Agriculture Through Ages: Modern Challenges Towards Biofuels and Bioenergy Crops Agriculture

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Abstract

Human civilization has been through culminations of great achievements. This paper explores agricultural development in ancient and modern times, and the challenges yet to be resolved. At the beginning man invented how to cultivate, how to make fire, and moved from wild lifestyle to more settled livelihoods. He learnt and practised extensive systems such as slash-and-burn cultivation for millennia, and as population increased and knowledge accumulated he developed intensive systems such as greenhouse agriculture. Great developments have been associated with the industrial revolution of the 17th, 18th and 19th centuries, especially in areas of mechanization and use of industrial agricultural inputs. Both agricultural practices and industrial production have cost the world greatly in terms of environment degradation and environmental pollution. While the world is looking for remedies to environment degradation and pollution that are now intolerably threatening climate change, a new agricultural economic opportunity has emerged, which is not only important because of economic necessity, but it is also an important option towards solving the global warming and climate change threats. This is the use of biofuels and bioenergy as alternatives to fossil fuels use as a source of energy and power. The urgency of bio-fuels agriculture, particularly, seems to overwhelm what is the basic ecological role of world food subsistence agricultural production, with an additional role of producing almost the same food products to satisfy also the bio-fuels industry. This will obviously conflict on land use choices and commodity priority, and needs very thorough effort in planning and appropriate use of resources to avoid probably un-manageable consequences in near future.

Key words: Bioenergy crops, biofuels, bio-process development, climate change, farming systems change, fossil fuels, global warming, greenhouse agriculture

Introduction

Human civilization owes a lot to agriculture, which has been through culminations of dramatic changes that have generally brought the world to its heights of development to-date. Great inventions have been the basis of known developments in the production of the biological (plant and animal) products that generally characterize agriculture as a unique industry. Perhaps the greatest of all was the invention of agriculture itself, which, according to historical records, is believed to have happened about 10,000 years ago (Kahn,

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1979; Stevens & Jabara, 1988). This began with domestication of crop plants when man concluded his observations and put into practice the biological processes of seed germination and plant propagation. Beforehand man was living totally in the wild; dependent of hunting and gathering. Animal agriculture seems to have been subsequent to plant agriculture. Earliest records of domestication of animals date about 6,750 BC, while cultivation of crops is considered to have begun about 7,000 up to 9,000 BC (Encyclopaedia Britanica, 1997). Since then knowledge has accumulated and techniques of production improved to the extent that in its most advanced state modern farming nowadays is not very different from industrial production.

Early Beginnings and Ancient Agriculture

Perhaps the most significant of all developments in agriculture has been domestication of crops and livestock. This also reveals the truth that agriculture was invented at least several times because centres of origin of different crops are sometimes very distant apart. Ancient men would not be able to move very long distances, especially if transcontinental. Different societies in different distant places must have invented how to cultivate on their own. That agriculture was invented independently in different places has also been documented by Hankock (2007). After these inventions, then the knowledge must have spread slowly and consecutively to nearby areas. It is comprehended, for example, that European early communities remained hunters and gatherers for a long time, and that agriculture was introduced in Europe from the East. According to Encyclopaedia Britanica (1997), it is pointed out that it may have taken about 3,000 years for agriculture to spread from Greece to Denmark and the British Isles (in Greece earliest records of agriculture date about 6,000 BC). Thus introduction of agriculture through migration and trade is another way that contributed greatly to the development of agriculture.

Perhaps concurrent with the invention of agriculture was the invention of fire making technology. Encyclopaedia Britanica (*ibid*) reports that though records of existence and use of fire date as early as 1,420,000 years ago, fire making technology is considered to have begun during the Neolithic age about 7,000 BC. In those earlier days the source of fire is considered to have been natural events essentially lightning and volcanoes. When the old stone age (Neolithic) people began to use fire more systematically and reliably, they could make it from drills, saws and other friction-producing mechanisms.

Fire must have improved life drastically. It was first used for warming especially in temperate areas, for cooking (and roasting) and for driving animals during hunting. Fire drives were also used during warfare. It is obvious that fire improved nutrition and health, making food and water cleaner, and various nutrients more digestible. In those early days agriculture must have been boosted tremendously by slash and burn practice. Fire also enabled improvement of farm tools when man knew how to make iron tools (iron age).

