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Review

Forest biomass resources and utilization in China

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Under the context of climate change, persistent high oil prices and rapidly growing dependence on imported oil prompt China to pay much more attention to biofuels that provide environmental benefits besides fuel. China has rich biodiversity with 30 thousand high plant species and 154 kinds of energy trees could produce seeds containing more than 40% of oil, with total production of the seeds totaling 5 million t, and 200 x10^9 t of biomass production per year, which is equal to 2 x 10^9 t of petroleum. There are over 2000 types of wild and cultivated firewood plants in the country. So far there is 4 million ha raising oil-bearing trees planted on some land in different regions. Another 57 million ha of waste land are available and suitable for planting trees for the production of forest bioenergy. On part of these lands, the central government plans to cultivate a total of 13 million ha of high-grade bioenergy forests by 2020. This will yield 6 million tons of diesel that would be enough to fuel power plants with a combined capacity of 11 GW each year. Moreover, forest biomass plantations potentially offer many direct and indirect environmental benefits. In view of climate change their globally significant environmental benefits may result from using forest biomass for energy rather than fossil fuels.

Key words: Biomass energy, China, forest biomass resources.

INTRODUCTION

With rapid socioeconomic development, China's energy development faces serious resource constraints. Its current energy resources are primarily from diminishing domestic fossil fuels, but it is becoming increasingly dependent on expensive imported fuels, ecologically disastrous hydroelectricity and vulnerable and expensive nuclear energy. Therefore, one of the most urgent problems the Chinese government faces is to build a safe, economic, clean and sustainable energy supply system, whilst solving the energy supply bottlenecks (National Economic and Trade Committee, 1998; World Energy Council, 1998; Zhang et al., 2009). Consequently the government is encouraging the use of alternative energy production with both incentives and privileges. One of the solutions is to develop biomass energy (Li, 2003; Research Group of Chinese Forest Bioenergy, 2006; Yaghoob Tahery, 2011).

China is rich in agricultural and forestry waste materials such as straw, bush and quitch. By year 2012, the total biomass generating capacity is expected to reach 300 million kilowatts and 1600 million kilowatts by 2020 (Research Group of Chinese Forest Bioenergy, 2006). Many areas have good conditions for developing biomass energy production (Ren, 2007; Zhang et al., 2010a). Of these materials forest biomass production plays an important role on bioenergy development in the country.

Forest bioenergy is the use of renewable forestry biomass to produce energy products, such as the lipid- and starch-rich materials from the forests could be processed into liquids to make biodiesel and ethanol fuel whereas woody biomass can be pelletized and used in power plants to replace coal, and thus reduce carbon dioxide emissions substantially (Liu and Diamond, 2005; Tahery, 2011).

The potential of the country's forest bioenergy would thus be equivalent to 200 million t of coal, the utilization of which would reduce the consumption of fossil energy by 10% (Deng, 2000). Currently, China is home to more than 4 million ha of oil plants nationwide and 154 kinds of energy trees could produce seeds containing more than 40% of oil, with total production of seeds totaling 5 million t. Another 57 million ha of waste land are available and suitable for planting trees for the production of forest

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Table 1. Two trees with high content of cellulose, sugar and starch.

Species	Part used	Productivity	Distribution	Environmental requirement	Application
Metroxylon sagu	Stem	120 to 260 kg/stock	Southeastern China	High temperature and humunity; tolerant to poor soil quality	Processing ethanol
Manihot esculenta	Roots and leaves	15000 kg/ ha	Along Huaihe river and Changjiangriver basin; mainly in Guangdong and Guangxi	Tolerant to poor soil quality	Raw material for starch

bioenergy (Shi, 2004).

Moreover, forest biomass plantations potentially offer many direct and indirect environmental effects. Under the context of climate change their globally significant environmental benefits may result from using wood for energy rather than fossil fuels. The greatest benefit is derived from substituting biomass energy for coal (Research Group of Chinese Forest Bioenergy, 2006). The degree of benefit depends greatly on the efficiency with which the wood-based material is converted to electricity. If the efficiency of conversion of wood to electricity is similar to coal conversion to electricity then the benefits are several. Airborne pollutants such as toxic heavy metals, ozone-forming chemicals, and releases of sulfur that contribute to acid rain will be reduced, which is one of the most serious pollutions in southwestern China. The ash and waste products from burning will, in most cases, be sufficiently benign to return to the soil (Zhang et al., 2002, 2011). There will be a considerable reduction in net carbon dioxide emissions that contribute to the greenhouse effect.

