

## **Bioenergy Crops an Alternative Energy**

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### **Abstract**

Bioenergy is “energy derived from recently living material such as wood, crops, or animal waste.” Bioenergy crops are defined as any plant material used to produce bioenergy. These crops have the capacity to produce large volume of biomass, high energy potential, and can be grown in marginal soils. Bioenergy can contribute to reducing the overall consumption of fossil fuels. It can take the form of solid material (biomass) for combustion or liquid products (Biofuels) that can be used to power vehicles. Both biomass and Biofuels can be derived from dedicated energy crops, agricultural co-products or waste materials. Switchgrass (*Panicum virgatum* L.), elephant grass (*Pennisetum purpureum* Schum.), poplar (*Populus* spp.), willow (*Salix* spp.), mesquite (*Prosopis* spp.), etc. have been touted as the crops with the most widespread promise.

Planting bioenergy crops in degraded soils is one of the promising agricultural options with C sequestration rates ranging from 0.6 to 3.0 Mg C ha<sup>-1</sup> yr<sup>-1</sup>. Bioenergy crops have the potential to sequester approximately 318 Tg C yr<sup>-1</sup> in the United States and 1631 Tg C yr<sup>-1</sup> worldwide. They contribute to the reduction of greenhouse gas emissions and thus the slowing of climate change and its negative impacts. Bioenergy can be used to produce fuel for the transport sector or through biomass combustion to produce heat and/or power. Biofuels appear to be the most viable low carbon transport fuel option in the short to medium term. With rising energy costs and uncertainty of fossil fuel reserves, it's important to oversee cheaper, safer, and more renewable forms of bio-energy. As a supplemental alternative energy to coal, bio-energy crops could play an important role as environmentally safe and economically profitable.

**Keywords:** Bioenergy crops; biofuels; biodiesel; renewable energy; biomass production; energy plants.

## 1. Introduction

Although the term energy crops may be unfamiliar to some, the concept of energy crops has been around for many years. In fact, agricultural and forestry crops and their residues were a major source of energy until the discovery of oil in 1859. Declining reserves of fossil fuels plus recognition that growing carbon dioxide emissions are driving climate change have focused world attention on the need to reduce fossil fuel dependence. In turn, this has increased interest in promoting bioenergy, including biofuels, as a renewable energy source. Theoretical biomass resources are potentially the world's largest sustainable bioenergy source comprising about 220 billion oven-dry tons or 4,500 EJ of annual primary production. Of these, in 2050, there may be 273-1381 EJ/yr provided by bioenergy crops (Smeets et al., 2007). Bioenergy crop plants that function as solar energy collectors and thermo-chemical energy storage systems are the basis for Biomass derived from bioenergy crops will play an important role in combating GCC and will increase the share of renewable energy sources worldwide (Karp and Shield, 2008). However; using biological systems to store carbon and reduce GHG emissions is a potential mitigation approach for which equity considerations are complex and contentious (IPCC, 2007; Lal, 2008a). Also they take up an equal amount of carbon dioxide that was released when burnt – therefore theoretically yielding no net carbon dioxide emissions from their combustion (carbon sequestration).

Bioenergy cannot entirely substitute fossil fuels at present due to the huge cropping areas requirement Nevertheless; it can contribute in reducing the overall consumption of fossil fuels. It can take the form of solid material (biomass) for combustion or liquid products (Biofuels) that can be used to power vehicles. Both biomass and Biofuels can be derived from dedicated energy crops, agricultural co-products or waste materials. Development of renewable energy can not only contribute to the energy supply, but also to achieve economic and environmental benefits. Biomass energy is the most abundant and versatile type of renewable energy in the world. In recent years, many countries have developed policies and objectives for bioenergy and this includes the production of heat, electricity, and fuel.

Growing energy crops at a large scale is bound to have significant effects on the countryside and on wildlife that lives in it. Such impacts may range from extremely negative to beneficial. Large-scale bioenergy crop plantations pose both opportunities and challenges, and will inevitably compete with food crops for land, water, nutrient resources and other inputs; whereas, biodiversity consequences of increased biofuel production will most likely result in habitat loss, increased and enhanced dispersion of invasive species, and pollution. Improvements in composition and structure of biochemicals in bioenergy crops will enable the production of more energy per ton of

biomass and will improve its caloric value, GHG profile, and GCC mitigation potential.

