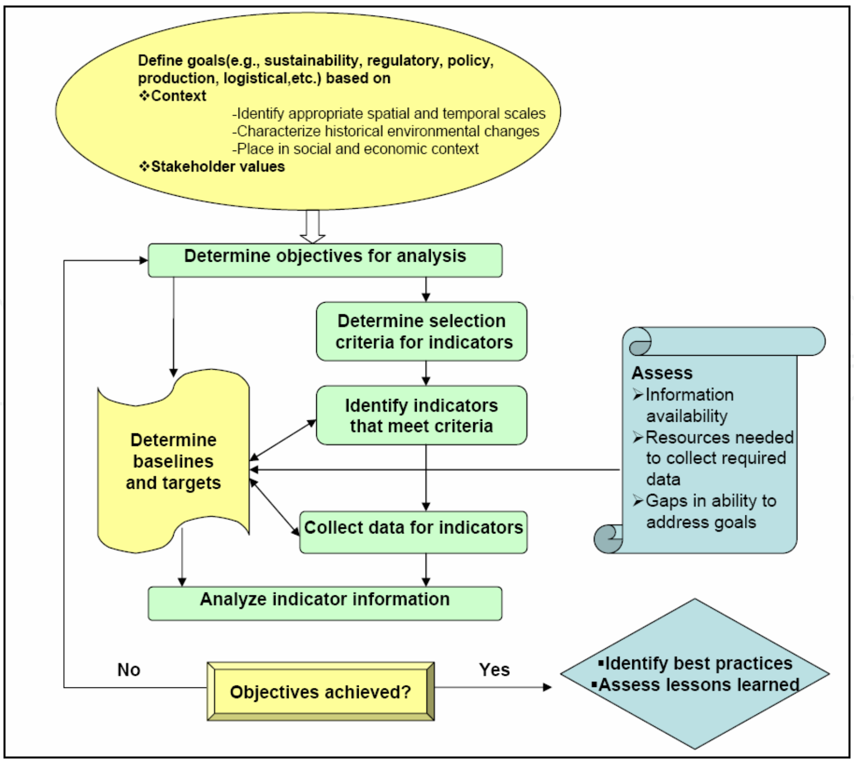

Fig. 2. Framework for Selecting Sustainability Indicators for Bioenergy (adapted from McBridge et al., 2011)

Considering changes in soil carbon associated with crop production can reduce GHG emissions. Where there is an increase in land carbon stocks this reduces net GHG emissions (Adler et al., 2007) and, if the carbon stock change is sufficient, GHG emission can become negative, i.e. a net removal (Brandão et al., 2010).

Searchinger et al. (2008) included indirect land-use change (ILUC) from major increases in ethanol production from US corn. There are large GHG emissions from the land use change, particularly from clearing of forests. They calculated that it would take 150 years of biofuel production before the aggregate GHG emission reductions from ethanol compared to fossil-fuel gasoline are larger than the GHG emission from biofuel-induced ILUC. Fargione et al. (2008) estimated that the GHG effects of ILUC increases the GHG emission for ethanol from US corn by 17 to 420 times. However, the analysis of Searchinger et al. (2008) has attracted criticism that it oversimplifies trade effects, neglects the effect of increases in yield over time, and the use of alternatives pathways to ethanol from feedstock other than corn (Mathews and Tan, 2009).

Kløverpris et al. (2010) used a global trade model to show that land use impact is complex and depends on where feedstock production is taking place. Gains in productivity are more feasible in some regions than others. For example, Denmark has high yield and restrictions on use of fertilizer and pesticides so opportunity for increased production is lower than countries with lower initial yield and fewer restrictions on farming activities. Feasible increases in yield of crops can overcome the ILUC associated with bioenergy. Schmidt et al. (2009) determined that selection of location for sourcing food to replace that lost from bioenergy is important to ILUC effects. For example, exports of Canadian rapeseed oil to Europe would displace palm oil from tropical countries where palm plantations threaten the rain forests in those countries (Klein and LeRoy, 2007). Similarly, by strengthening the market demand for field crops in the Canadian Prairies, the demand for biofuel feedstock will increase the area seeded to crops, rather than left fallow, a practice that is known to increase wind erosion (Dyer et al., 2011).