Most ancient and pre-industrial revolution agriculture involved extensive practices such as shifting cultivation, slash and burn, and pastoralism. The great strategy during this period was exploitation of nature's resources, with increasing production mostly through expansion of land area and opening up virgin, previously uncultivated land. Up to the Roman epoch (200 BC–600 AD) and the medieval era (600–1600 AD), however, man had already learnt important techniques such as systematic land use by crop rotations and cultivation with draft power (*Ibid*).

Major Agricultural Changes Prior to and After the Industrial Revolution

Important agricultural developments that were existing soon prior to the industrial revolution can be noted to include advances in land use including land reclamation techniques in the Netherlands (*ibid*). During the industrial revolution era (17th, 18th and 19th centuries or 1600-1900) very significant developments were made also in agriculture as it had been in industry. These include first stabilization of systems and techniques that were developed previously, and several new discoveries. Crop rotations and livestock systems were developed for more intensive use of land. Extensive new areas of land were opened for agriculture when explorers were able to settle in new areas, especially in the tropics.

Great developments during the industrial revolution that have revolutionized agriculture also can be cited in areas of soil fertility management, animal nutrition, mechanization, and insect pest and disease control. Industrial chemical fertilizers were introduced to agriculture in 1840s after the German scientist Justus von Liebig published his work on "Organic Chemistry in its Applications to Agriculture and Physiology" in 1840, followed by the beginning of industrial production of chemical fertilizers after John Bennet Lawes patented manufacture of superphosphates in 1842 (McGrawHill Encyclopaedia, 1982). Lawes also founded the Rothamstead Experiment Station in England (*ibid*). The discovery of nutrients contribution to crop yields also stimulated research in animal nutrition and consequently revolutionized livestock production.

During the same period, arsenic compounds were discovered to be effective insecticides and began to be used in 1860s, followed by the accidental discovery of Bordeaux mixture (mixed copper sulphate and lime was meant to scare thieves as 'poisonous' when grapes in the field were coated with the mixture) in 1880s, which became the first effective fungicide to be used (*ibid*).

Though mechanization of agriculture started long earlier, 19th century is generally considered to have been a power revolution era (Encyclopaedia Britanica, 1997) when machines like seed drills, threshers, reapers, and indeed locomotive engines powered by steam (1830s–1860s), and afterwards petroleum oil (1890s) were invented. Agricultural productivity thus improved tremendously as a result of mechanization, soil nutrients supplementation and ability to control pests and diseases. Later during early 20th century another great development was widespread introduction of modernized agricultural systems in tropical and sub-tropical areas as these areas were conquered as colonies. These include, for example, tea plantations in Ceylon and elsewhere, coffee and sisal in East Africa, cocoa and oil palms in West Africa, rubber in South-east Asia, etc. Following developments in plant breeding techniques, especially in USA in 1930s, the Green revolution was initiated in developing countries, particularly in the tropics, beginning 1950s. In several of these countries industrial input-supported agriculture has boosted production and previously subsistence or food-deficit economies tremendously.

Greenhouse Agriculture

Ever since it was invented, agriculture grew gradually from most extensive to intensive, input dependent practices along with population increase and commercial entrepreneurship. Increasing population pressure and urbanization made land for agriculture very scarce and the challenge of feeding the masses of people, especially with fresh and perishable products, in urban areas very severe. More importantly, the seasonal nature of agriculture made availability of the fresh agricultural products (fruits and vegetables) very difficult out of the season. This led to controlled environment, and especially greenhouse agriculture.

A greenhouse is a building (framed or inflated structure) designed for protection of tender or out of season plants against vagaries of the environment, usually covered with a transparent or translucent material that permits optimum light transmission for the growing plants (Jensen & Malter, 1995). Greenhouse agriculture is an example of agricultural development that is worthy particular attention as a very efficient and highly productive system that science has managed to develop, just like other industrial agriculture innovations like in areas of intensive livestock production. This paper restricts its exploration of modern, highly intensified agricultural systems, with a brief note of greenhouse agriculture to serve as an example of pride that modern agricultural development can claim. Perhaps the climax of this pride is yet to come.