On the other hand, locally significant environmental benefits can include: protection of water quality, reduction of floods during wet seasons and maintenance of water supplies during dry seasons, improvement of local microclimate through evaporative cooling and humidification, wind breaks and shelters that reduce erosion and conserve water, particularly in dry regions, reduction of fire danger, reduction in use of fertilizer and agricultural chemicals, improvement of soil properties, and protection of wildlife and other components of biodiversity (Hall et al., 1997). Forest biomass plantations have also been shown to reduce evaporative losses of water, and improve soil moisture conditions sufficiently to allow cropping on degraded lands (Zhang et al., 2009, 2010b). Especially by selecting nitrogen-fixing species, such as acacias and leaucena, can improve the soil, reduce the need for expensive nitrogen fertilizer, and produce fodder for farm animals in rural areas.

Hence, the government recognizes this importance and significance and is aiming to speed up forest biomass development not only in major grain-producing areas but also in degraded lands.

FOREST BIOMASS RESOURCES IN CHINA

China has rich biodiversity thanks to having great variety of climatic conditions and soil types, with 30 thousand high plant species (Yang, 2005) and 200 x 10^9 t of biomass production per year (Li et al., 1998), which is equal to 2 x 10^9 t of petroleum and about three times the current one-time-consumed energy. Here biomass production is estimated based on the production per unit of land area and its total growing area for different plants. China has diverse oil plants—over 800 of them have oil content of 10% or more, and over 100 are petroleum plants. As energy plants they have different features and various applications (Tables 1, 2 and 3). Some oil plants have very high oil content but are less abundant, such as *Litsea subcoriacea* and *Lindera*, which produce seeds with oil content of 64.4% and 67.2%, respectively. Some not only have very high oil content but also are very abundant, such as *Artemisia monosperma* and *Artemisia ordosica*, which are mainly distributed in northwestern China, with seed oil content of 16 to 23% and total storage of 500 thousand t (Wu, 2004). China also has over 2000 types of wild and cultivated firewood plants. Some of them are introduced species. For example, there are over 60 introduced *Eucalyptus* tree species in China. Most (ca. 75%) plant species grown for fuel are distributed in south China and the rest mainly in temperate areas of China.

In no more than five years, the *Pistacia chinensis* Bunge, whose seeds have an oil content of up to 40%, will yield 5 t of fruit and contribute about 2 t of high-quality biodiesel. The tree tolerates poor, dry soils and has relatively low water needs. Hebei province is among the seven regions designated by the State Forestry Administration (SFA) in 2006 to develop biofuel demonstration forests. Hebei, Anhui, Hunan, Sichuan, Yunnan and Shanxi provinces and Inner

Table 2. Some trees as raw material for producing petroleum.

Species	Parts used	Productivity	Distribution	Environmental requirement	Application
Jatropha curcus	Seeds	Oil content 40 to 60%	Guangxi, Guangdong, Hainan, Yunnan, Sichuan	Widely growing; high temperature	Alike diesel
Sindora glabra Merr, ex de	Whole tree	Stem up to 12 to 15 m height begin to produce biodiesel; 20 to 60 kg/stock	Hainan	Sunny; high temperature	Biodiesel
Cornus wilsoniana Wanger	Fruit and nuts	Oil content 33 to 36%, productivity 25 to 30%	Henan, Gansu, Fujian, Jiangxi, Hubei, Hunan, Guizhou, Sichuan, Guangdong and Guangxi	Widely growing	Oil; biodiesel
Euphorbia tirucalli	White sap from stem	High content of carbohydrate	Introduced from Africa; cultivated in southwestern China	Sunny; High temperature and humunity	Raw material for petroleum

Table 3. Some trees with high content of lipid.

Species	Parts used	Productivity	Distribution	Environmental requirement	Application
Pistacia chinensis	Seeds	Oil content 42.05%	The middle and lower reaches of Changjiang river; northern and southwestern China	Widely growing	Lubricating oil; biofuels
Camellia oleifera Abel	Seeds、nuts	Oil content for seeds 36.6%, for nuts 55.9%	Anhui, Jiangsu, Zhejiang, Fujian, Jiangxi, Hunan, Guangdong, Sichuan	High temperature and humunity; acidy soils	Lubricating oil; raw material for candle、soap
Garcinia multillora Champ, ex Benth.	Seeds	Oil content 51.22%	Taiwan, southern and southwestern China, Jiangxi, Hunan, Fujian	Widely growing	Lubricating oil; raw material for soap
Simriaondsia chinensis	Seeds	Oil content 50%	Subtropical zone	In test	Lubricating oil
Cinnamomum pauciflorum	Branches, leaves, stem, bark	Oil content for leaves 3.15 to 4.36%	Sichuan, Yunnan, Guizhou	Widely growing	Industrial raw materials
Sapium sebiferum	Fruits and nuts	Oil content for fruits 70.3%, for nuts 31.7%	Tropical and subtropical zone	Widely growing	Raw material for candle, soap and lubricating oil

Table 4. Estimated current and planned *Jatropha* area in southwestern China by province.