4.2 Land use and biodiversity

Gomiero et al. (2010) have argued that agreed limits to human appropriation of ecosystem services and global net primary productivity are needed. The world will not be able to support biofuels and food production when loss of agricultural land for transportation, industry, and settlements are considered. Appropriation of net primary productivity beyond the current 50% is unsustainable. They point out that the area impact of biofuel is already much larger than that of fossil fuels considering their relative impacts on energy supply. Fibre and bioenergy needs will exacerbate the pressure on global biodiversity from conventional food production. Bioenergy is a tradeoff between GHG reductions and biodiversity (Schmidt et al., 2009).

Land use impact is not only how much land but also what land and how land is used. Dale et al. (2010) present a potential scenario of increases in biofuel production with increases in biodiversity, mostly through increase production of perennial biomass crops included vegetation mixtures more similar to natural prairies. Solid biofuels for commercial and industrial applications could be an effective and sustainable way to grow the bioeconomy. The use of biomass pellets – which can be produced from wood, switchgrass or straw, would not only create new market oppourtunities for the forest and agricultural industries, it would reduce dependence on coal as well as the GHG emissions associated with coal use. Sophisticated geographical analysis involving land use, habitats, and sensitive ecosystems allows for design of bioenergy production that minimizes potential biodiversity impact (Dragisic et al., 2010). However, Gomiero et al. (2010) note that efficient biofuel production requires monoculture and mechanization for land near the biofuel plants to achieve maximum efficiency. Such production practices could be detrimental to biodiversity.

Bioenergy feedstock production will affect land use which can impact biodiversity to varying degrees, depending on the crop type and the region. Growing grain crops probably has the greatest detrimental impact on biodiversity if these crops are managed more intensively, with increased inputs and fewer rotations (Dyer et al., 2011). Growing perennial herbaceous crops on marginal land can often reduce biodiversity loss compared to using the land for row crops such as corn (Williams et al., 2009). However, Dyer et al. (2011) found that if the marginal land is natural grassland, such as much of the rangeland in Western Canada, rather than the result of land degradation, even a perennial feedstock crop (such as switchgrass) could result in the loss of extensive areas of natural habitat. When cattle are displaced by feedstock crops (**ILUC**), they may be grazed at unsustainable stocking rates or in rangeland not previously used for grazing (Dyer et al., 2011). Good geographic planning of bioenergy development can protect high-carbon high-biodiversity compared to letting market forces determine land use (Schmidt et al., 2009).

4.3 Sustaining land productivity

Crop residues are an attractive feedstock for bioenergy since they do not reduce food production, are available in large quantities, and are relatively low cost. However, crop residue protects the soil from erosion and maintains soil organic matter.

The removal of 20-30% of crop residue is probably sustainable (Gomiero et al., 2010) although residue removal will eventually require additional fertilizer to replace nutrients removed (Wilhelm et al., 2010). The balance between the residue removal rate and long-term soil health is a challenge (Williams et al., 2009).

Soil erosion is affected by crop type and its production practices. Generally, increased bioenergy production increases erosion risk (de Vries et al., 2010). The choice of crops is important, especially if maize replaces grass and forages (Searchinger & Heimlich, 2009). Production practices, such as winter cover crops where appropriate, can mitigate erosion risk (Kim & Dale, 2005).

4.4 Eutrophication

Nutrient loss through runoff leads to eutrophication of water bodies. This is largely a consequence of fertilizing crops for bioenergy feedstock (Dale et al., 2010). Consequently, bioenergy can increase eutrophication compared to fossil fuels even in highly optimized production systems (Cherubini & Jungmeier, 2010). The use of perennial biomass crops for bioenergy feedstocks can decrease contamination of water with nutrients compared to annual crops (Williams et al., 2009). Similarly, removal of crop residue can increase nutrient contamination from surface runoff (Blanco-Canqui et al., 2009).

5. Economic impacts of biobased economy

The economics of biofuels critically depend on the price of fossil fuels, price of feedstocks, the cost of conversion (including investment needs) and the revenues generated by the by-products. Storage, transport and logistic costs also need to be included (Vermeulen & Vorley, 2007). Two major sources of revenue from biofuel production are sale of the fuel, and sale of by-products, which may include dry distiller's grain and sollubles (DDGS), glycerine and carbon dioxide, as well as rapeseed or soybean meal.