## **2. Bioenergy Crops: Characteristics**

Plant species, with fast growth, tolerance to biotic and abiotic stresses, and low requirements for biological, chemical or physical pretreatments, are being evaluated as potential bioenergy crops. Here are some characteristics of energy crops:

### **2.1 Agronomic and architectural traits:**

Agronomically bioenergy crop should require low inputs for establishment, need low fossil fuel inputs, should be adaptable to marginal lands, and provide high biomass and energy yield that is expected to help reduce global warming and combat Global Climate Change(GCC). Also agronomically they should not be limited to low proportional allocation of dry matter to reproductive structures, long canopy duration, perennial growth, sterility to prevent escape, and low moisture content at harvest. Architecture of a DEC plant should help minimize plant-to-plant competition and effectively maximize competition with weeds, maximize radiation interception and Water Use Efficiency (WUE), accelerate drying in the field, and facilitate mechanical harvesting. This can be achieved by adjusting branching habit, having a thick, straight, upright stem and resistance to lodging. Trees can be optimized to have short stature to increase light access and enable dense growth, large stem diameter, and reduced branching to optimize energy density for transport and processing.

### **2.2 Physiological and eco-physiological traits:**

A bioenergy crop plant can be viewed as a solar energy collector and thermo-chemical energy storage system. Numerous physiological and eco-physiological traits needed to maximize radiation interception, radiation, WUE and NUE, and to confer environmental sustainability, should be targeted to enhance plant biomass and bioenergy production. Eco-physiological traits that can help to change thermal time sensitivity to extend the growing season and increase above ground biomass without depleting below ground biomass include: high growth rate, response to light competition, canopies with low extinction coefficients, leaf traits for efficient light capture (including optimum leaf area index (LAI), and specific leaf area(SLA) C4 or CAM photosynthetic pathway coupled with large WUE, long canopy duration, large capacity for C sequestration and nutrient cycling, and low nutrient (e.g., N and S) requirements and content of above-ground biomass.

### **2.3 Biochemical composition and caloric content:**

The caloric value of a material is an expression of the energy content, or heat value, released when burned in air. Plants differ in their biochemical composition (i.e., carbohydrates, proteins, lipids, organic acids, etc.) and in the amount of glucose to produce a unit of these organic compounds therefore; plant composition determines the availability of energy from specific biomass type, when adjusted for moisture content,

and results in differences in energy output. Besides their effect on energy yield, biomass yield and composition affect GHG profiles and GCC mitigation potential of bioenergy crops. For example, hybrid poplar produces the largest energy yield (6.15 MJ/m<sup>2</sup>/yr), followed by switchgrass (5.8) then reed canary grass (4.9); however, reed canary grass has the largest net GHG emission ratio of 3.65, as compared with switchgrass (2.42) and hybrid poplar (2.37)

### **3. Bioenergy Plants**

Biomass produced from fields consists of residues (straw tops etc.) and specifically cultivated crops (for example, Miscanthus, poplar, willow, reed canary grass, rapeseed, maize). Not all residues are available for bioenergy production because they are needed for livestock feed and litter and to maintain soil fertility. Biomass is a heterogeneous aggregation of different feedstock's, conversion technologies, and end-use with different traditional and connotations in different parts of the world. Traditional biomass provides 38±10 EJ/yr as fuel wood, manure, and other forms (Smeets et al., 2007). Estimates of the bioenergy production potential vary from 33 to 1135 EJ/yr due to the uncertainty of land availability and yield of bioenergy crops (Hoogwijk et al., 2009). The grand challenge for biomass production is to develop crops with a suit of desirable physical and chemical traits while increasing biomass production by a factor of 2 or more ( Lal, 2008a). Crop residues and dedicated bioenergy crops together constitute 3 – 9 EJ of bioenergy potential.

Conventional grain and oilseed crops and crop residues, perennial herbaceous and woody crops, perennial oilseed crops, halophytes, and algae, among others, are candidate bioenergy crops and are expected to combat GCC ( Eisenbies et al., 2009). On the basis of biomass production and their use as energy crop they are classified under following categories:

#### **3.1 Traditional Bioenergy crops:**

Traditional biofuels derived from natural vegetation or from crop residues. Such biofuels still are the main energy source in number of countries (e.g., Bhutan 86%, Nepal 97%) but they are not sustainable, their exploitation may contribute to land degradation and desertification and are unable to mitigate the impact of GCC.

#### **3.2 First generation bioenergy crops (FGECs):**

The vast majority of current liquid biofuels production is based on FGECs. It can also be used for food therefore; their raw materials compete with food for fertile land and inputs. For example corn, sugarcane, oil palm and rapeseed. Biofuels derived from FGECs rely on fermentation of sugars to produce ethanol or on trans-esterification of plant oils to produce biodiesel.