Parameter	Estimated current area	Planned area
Guizhou	0.02 million mu (1,300 ha)	0.4 million mu (26,667 ha)
Sichuan	0.30 million mu (20,000 ha)	5 million mu (333,333 ha)
Yunnan	0.75 million mu (50,000 ha)	10 million mu (666,667 ha)
Total Southwest China	1.07 million mu (71,300 ha)	15.4 million mu (1.03 million ha)

Table 5. Estimates of potential benefits of *Jatropha* plantations in southwestern China.

Parameter	Planned *Jatropha* area (million mu)	Estimated reduction in national crude oil imports (%)	Estimated reduction in national GHG emissions from petroleum products combustion (CO_2)	Estimated increase in provincial forest cover (%)
Guizhou	0.4	0.0-0.0	0.0-1.4 million t	0.6
Sichuan	5	0.1-0.4	0.3-1.8 million t	2.2
Yunnan	10	0.1-0.8	0.6-3.6 million t	0.4
Total region	15.4	0.2-1.2	0.9-5.6 million t	1.2

Mongolia Autonomous Region will grow a total of 400,000 ha of demonstration forest. All plants will be oil-bearing shrubs and trees, many of who will contribute to fighting erosion and desertification. The trees include *Pistacia chinensis*, *Jatropha curcas*, *Metroxylon sagu*, *Manihot esculenta* Crantz. *Euphorbia tirucalli*, *Cornus wilsoniana* and *Xanthoceras sorbifolia*. All of these are perennial shrubs and trees that can be established relatively easily. The seeds will be used for oil, and the wood they yield might serve as a biomass feedstock for bio-electricity or second-generation fuel production after the useful life of the plant. The tree *C. wilsoniana*'s fruit is a source of oil (up to 30% oil content), the leaves are used for livestock feed, and the dense wood has a high energy value. *X. sorbifolia* (yellow horn) is a hardy, self fertile nut producing shrub native to northern China. Belonging to the Sapindaceae, its oil-rich nuts and pods resemble those of chesnuts. It will plant an impressive 870,000 ha of saplings of various kinds of biodiesel trees in its vast mountain areas, where few other commercial crops grow well.

CURRENT STATUS OF CHINESE FOREST BIOENERGY

Persistent high oil prices and rapidly growing dependence on imported oil prompt China to further invest in biofuels that yield environmental benefits besides fuel (Li et al., 2004; Lu, 2004). The State Forestry Administration of China had planted nearly 7,000 ha of oilseed bearing trees in the northern province of Hebei in 2008, part of a much larger national campaign to fuel the fast growing economy in a greener way. The 7000 ha demonstration project will grow Chinese pistachio trees. They kickstart Hebei's program aimed at planting a total of 870,000 ha of multi-purpose bioenergy trees in uninhabited mountainous areas over the coming decades.

Among the energy plants *J. curcas* and the genus *Jatropha* are very important. *J. curcas* is a drought-resistant perennial plant belonging to the Euphorbiaceae family while the genus *Jatropha* contains approximately 170 known species. The oil from *Jatropha* seeds, which are highly toxic, can be extracted for direct use in modified diesel engines, or refined into biodiesel for use in standard diesel engines.

Jatropha is in many ways, well suited to the complex landscape of southern and southwestern China; growing conditions are shown in Tables 4 and 5 (Horst et al., 2007). The plant grows on diverse soil types and in a variety of climatic conditions, has a relatively short gestation period, and requires comparatively low physical and human inputs.

From a policy perspective, the two primary advantages of *Jatropha* over many other oil-bearing plants are indeed that it can grow in a variety of landscapes, and thus does not necessarily compete with food production systems; and requires fewer inputs, and thus has a higher energy return on investment and lower CO_2 footprint than other oil-bearing crops, such as soybean or rapeseed (Chen, 2003).

Government strategy for expanding the area under *Jatropha* cultivation focused on planting plantation-scale forests on barren lands. ‘Barren’ land is specific, if slightly ambiguous designation used in Chinese agriculture and forest accounting that loosely indicates land that is not being used for more obvious productive purposes. Some barren land is owned by the government and would be managed by government agencies if put to use; a significant amount of barren land is owned by village collectives, with use rights granted to individual house-holds (Lang and Wang, 2004).