Investigations by $(S+T)^2$ & Edna Lam Consulting (2005) for ethanol and biodiesel production suggest that these products cannot compete with fossil-based products without a subsidy. The impact of biofuel production on various sectors of the society is also very different. Benefits are realized by the ethanol industry, but at the cost of state revenues, and consumer expenditures. But with new markets that respond differently than conventional food markets, the rural economy is enhanced (Klein and LeRoy, 2007). Society as a whole benefits from the country's reduced reliance on crude oil imports and reduced economic costs for mitigating GHG emissions (Hardy, 2002; Domac et al., 2005).

5.1 Job creation and rural development

Brazil is one of the examples of successful job creation from bioenergy industry. The bioenergy industry offers direct or indirect employment opportunities[1]. Employment generation from a biofuel plant differs between the two stages: construction stage and operations stage. During the construction phase, employment impacts are large but

[1] Direct employment refers to the creation of employment opportunities from increased biofuel feedstocks production, transportation and construction and operation, maintenance of conversion processing plants. Indirect employment is jobs created through the supporting industries, for example, marketing and distribution of end products from biofuel industries (Domac et al., 2005).

temporary in nature. Plant operation generates fewer but permanent jobs. For example, Haig (2006) estimated that the impact of producing 2 billion litres of ethanol on the rural economy would generate 6,645 jobs in rural Canada.

Urbanchuk (2006) has found that local ownership of biofuel plants maximizes the rural development potential. He estimates that the full contribution to the local economy of a farmer-owned co-operative ethanol plant is likely to be as much as 56 percent higher than the impact of an absentee-owned corporate plant. This is attributed to two main factors unique to farmer owned plants: (1) A larger share of operational expenditures is made in the local community; and (2) The distribution of dividend payments to farmer-owners of a co-operative ethanol plant represents additional income to farmers and their families.

Meanwhile, if a market for selling carbon credits could be established, this would provide another source of revenue to farmers.

5.2 Improved trade balance

The activities associated with the biobased economy such as the expansion of biofuel would cause, in some cases, substantial increase in exports of agriculture commodities (Timilsina et al., 2010) due to a diversified set of agricultural products. In addition, a biobased economy is economically viable in a longer term perspective. In a study of Thailand, although the costs of biofuel production may exceed the cost of importing equivalent petroleum, domestic production of biofuels allows virtually all of the money to stay within the country's economy, and thus, adds to the balance of payment for the country (Bell et al., 2011).

5.3 Establishment of new industries

An increase in feedstock production for biobased industry results in an increased production of by-product and residues that are in turn utilized as raw materials for several other sectors, such as livestock production, cosmetics and pharmaceutical industries, among others (IEA-Bioenergy, 2009). Input providing industries, such as agricultural equipment manufacturing firms and fertilizer industries, will expand to supply additional goods and services to support the increased biomass production activity (Han et al., 2011). Byproducts and inputs can be important criteria for feedstock crop choices. For example, soybean-based biodiesel was shown to have a lower carbon footprint than rapeseed-based biodiesel due to both providing more livestock feed byproduct than rapeseed oil and being a legume that does not require N-fertilizer input (Dyer et al., 2010).

The oil price plays an important role in determining the economics of biofuels (Baker and Zahniser, 2007). If the world oil price remain high, biofuels will be more financially viable even without government support. The remote areas (or countries) usually have the comparative advantage of labor, but due to poor facility and transportation system, prices of oil may be markedly higher than the international prices. In these cases, if biofuel production and processing are located near consumption centers or can be transported to them at relatively low costs, they can be competitive against imported fossil fuels (Vermeulen & Vorley, 2007).