Though it has persisted for a long while, greenhouse agriculture is still a novel practice of producing vegetable crops. It is known to enable a diverse range of benefits such as production throughout the year, protection from destructive rainfall, high global radiation, cold and wind, better protection against pests and diseases, planned and protected use of fertilizers, better yields, better quality products, water saving by drip irrigation, collection and storage of rainwater for use in dry season, planned production and controlled cultivation for production deadlines, more favourable working conditions for people working within protective structures, etc (Von Zabeltitz & Baudoin, 1999). Significant greenhouse production of food began in the late 16th century (1597) when a selected choice of vegetable crops were produced, and by 1670 in Europe, greenhouse structures similar to those currently in use were being used (http:/www.cornelicea.com/about_CEA.htm).

Greenhouse agriculture has generally enabled modern man to make great achievements in productivity. According to Jensen and Malter (1995), yields of several crops (example tomato, pepper) doubled under greenhouse conditions as compared to open-field cultivation, on top of the fact that up to four crops (at least two crops) can be harvested per year in a greenhouse. Therefore in most instances total yield per year is more than doubled, tripled or even quadrupled in a greenhouse compared to open-field yields (Table 1). No wonder, therefore, that greenhouse production of crops—especially vegetables and cut flowers—has grown substantially in various countries (example Figure 1).

Table 1: Yields of greenhouse and open field produced vegetables (an example from Abu Dhabi)

Crop	Greenhouse yield (MT/Ha)	Field grown good yield (MT/Ha)	Number of crops per year (g/house)	Production per Year (g/houses) (MT/Ha)
Cabbage	11.5	7.5	4	46
Cucumber	57.5	30	3	172.5
Eggplant	28	21	2	56
Pepper	32.5	15.6	2	65
Tomato	150	75	3	450

Source: Jensen and Malter, 1995)

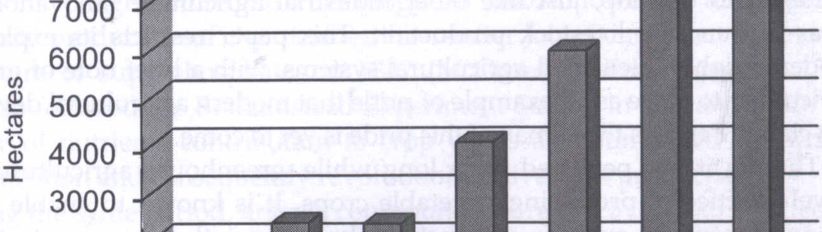

Figure 1: ***An Example of Growth of Greenhouse Agriculture (Netherlands 1912 - 1990): Total Production***

Note: Data used in plotting this graph from Jensen and Malter, 1995

Biofuels and Bioenergy Crop Production Agriculture

Reliable and adequate supplies of energy are necessities for economic prosperity and development of all societies of the world. Various forms of energy are available for human use. Among most important ones include heat energy (for cooking and some industrial processes such as boilers and smelters), electricity, light (for illumination and scientific observation/ examination), sound (communication and entertainment) and mechanical energy (for automotive and all motor operations). Various forms of energy are inter-convertible.

One of the greatest challenges of development is the ability to make use or ensure availability of a specific form of energy for performing specific functions. Of greatest significance in this context is perhaps the way to obtain mechanical energy that is used to run automotive engines and machines. Historically one of the most dependable sources of mechanical energy has been use of fuels.

Biofuels

Biofuels, by definition, are fuels produced by conversion of biological materials (biomass), including agricultural products. Fuels are generally chemical substances that can release energy when their energy-rich chemical bonds are broken. Perhaps the simplest and best known energy conversion processes is combustion. Combustion is simply a reaction between a fuel—be it fuel wood, natural gas, paraffin etc.—and an oxidizer, most usually O_2. Most interesting of fuels is perhaps those used in combustion engines.

Combustion engine fuels that have been in use ever since market use of such engines began are usually of two types: gasoline and diesel. According to The United States Patent 4424063, composition of these two types of fuels is not very different (http:/www. freepatentsonline.com/4424063.htm): they both contain 20% normal isobutyl alcohol, 73% kerosene, 5% methyl isobutyl ketone, 1.5% picric acid, 0.08% nitrobenzene, 0.05% primene 8IR and, whereas gasoline contains 0.02% copper carbonate hydroxide, diesel contains 0.01% elemental iron instead. These types of fuels, arising essentially from crude petroleum oil, are usually known as fossil fuels.