### 3.3 Second generation bioenergy crops (SGECs):

The SGECs are expected to be more efficient than FGECs and to provide fuel made from cellulose and non-oxygenated, pure hydrocarbon fuels such as biomass-to-liquid fuel. Biofuels produced biochemically or thermo-chemically from lingo-cellulosic SGECs, have more energy content (GJ/ha/yr) than most FGECs biofuels. They avoid many of the environmental concerns, and may offer greater cost reduction potential. Early SGECs include perennial forage crops such as Switchgrass., *Phalaris arundinacea* L., *Medicago sativa* L., *Pennisetum purpureum* Schumach., and *Cynodon* spp (Oliver et al., 2009). The capacity of *Miscanthus* to fix CO<sub>2</sub> ranges from 5.2 to 7.2 tC/ha/yr, which results in a negative C balance (Boe and Beck, 2008; Jakob et al., 2009). The contribution of non-edible plant oils (e.g., from *Jatropha curcas* L., Euphorbiaceae; 30-50% oil) and soapnut (*Sapindus mukorossi* and *S. trifoliatum*; 52% oil), as new sources for biodiesel production have the advantage of not competing with edible oils produced from crop plants (Ram et al., 2008).

### 3.4 Third generation bioenergy crops (TGECs):

The TGECs include boreal plants, CAM plants, Eucalyptus spp. and micro-algae. The boreal and CAM plants are potential sources of feed stocks for direct cellulose fermentation and Eucalyptus for bioenergy production through thermo-conversion whereas, algae is a potential source of biodiesel. A number of TGECs oleaginous crops being tested for biodiesel production include: African palm (22% oil), coconut (55-60% oil), and grain of castor bean (45-48% oil), and peanut (40-43% oil). They can help to reduce GHG emissions by capturing CO<sub>2</sub> released from power plants or by generating biomass through photosynthesis.

### 3.5 Dedicated bioenergy crops (DECs)

DEC have been proposed as a strategy to produce energy without impacting food security or the environment. Their Genetic resources requirements for biological, chemical or physical pretreatment are more environmentally friendly and will contribute more to GCC mitigation (Petersen, 2008). They are beneficial in providing certain ecosystem services, including C sequestration, biodiversity enhancement, salinity mitigation, and enhancement of soil and water quality. crops include (1) cellulosic crops including short rotation trees and shrubs such as eucalyptus (*Eucalyptus* spp.), poplar (*Populus* spp.), willow (*Salix* spp.), and birch (*Betula* spp.); (2) perennial grasses such as giant reed (*Arundo donax*), reed canary grass (*Phalaris arundinacea*), switchgrass (*Panicum virgatum*), elephant grass (*Miscanthus x giganteus*), Johnson grass (*Sorghum halepense*) and sweet sorghum (*Sorghum bicolor*); and (3) non-edible oil crops such as castor bean (*Ricinus communis*), physic nut (*Jatropha curcas*), oil radish (*Raphanus sativus*), and pongamia (*Pongamia* spp).

#### 4. Conclusion

Bioenergy crops currently provide the only source of alternative energy with the potential to reduce the use of fossil transportation fuels in a way that is compatible with existing engine technology, including in developing countries. The use of organic waste and agricultural/forestry residues, and of lignocellulosic crops that could be grown on a wider spectrum of land types, may mitigate land and water demand and reduce competition with food. Energy crops act as filter systems/ supplemental crops for pollution control as they remove pesticides and excess fertilizer from surface water before it pollutes groundwater or streams/rivers. They can protect a stream's bank and water from erosion, siltation, and chemical runoff and can still be harvested for energy. Research has also shown that energy crops have increased soil stability, decreased surface water runoff, decreased transport of nutrients and sediment, and increased soil moisture, in comparison to traditional crops.

They also require less fertilizers, herbicides and insecticides than traditional row crops, this reduction in herbicide and pesticide use reduces the potential for water pollution and other environmental problems. Another environmental benefit from the use of energy crops is a decrease in emissions. Unlike fossil fuels, plants grown for energy crops absorb the amount of carbon dioxide (CO<sub>2</sub>) released during their combustion/use. Therefore, by using biomass for energy generation there is no net CO<sub>2</sub> generated because the amount emitted in its use has been previously absorbed when the plant was growing. It has been assessed the potential for CO<sub>2</sub> emission reduction by developing non grain based ethanol crops. The results show that non-grain based bio-ethanol production can potentially reduce CO<sub>2</sub> emissions from the 2007 levels by 11 million tons and 49 million tons in 2015 and 2030, respectively.

Energy crops may also protect natural forests by providing an alternative source of wood, which can be grown on farm or pasture land that is no longer suitable for traditional row crops. Bioenergy-driven restoration of degraded ecosystems can also increase terrestrial carbon sequestration due to large biomass production and root residues as well as slowing decomposition of soil organic materials under no-till conditions.

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