5.4 Fiscal effects of biofuel development

Biofuel development can affect several levels of governments through one or a combination of three pathways: (1) Provision of public subsidies; (2) Generation of new and different sources of government revenues; and (3) Change in government expenditures. Under current fossil based fuel prices, biofuels are not competitive. Many jurisdictions have accepted the need for public subsidies to enhance the public cause. However, biofuel support programs can act as a substitute for other agricultural program subsidies. For example, the U.S. ethanol tax credit, according to Gardner (2003), has served to displace some of the government deficiency payments related to corn. The financial impact on government is likely to include both positive and negative components. There is a cost to government for any incentives provided to the biofuel industry, but there will also be tax revenues that flow to government from the income generated by these operations. Intuitively, if subsidies are retired at some point in time, the benefits from the program would exceed costs to government.

In the case of an energy importing country, impact on the government would be through replacement of petroleum imports. However, this cost should be weighed against government spending to develop the biofuel industry. In some countries such as Brazil, development of the biofuel industry has resulted in a net benefit even after all government support expenditures are included.

6. Social implications

There are mainly two major social benefits of biobased industry: increased standard of living and increased social cohesion and stability (Domac et al., 2005). While the biobased industries help create income generation and other positive impacts, their effectiveness depends on a number of other factors, as shown in Fig. 3. These may include: whether the industry can provide full-time jobs or part-time and night shift jobs; total employment created per energy unit or per amount of land; number of households or people employed in a region; whether skilled or unskilled labour are required, etc (Domac et al., 2005). Some of the identifiable social benefits and social costs are discussed below.

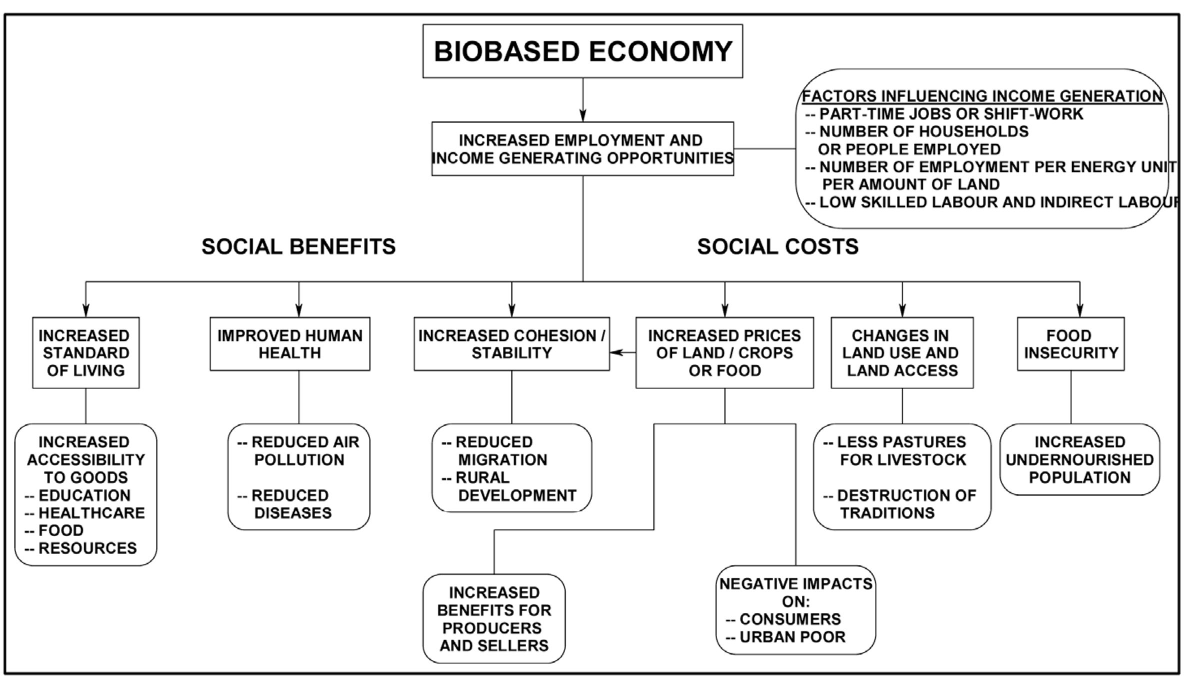

Fig. 3. Possible social costs and benefits of the biobased economy

6.1 Social benefits

6.1.1 Improved quality of life in rural areas

The increased income in a household or community would further help increase a community's or individual's accessibility to good education, health care, resources (e.g. water, land), food products and employment opportunities etc. Biobased industry, being located in rural areas, may provide many of these benefits by establishing livelihood opportunities for the local people. In addition, increased income may help strengthen the cohesion or stability of a community.