The fossil fuel industry has been confronted by critical problems of limited (diminishable) resources and environment polluting emissions. It is estimated that petroleum reserves worldwide may be depleted in several decades' time. The world consumes about 4.8km^3 of petroleum oil every year (30 billion barrels), which makes the industry the largest in the world. According to literature (Ruhl, 2007), the prospective lifespan of petroleum reserves is estimated to be 79.5 years in the Middle East, 41.2 years in Latin America, and only 12 years in North America. At current production levels, the world's oil reserves were estimated in 2007 figures to be depleted in 40.5 years (*ibid*).

On top of depletion fossil fuels emit perhaps most of the greenhouse gases (carbon dioxide, carbon monoxide, methane, nitrous oxide, chlorofluorocarbons, etc.), which add to global warming and consequently climate change. An alternative to both scenarios has been sought to be biofuels.

Biofuels are also known as biomass fuel, and are contrasted to fossil fuels (coal, oil, natural gas). They include biogas, but most interesting are perhaps those that can substitute liquid fuels (fuel petroleum oils). These are simply biodiesel and bio-ethanol, and according to Brittaine and Lutaladio (2010), also straight vegetable oils, as also quoted from Achten *et al*, 2008; de Jongh and Adriaans, 2007; Cloin, 2007.

Biodiesel

Biodiesel is a diesel type of fuel that is obtained from vegetable oils (vegidiesel) or animal fats (bio-lipids) by the process of transesterification. Crops that have been used for biodiesel production include soybean and oilseed rape. Other suitable crops include sunflower and castor. Perhaps simsim and groundnuts can also be important candidates. Among tree crops, Jatropha, copra (and cashewnuts) have proved to be excellent fuels even as pure oil, the oil palm is also now extensively cultivated and earmarked for biodiesel (Pye, 2008; 2009; 2010; Borras *et al*, 2010; White & Dasgupta, 2010).

Chemically, biodiesel is a mixture of compounds that varies in physical properties according to feedstock used to produce it, unlike bio-ethanol (ethyl alcohol), which is a chemical compound (Brittaine & Lutaladio, 2010). Additionally, most biodiesels consist of alkyl (usually methyl) esters instead of the alkanes and aromatic hydrocarbons of petroleum-derived diesel. They have combustion properties very similar to petrodiesel but they are better burning alternatives in terms of emissions. Biodiesel can be mixed with petrodiesel in any amounts in some modern engines, in essence in fractions up to 99% (http:/www.en.wikipedia.or g/wiki/Diesel). B100 (100% biodiesel) cannot be used to-date in diesel engines with particulate filters, which have been made quasimandatory (Krahl *et al*, 2007).

Biodiesel has the advantage of environment friendliness. Particulate matter in biodiesel averages about 47% (Kousoulidou *et al*, 2008) and up to 77% (Knothe & Sharp, 2006) less than in petrodiesel; carbon monoxide emission is reduced by 50% and exhaust emissions of total hydrocarbons up to 93% lower than in petrodiesel. Biodiesel in addition lacks sulphur and sulphate emissions. No wonder that many countries where biodiesel is been produced have been recommending mandatory use of biodiesel gradually as a substitute for petroleum diesel. Most recommended blends currently do not exceed 5% biodiesel (Krahl *et al*, 2007) but they generally range from 2–20% (Hamburg *et al*, 2006). In South Africa (Reichard, 2007), a Biofuels Association has been pressing the government demanding a mandatory mix of 55% biodiesel in its diesel fuel.

Bioethanol

Bioethanol is ethyl alcohol (ethanol) produced from feedstock or biomass. The alcohol can be used as a biofuel alternative to gasoline. As a fuel, ethanol has several advantages over gasoline, mostly related with reduced emissions. Carbon dioxide and toxic emissions respectively are 30% less in bioethanol than in gasoline, other exhaust emissions including particulate matter are also less. Kousoulidou *et al* (2008) reports reduction of NO_X (oxides of nitrogen) by up to 67% in bioethanol as compared to gasoline, and that of particulate matter by an average of 50%. As much as 80% reduction of particulate matter has been reported by DeServes (2005).

Ethanol can be mass-produced by fermentation of sugar or by hydration of ethylene (ethene CH_2=CH_2) from petroleum and other sources. Petroleum-derived ethanol is chemically identical to bioethanol, and the two can only be distinguished by radiocarbon dating. About 2,000,000 tons of petroleum-derived ethanol is produced worldwide annually (http:/en.wikipedia.org/wiki/Ethanol_fuel). To-date bioethanol production far exceeds petroleum-derived ethanol. World production of bioethanol in 2008 was about 17.33 billion US gallons, with USA and Brazil producing about 89% of the quantity (*Ibid*). Brazil produces most of its bioethanol from sugarcane while USA produces the fuel from corn.