Raising biofuel forests in mountain areas will save farmland, make full use of the uninhabited mountains, and increase local people's family income if they are employed to take care of the trees. By 2050 harvests should yield as much as 5.5 million t of seeds for extraction and refining into biofuels. China, which has realized consecutive years of gross domestic product (GDP) growth of about 10% is promoting the development of biofuels with financial support which sees them as environmentally-friendly sources to ease the growing thirst for energy (Yunnan Forestry Department, 2006). The country has been raising oil-bearing trees on some 4 million ha of land in different regions so far with an expected fruit output of 4 million t. More could be planted on 57 million ha of what is now called 'underdeveloped wilderness'. On part of these lands, the central government plans to cultivate a total of 13 million ha of high-grade bioenergy forests by 2020. This will yield 6 million t of diesel that would be enough to fuel power plants with a combined capacity of 11 gigawatts (GW) each year, according to a forestation plan compiled by the State Forestry Administration (SFA). The country would increase biodiesel output for transport to 200,000 t by 2010 and 2 million t by 2020. Moreover, it has been investing heavily in afforestation campaigns in an effort to fight desertification. This program has met with considerable success and is now being rethought within the context of bioenergy. So far, several projects in northwestern China and in Inner Mongolia have shown that trees for energy can help in the fight against erosion and desertification, besides producing renewable, low carbon fuels, and jobs to local people.

With agriculture and forestry development, an increasing amount of straw, bush and quitch is now burnt in the open in many regions in China. The burnt portion can be as much as 80% of the straw, bush and quitch produced and causes serious environmental problems (Editorial Committee of China's Rural Energy Resources, 1997).

Instead of open burning, straw, bush and quitch can be used to generate electricity in an environmentally friendly manner. By 2010, China will have between 350 million t to 370 million t of unused straw. If this huge amount of straw is used for power generation, it would represent an additional 450 billion KwH of electricity. Biomass waste to energy is therefore a very sustainable and environmentally friendly potential energy source in China.

Conclusions

As earlier discussed, land degradation is a serious issue in China, likewise other Asian countries as well. China is increasingly suffering from salinization throughout its arid regions as new irrigation oases are being developed and affects more than a fifth of land in China, particularly in Ningxia and Hetao irrigated plains along the Yellow River (Zhang et al., 2010a, 2011). Waterlogging and salinization affect between 2 and 3 million ha in India and Pakistan respectively. The worst affected area is Central Asia with a total of nearly 60% of land affected in some form, followed by South Asia (nearly 50%) and Northeast Asia (nearly 30%). In Central Asia, the worst affected country is Turmenistan, where desertification affects two-thirds of its territory. In South Asia, Afghanistan is the most severely affected (over four-fifth of its land is affected), followed by India, Pakistan and Islamic Republic of Iran. In Northeast Asia, about 41% of the total land in Mongolia has been affected by desertification in some form. In Central Asia, a rise of the groundwater table around irrigated areas and canals has resulted in salinization and waterlogging of soil, spoiling vast area of grazing lands and cotton plantations by almost irreversible level (Ali et al., 2011; United Nations, 2000).

In order to combat the problem, improving environment in view of local conditions and developing optimum production type is significant. No doubt increasing vegetation coverage in these degraded lands and generating bioenergy is a feasible and practicable. Forest biomass is any plant or tree material produced by forest growth. Forest landowners and existing forest industry have the potential to grow this new bioenergy industry rapidly by providing the needed biomass fuel and infrastructure for new mills that will produce wood pellets, industrial heat, electricity, and transportation fuels. For biodiesel production there are different ways in Asian countries such as palm oil – large program in South east Asian countries; Jatropha – large program in India, China, etc; with tree species yielding oil seeds such as Pongamia, Shorea, Madhuka, etc in India. Besides of woody biomass, there are bio-ethanol production form sugarcane, sweet sorghum, maize, cassava, etc.

Developing plantations for production of biomass energy have numerous potential environmental benefits (Zhang et al., 2009, 2010b). When energy crops are included in the general mix of agricultural crops in a considered and informed way, environmental damage can be avoided; in fact, there could be significant environmental and ecological benefits achieved in tandem with the development of a fully sustainable energy resource.

China's biomass energy resources include mainly straw and other agricultural wastes, waste from forestry and forest product processing, animal manure, energy crops and plantations, organic effluents from industry, municipal wastewater, municipal solid waste, etc. Of about 600 million t of crop straw produced every year, nearly 300 million t (or around 150 million t of coal equivalent) can be used as fuel. Of about 900 million t of waste from forestry and forest product processing available every year, nearly 300 million t can be used for energy production. In addition, there are large areas of marginal lands in China that can be used to cultivate energy crops and plantations.

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