6.1.2 Improved human health

The biobased economy may also play an important role in improving human health and safety. For example, sugarcane bagasse used for making paper and fiberboard would otherwise be burnt in the field releasing harmful air pollutants (Phalan, 2009). In addition, improved air quality will reduce diseases such as asthma, and biodegradability characteristics of biobased products, compared to petroleum-based alternatives, are an added advantage (Hardy, 2002). Finally, the local energy security created by bioenergy sector especially biogas will help replace the use of firewood which otherwise would cause air pollution creating negative impact on health of people. In poor countries, increased family incomes would make health care more affordable.

6.1.3 Poverty alleviation

Although liquid fuels are currently being developed for transportation, modern technologies to convert biomass into energy promises to be a more directed way to alleviate poverty, especially in remote oil-dependent regions (Federal Ministry of Food, Agriculture & Consumer Protection, 2006). Some of this would happen through providing employment opportunities in regions where alternatives are scarce or non-existent.

6.1.4 Economic and social impacts on indigenous people

Well-planned biofuel projects could allow indigenous communities to generate capital and maintain or rebuild livelihoods based on the sustainable use of natural resources. In Canada, there is evidence that aboriginal communities and organizations have seldom been incorporated into rural/regional economic development planning, and biobased economy could offer them this opportunity.

6.2 Social costs associated with biobased economy

Some of the social challenges that may arise from biobased industry include changes in land-use rights, food insecurity, and destruction of traditions, among others. Selected social costs are shown in Fig. 3.

6.2.1 Land-use change and impacts on land access

Changes in land use due to increased expansion of agricultural lands for the cultivation of biofuel crops may affect land access and rights of local people (Cotula et al., 2008). In addition, increased economic value created for agricultural biomass may attract agricultural producers to shift from food or cash crops to feedstock. This change would indirectly affect many others whose livelihoods are partially or completely dependent on food crops (Cotula et al., 2008). Further, land values tend to rise when policies and market incentives are provided to convert lands for biofuels production. This increased land value may displace poor people from their land (Cotula et al., 2008).

6.2.2 Food security and cultural impacts

Several studies have argued that increasing demand for biofuel feedstock will pose some serious threats to the food security of people (Yang et al., 2009; Pimentel et al., 2009). In general, development of biobased industry could affect food security in two ways. One, higher food prices caused from the demand of feedstock for biofuel production will limit the purchasing power of the poor or marginalized people (Yang et al., 2009). Two, higher land-use change, such as diverting crop lands to biofuel feedstock production, can have major negative effects on local food security and on the social and cultural dimensions of land use (Cotula et al., 2008). Increased livelihood opportunities from biobased industry would lead to destruction of traditional economic or cultural activities, such as hunting, fishing and trapping. Additionally, using food and feed crops for ethanol production would increase the prices of other food items which are derived directly (e.g. breads, cereals) or indirectly (e.g. chicken, eggs, milk) from these biofuel crops. Although higher food prices represent higher income for farmers, they will affect those whose livelihoods are not linked to agriculture (e.g. urban poor).

6.2.3 Social impacts of rapid growth

Biofuel development could occur over a very short period of time and could change the social fabric of communities. New industrial developments always bring about some costs to communities. According to Finsterbusch (1980) some of these costs include: (i) new residents are frustrated by crowded housing (mainly trailers) and lack of amenities – especially recreational opportunities; (ii) These conditions aggravate family relations and lead to family tension, child abuse and neglect, and delinquency; and (iii) Reported cases of depression, alcoholism, and attempted suicide greatly increase, as do mental health cases. Researchers have provided documentation of a general increase in crime, drug abuse, mental illness, child abuse, and related problems in communities among both new and long-time resident (Gartrell et al., 1984) resulting from a rapid growth over a very short period of time.

7. Providing the balance to sustainability – trade-offs to be made

Biobased economy cannot provide all of society's material and energy needs. One therefore, needs to look at the value of displaced food production in social-economic context to know if trade-offs are worthwhile. Other possible trade-offs that may exist are: (i) Between economic and environmental goals of the society; (ii) Between environmental and social objectives of the society; and (iii) Between economic and social objectives.