Bioethanol can be produced from starch, sugar and practically all cellulosic plant materials. Currently crops mandated to bioethanol production are corn, sugarcane, cassava and sweet sorghum (http:/www.bar.gov.ph/ downloadables/2008/biofuels/Bioethanol.pdf). Other feedstocks that can be used include sugarbeet, barley, grain sorghum, wheat, sweet potatoes, Irish potatoes, fruits, molasses, baggase, kenaf, etc. According to http:/en.wikipedia.org/wiki/Ethanol_fuel) switchgrass, *Miscanthus spp.*, stover, straw, cotton, other biomass and many types of cellulose can also be used to produce ethanol.

In several countries bioethanol is increasingly blended with gasoline as a biofuel because of its easiness to manufacture from several alternative feedstocks. Anhydrous ethanol (< 1% H_2O) can be blended with gasoline in varying quantities up to pure ethanol (E100), and can be used to power automobiles and even other vehicles such as tractors and aeroplanes. To-date in Brazil, for example, all light weight vehicles no longer run on pure gasoline. A mandatory blend of between 20 and 25% ethanol is in use countrywide and there are millions of cars running on E100 and dual or flexible fuel (ethanol and gasoline in any proportion). In USA, also, most cars run on blends up to 10% and as much as 85% ethanol (*ibid*).

Bioenergy Crops Production in General

The world has generally been looking for renewable sources of energy to counteract fossil fuel emissions. Plants or biological materials are important stores of chemical energy originating from photosynthetic activity that can be converted to other forms of energy and power for human use renewably. In addition to the production of biofuels there are also prospects to-date for the production of electricity from biomass. The United Kingdom, for example, in early 2000s targeted production of 10% of its electricity from renewables by 2010 (Bullard & Nixon, 2002). The European Union in general and other industrialized countries are working towards the renewable energy sources prospect.

Practically all forms of energy that can be used domestically or in industry can be generated from biomass with the use of biophysical, biochemical or biological processes. Such processes may include combustion, pyrolysis, gasification, fermentation and digestion. Njie (2008), for instance, showed an example of how various forms of energy (electricity, heat, mechanical power) can be produced from biological materials such as straw as Figure 2 shows.

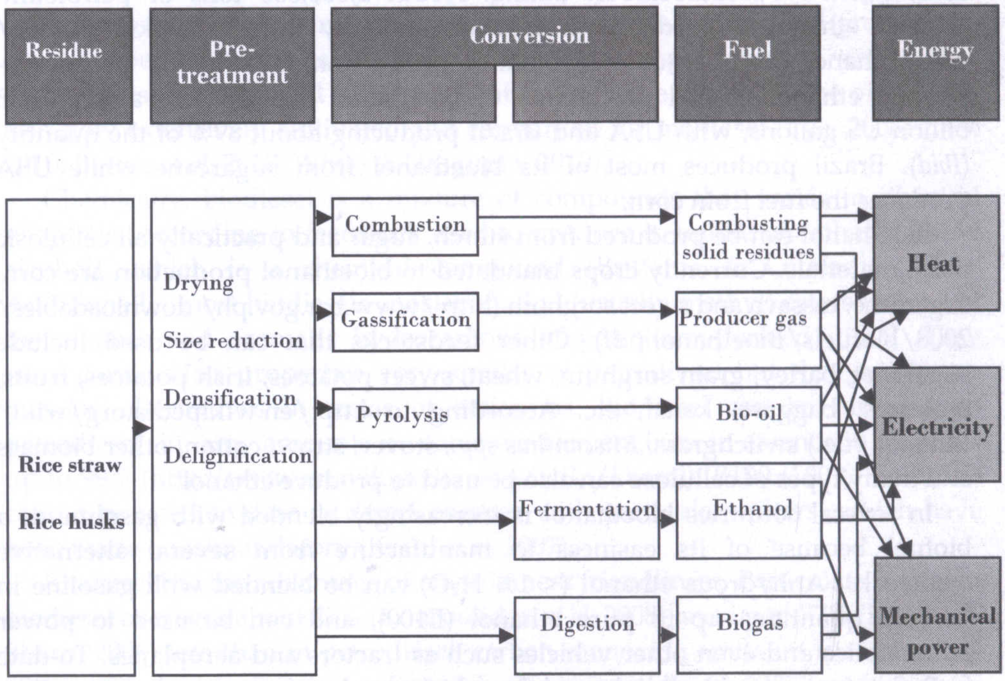

Figure 2: ***Pathways for producing energy from rice residues***
(Adapted from Bridgewater, 2006)