7.1 Environment and economy

Traditionally, there has been a view that investments for mitigation of environmental damage (environmental protection) is a cost that takes resources away from investments that would increase production efficiency. Consequently, there are trade-offs between environment and the economy. Many countries have developed (or proposed) policies for reducing GHG emissions, such as subsidies, carbon tax, import tariffs for biofuels, and mandates for quantities to be produced or blended. These policies may promote investments in environmental protection and related technology development, while they can also distort markets and are subject to political decisions that may make them unsustainable. At the same time, some policies strive at maximizing the economic benefit, but will cause environment degradation. An example of this is the U.S. volumetric tax credit for cellulosic biofuels, that does not differentiate across feedstocks and rewards monocultures of high-yielding biofuels per unit of land and are therefore unlikely to create incentives for maintaining biodiversity (Khanna et al., 2009).

7.1.1 Climate change mitigation vs. energy security

Biofuels are attractive to governments which can diversify energy budget and reduce their exposure to international oil market to maintain economic sustainability. Corn-based ethanol in the United States and sugarcane-based ethanol in the Brazil have been built successfully with this objective in mind. While the well–to-wheel environmental benefits are different, such as sugarcane-based ethanol and cellulosic biofuels may achieve significant reduction of GHG, the corn-based ethanol performs poorly due to intensive fossil fuel input (Vermeulen et al., 2008).

7.1.2 GHG vs. other environmental goods

Besides GHG emission reduction, there are many other environmental benefits associated with a biobased economy, such as decreasing soil erosion, water eutrophication, loss of biodiversity, that should be considered. Treating GHG emissions as the only environmental cost, with no concern for other environment threats, can probably result in the other environmental goods and services, such as soil, water and biodiversity, becoming the unintended casualties. Decision makers need to include the full range of desired environmental outcomes in the design of appropriate and robust biofuel policies.

7.2 Environment and society

Emphasis on biofuels as renewable energy sources has developed globally. The use of food crops for biofuel production raises major nutritional and ethical concerns (Pimentel et al., 2009). As a result some trade-offs may exist. One such trade-offs is use of agricultural commodities for food vs. for fuel production.

The food versus fuel debate arises because increased use of land and water for bioenergy production reduces the availability of these resources to produce food for human consumption. The competition is direct in terms of first generation biofuel production that uses feedstocks of cereal grains (e.g. corn, wheat, etc.), oilseeds (e.g. rapeseed, soybean, palm oil), or other crops (e.g. sugar cane) that are conventionally used for food. However, even if the bioenergy feedstock crop is not suitable for food directly, it uses land that could be used for food production.

Secure and affordable food is basic to social sustainability. However, bioenergy may be at the origin of social benefits in providing better quality of life for rural population. It also has great potentials to mitigate environmental impacts. Therefore, if bioenergy is seen as a net environmental benefit, then the extent to which bioenergy production threatens the supply of secure and affordable food becomes an environment and society trade-off. However, if bioenergy is seen as environmental benefit, then the trade-off becomes between society and environment.

7.3 Economy and society

Usually, it is hard to clearly distinguish between economic and social issues. While economic sustainability emphasizes the economic feasibility and viability, society sustainability focuses more on distribution, human health, human rights and equity. Some social conflicts hide behind the economic benefit maximization. For example, the smaller scale operations generally have higher cost. However, the social sustainability policy goals for biofuels include promotion rural development and inclusion of small farmers. This trade off is important as many commodity dependent developing countries are characterised by a high proportion of small producers (Vermeulen & Vorley, 2007).

If an industrialized form of bioenergy crop cultivation is practiced, then the land required will most probably be controlled by large land owners or national companies (WWF, 2006). From maximization of the economic profits, crop cultivation tends to be industrialized which in turn will affect small landowners and poor people's right and welfare. Land ownership should be equitable, and land-tenure conflicts should be avoided. This requires clearly defined, documented and legally established tenure rights. To avoid leakage effects, poor people should not be excluded from the land. Customary land-use rights and disputes should be identified. A conflict register might be useful in this context (WWF, 2006).