Cultivation of many herbage and forage plants is now been sought in addition to crop residues for bioenergy production beyond biofuels. Important crops that have been most prospective for bioenergy production include the switchgrass, *Panicum virgatum* L, (Bakker *et al*, 2004; Rinehart, 2006; Brown *et al*, 2008; Mitchell & Vogel, 2008), *Miscanthus spp* (Bullard & Nixon, 2002; Richard *et al*, 2008; Masters, 2009; Karp *et al*, 2011), the Willow, *Salix spp* (Abrahamson *et al*, 1998; Bullard & Nixon, 2002; Bakker *et al*, 2004; Masters,

2009) and even the elephant grass, *Pennissetum purpureum* (Konecsni, 2010). Under the Energy Crops Scheme in UK there were in 2009, for example, about 12,627 and 2600 hectares in England and Wales respectively planted with the bioenergy crops *Miscanthus* and *Salix spp* (Annon, 2009). *Miscanthus* and *Salix* are complexes embracing many species. Species of *Miscanthus* include *M. floridulus, M. sinensis, M. condensatus, M. transmorrisonensis, M. flavidus* etc, all belonging to one of the genera constituting a sub-family where sugarcane is a member (Chou, 2008). All species can be used for bioenergy but suitability depends on how much biomass can be harvested, which varies with species. *M. floridus* is a very high yielder, but there are even hybrids such as *M. x giganteus*, that are being developed for bioenergy (Chou, 2008). Species of *Salix* are also many, including the black willow (*S. nigra*) and many others such as *S. acutifolia, S. alba, S. aquatica, S. brachycarpa, S. caprea, S. cinerea, S. exigua, S. fragilis, S. matsudana* and others (http://www.bluestem.ca/willows-uses2.htm).

Modern Challenges with Biofuel Crops Production

A relaxed world with assumption that the energy problem has long been resolved and that fossil fuels emissions can be tolerated is now heavily burdened with reality. It is now perhaps a noble coincidence that we have the option of biofuels not solely as an approach to counteract global warming but as insurance against challenges that would overwhelm the fuels energy sector this century.

While agriculture is awaiting the biofuels crop production boom, there are also a lot of worries whether the already and ever constrained food insecure agriculture will be able to sustain perhaps an even greater challenge of attaining world food sufficiency, and additionally satisfying the biofuels market. Current biofuels production is still a very small fraction of the world fuel needs. In 2006 the oil consumption worldwide was about 4000 million tonnes per year or 84 million barrels per day (http://en.wikipedia.org/wiki/Ethanol_fuel). Agriculture has to invest tremendously to approach such quantity of bioethanol, biodiesel, or biomethane.

If the world has not been able to satisfy food subsistence priority goals in pre-biofuels agriculture, the challenges that biofuels agriculture has to resolve are indeed great. It is hoped that biofuels crop production will need extensive use of land or, in other words, great expansion of area under cultivation and perhaps shrinkage of area currently under food crop production. At the same time, not only that food surplus and perhaps some of the food that is currently been produced may be devoted to biofuels, but it is also expected that price of food will increase as long as food resources are shared competitively with biofuels. According to Smith and Elliott (2008), biofuels have already contributed to rise in international wheat prices. Linkage with higher food prices has also been reported by Dauvergne and Neville (2010). There are also environmental worries that currently unused land whose natural vegetation plays a very significant role in CO_2 absorption may be converted into biofuels agriculture, thus disturbing the carbon balance and contributing to global warming. At the same time this may also cause loss of biodiversity existing in these areas.