7.4 SWOT analysis of biobased economy development

A Strength-Weakness-Opportunities-Threats (SWOT) analysis of the biobased economy is developed which would help decision makers understand strengths and need for developing appropriate policies to overcome limitations for such developments in the future. This analysis is presented in Table 3. One can see whether taking an action or building a project based on biobased economy depends on consideration of many positive and negative factors.

	Internal	**External**
Positive	**Strengths** • Energy security • Job creation and rural development • Improved trade activities • Establishment of new industries • Reduce GHG emissions	**Opportunities** • Renewable energy requirement • Policy encouragement and technology development
Negative	**Weakness** • Food security • Economic viability • Environmental impact uncertainty • Equity concerns	**Threats** • Rise in fuel and food price • Natural hazards and Crisis on financial market

Table 3. Relevant factors identified in each SWOT category

How to get win-win outcomes from biobased economy development? A map and related policies are urgently needed for the global biofuels industry that supports sustainability. Preventing environmental degradation and social-economic disruption from activities associated with bioenergy supply is seen as a basic principle of sustainability (WWF, 2006). Vermeulen et al. (2008) mentioned that it may be better for the EU to miss its target of reaching 10 per cent biofuel content in road fuels by 2020 than to compromise the environment and human wellbeing. The "decision tree" outlined in Fig. 4, which is developed by Vermeulen et al. (2008), can guide the interdependent processes of deliberation and analysis needed for making tough choices in biofuels to balance the tradeoffs between environment, economy and society.

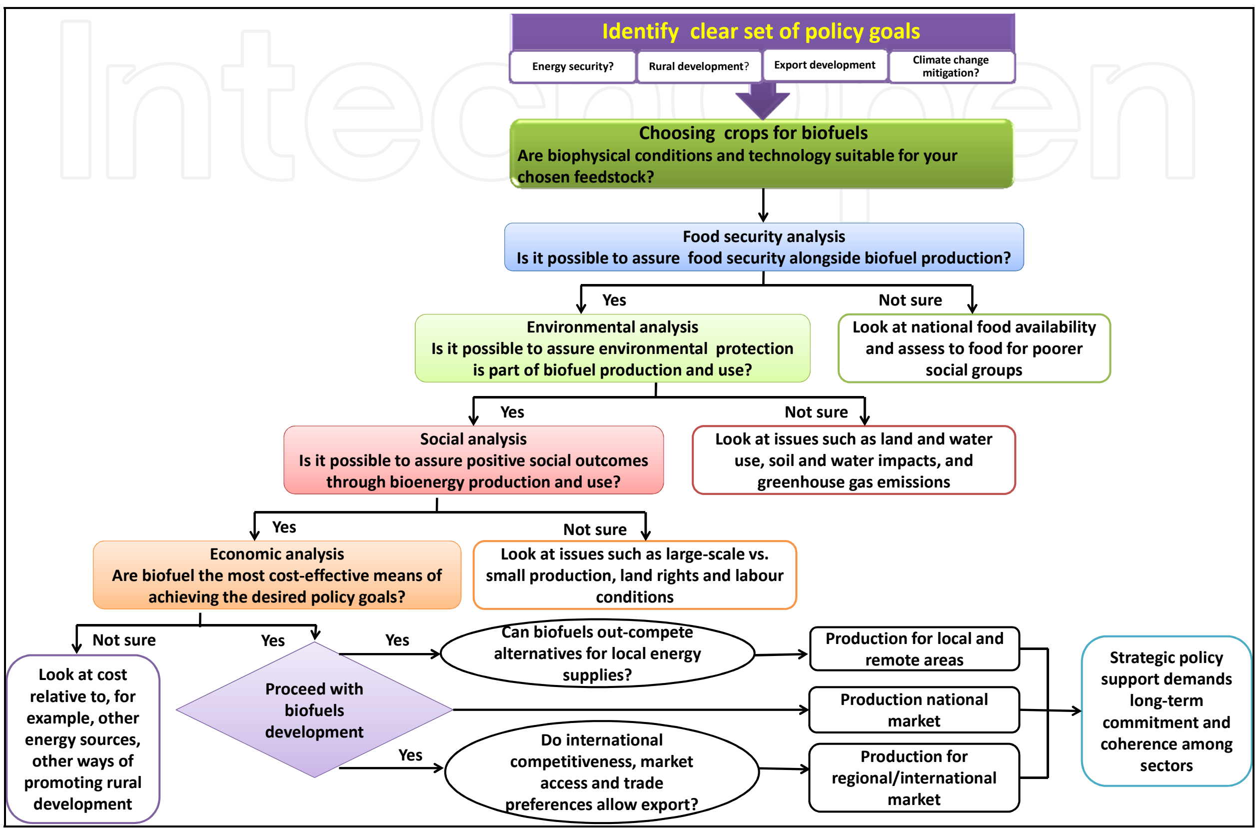

Fig. 4. A decision tree for sustainable strategic national choices on biofuel development (Vermeulen et al., 2008)

8. Conclusions

There exist significant opportunities and challenges with biobased economy. If done correctly, such developments can provide important environmental, economic, and social benefits. The challenge is to have desired outcomes well defined and then develop structures and policies to make those outcomes a reality.

The biobased economy is a major new opportunity for agriculture, which could enable to take it from its recurring overproduction for limited food, feed, and fiber markets to a more sustainable and profitable productions. But the benefits of this biobased economy will extend beyond agriculture to society as a whole, necessitating broad-based support in terms of public policy and investment.

Biobased economy, being located in rural areas, may provide many social benefits, including: (i) Increased employment opportunities in rural areas, resulting in reduced out-migration of local people; (ii) Health and sustainable rural communities; and (iii) Emergence of new investment opportunities for local entrepreneurs (e.g. trucking). Many new challenges would also emerge as a result. Among these are included some of the economic challenges, such as: (i) biomass crops have only one local market, making the local economy more sensitive to its price; (ii) Cost of infrastructure improvement and maintenance; (iii) Increased specialization; (iv) Lack of local control (since heavily capitalized portions of business are less likely to be locally owned -- such as biorefineries to process corn into ethanol); (v) GHG mitigation could cause agricultural activities to be reduced (e.g. through decreases in livestock population which currently provide important incomes and employment); (vi) Higher priced food (local, national, and international); (vii) seasonal employment; (xi) Many low-skill jobs, e.g. machinery operator, truck driver, etc.; (x) Road congestion, less safe highways due to truck traffic to transport biomass; (xi) Potential competition for water between population and industry, affecting some social functions in the communities; and (xii) Destruction of traditions, e.g. displacement of livestock, farmers into forest plantation managers, pastures into biomass grass.

To develop a sustainable biobased economy, two important needs must be addressed. First, it is essential to identify and implement mechanisms for the sustainable production of biomass as current practice of agriculture already facing challenges related to environment degradation and food security due to unsustainable practices. Policy incentives to adopt sustainable agriculture methods that help maintain soil cover, increase water use efficiency and reduce soil erosion are critical (Langeveld et al., 2010) and, research focus on ecosystem services to provide the necessary information to make appropriate land management decisions is also required. Second, developing technologies in order to improve the efficiency of conversion of biomass to biofuels is essential. This not only improves the energy yield of bio-fuels but also reduces the overall environmental and economic burden and hopefully could provide sufficient quantities to satisfy the energy needs of the society.

Ultimately, in a short to medium term, the success of biofuels market completely dependent on the economic factors and not ecological aspects (Festel, 2008). However, Coelho (2005) argues that the full potential of biofuel industry is hindered currently because the fossil fuels do not reflect their real costs and risks. The externalities associated with fossil fuels, such as additional health and environmental costs, are not taken into consideration and the policies of biofuels are mostly focus on side effects, such as local agricultural and food effects.

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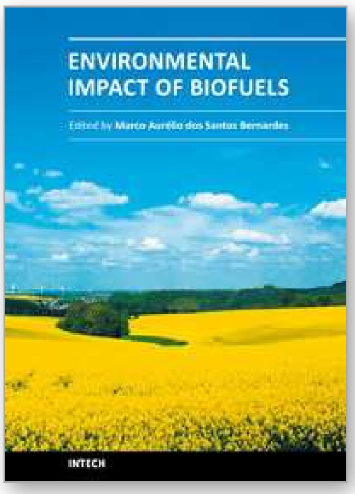

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