Prospects of great agriculture-based economic and social development and less polluted environment because of biofuels and bioenergy crop production are also great. Annon (2009) reported that growth of the biofuels industry in the USA, for example, will reduce annual oil imports by $70 bn (roughly Tsh 100,000bn in current price) by 2022. The report further shows expectation that due in part to biofuels US land devoted to 8 major crops cultivated in the country (area has been declining since 1980; perhaps due to increasing productivity) will remain stable through the next decade. Brazil, on the other hand, which in 2006 was having about 300 sugar-ethanol mills and over 30,000 filling stations nationwide—where up to 100% bioethanol could be purchased at 50% of the price of gasoline (ISIS, 2006)—is set to double its ethanol production in the next decade. Lehtonen (2008) reported further that only 2% of the land currently used for agriculture in the country would be enough to double the bioethanol production even though a question remained about where this land would be located. There are also contradicting reports of poor farmers been marginalized because of biofuels land expansion (ISIS, 2006); and other poor farmers being economically boosted because of biofuels crop production (Soroso, 2008).

Agricultural production for bioethanol and biodiesel is already extensively practiced and projections are tremendous. It is estimated that although currently only about one to two percent of the world's arable land is devoted to agrofuels, this is expected to increase to four percent by 2030 and 20 percent by 2050 (Liversage, 2010). Many countries and even regions, like the European Union, have set production and development targets for biofuels, many of them to be realized in short and medium term (Vidal, 2007; Holt-Gimenez, 2007; Altieri, 2009; Borras *et al*, 2010). Tension and prospects posed by this new and prospering industry are real. Thus despite those actual and planned developments, criticism about the biofuels industry is extensive (Pimentel et al, 2007; Ernsting, 2007; Diouf, 2007; Clancy, 2008; Oxfam, 2008; Cotula *et al*, 2008; Dauvergne and Nevile, 2009; Giampietro & Mayumi, 2010). Most of the criticism is, however, not centred on technological urgency and resource alternative, rather in most instances it is centred on socio-economic imbalances and agrarian struggles.

Whether worries or prospects, agriculture will always embrace the technological opportunities of biofuels and bioenergy crops production before petroleum oil reserves become depleted perhaps in 40 years. Since some of the crops for biofuels production are those suited to indigenous or traditional crop production systems, even small farmers can be involved in this very commercially attractive land resource use. This commercial incentive even with crops that had no reliable market previously will stimulate both increased acreage and improved production practices to increase production and yield. At the same time, commercial and perhaps industrial plantation agriculture will beseech to invest heavily in biofuels production. Both scenarios will require very judicious land use and economic planning that will ensure growth of the bioenergy crop production industry without land use imbalances and unmanageable consequences to the environment.

Conclusion and Recommendations

The agricultural past can be an important example showing that, in addition to many other things, development is generally a lengthy and difficult process. Obviously the challenge that agriculture is encountering to-date is more important than the historical past. Current and—perhaps very close—future circumstances put the field of agriculture in an important turning point that necessitates balancing of a number of perhaps equally important scenarios. In one scenario, agriculture must play a very significant role that is now bestowed with: fighting global warming and climate change, which it can do using various approaches. One approach is by reducing greenhouse gas emissions from fossil fuels through use of biofuels and bioenergy alternatives. Another approach is by conserving natural vegetation (invaluable carbon sink) while in dire need of expansion, and by abandoning completely traditional techniques like slash and burn. Unfortunately, the slash and burn agriculture still supports millions of people whose means of livelihood and geographical location cannot be easily intervened.

In another scenario, through use of biofuels, agriculture seems, perhaps, to be the only most rational alternative, after depletion of fossil fuel reserves, which worldwide is just around the corner. Another scenario is land use conflicts between biofuels production and food (and other) crops production, which may actually involve also diversion of food commodities into biofuels, leading to food shortages and unmanageable food prices; and between agricultural production and conservation. All these need extra perfection in planning to be able to balance all forces equally sufficiently and avoid un-manageable consequences. Another important scenario is an obvious farming systems change and adaptation that is necessary to accommodate biofuels and bioenergy crops agriculture. Our farmers—in Tanzania constituting about 85% of the population, and majority of whom are still not seriously commercial,—should now consider themselves being challenged with the opportunity of escaping from agricultural poverty through biofuels agriculture. This needs overhauling of the existing farming systems to be totally free from any predominance of subsistence and assume an absolute and always urgent commercial status. This, of course, calls for an equally institutional preparedness to harness the necessary shifts in farming systems towards biofuels agriculture, in the form of developing proper marketing arrangements and bio-processes.

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