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### GOING BEYOND JATROPHA

CAN AN EXPANDED LAND AND FEEDSTOCK BASE HELP INDIA MEET  
ITS AMBITIOUS BIODIESEL TARGET?

## Going Beyond Jatropha

### Can an Expanded Land and Feedstock Base Help India Meet its Ambitious Biodiesel Target?

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**ABSTRACT**

*Increased use of biodiesel is an important part of India's strategy for climate change mitigation. After its earlier plans to begin mandatory blending of fossil diesel with biodiesel by the year 2005 failed to take off due to inadequate production of biodiesel caused by near complete reliance on one species, *Jatropha curcas*, India decided to broaden its feedstock and land choices in order to achieve 17% blending by year 2017. This research work uses information on land and oil seed species available in the databases of relevant Indian institutions for identifying marginal lands unsuited for agriculture in various agro-climatic zones. After accounting for other existing uses and impracticality of use, the marginal lands actually available is estimated at 11.2 million hectares and thirteen species of trees bearing oil seeds suitable for planting on these lands have been identified. In addition, 20% of seeds of Sal (*Shorea robusta*) occurring gregariously over 10 million hectares of natural forests across the country, and of Rubber (*Hevea brasiliensis*) over about 0.5 million hectares of large scale plantations in peninsular India, could be beneficially used for this purpose. But even after this resource base enlargement, the annual biodiesel yield in 2020 is estimated at only 8.83 million tons enabling about 8% blending by that year. Since China is also intending to develop an ambitious biodiesel blending plan a limited comparison with China has been drawn. Huge demands for biodiesel in these countries would necessitate large scale imports unless there is a major technological breakthrough in lignocellulosic liquid biofuels. Experiences of past indicates that import of biodiesel in such large quantities could create severe adverse ecological and socio-economic consequences for the producing country, particularly if it happens to be a developing country with inadequate governance. For ecologically sustainable imports of such large quantities of biodiesel India and China would need to coordinate with concerned international bodies like FAO to develop appropriate import strategies well in advance.*

**Keywords-** Blending, Non-Edible Oil Seeds, Feedstock, Agro-Climatic Zones, Wastelands

## 1. Introduction

Liquefied biofuels hold a high potential for climate change mitigation as transport sector, the single largest demander of energy in the world, offers an endless opportunity for blending fossil fuels with biofuels. The transport sector consumes one fifth of the world's delivered energy and accounts for the consumption of half of world's liquid fuel, a share which is projected to rise by 61% by 2035 and in the years leading upto 2035 the growth in transport energy use would account for nearly 87% of the total increase in world liquid fuel consumption (US-EIA, 2010).

A large part of this increase in the demand for transportation fuels is coming from the emerging developing economies. The non OECD transportation energy use grew by 4.5 % in 2007, 7.3% in 2008 and even in the steep recession of 2009 it grew by 3.2%. However, economic recession combined with high oil prices, saw, a decrease in the transport energy use in developed countries by an estimated 1.3% in 2008 and 2% in 2009 (US-EIA, 2010) and as the recession recedes the transport energy use is registering rise relative to the year 2009. Expectedly, the transport sector is one of the largest contributors to the greenhouse gas emissions. In 2010 the transport sector accounted for 19% of the total greenhouse gas emissions which was second only to the energy sector. The estimate emission from this sector is projected to reach 20 Gt in 2050 from 7 Gt in the year 2005 (IEA, 2008).

If a part of the energy used in this sector could come from the renewable liquid biofuels it would offer an enormous opportunity for reducing GHG emissions. In recent years the biofuels have shown steady growth, but still only represent 3% of global road transport fuel consumption in 2010 (IEA,2011). Blending with biofuels has been in practice in Brazil for atleast last 40 years where mixing sugar based alcohol with petrol is the preferred option. Europe and North America have also had widespread blending programs using corn based ethanols, palm oil and waste cooking oil. However, these liquid biofuels compete with the food resources and are inadvisable for use in developing countries where food is almost always a scarce resource.

### 1.1 Mandatory blending of diesel with biodiesel

It is for this reason that India, and many other developing countries, have sought to explore tree based oil seeds that are neither edible nor do they compete with the food crops for land. These non-edible vegetable oils, however, contain large amounts of free fatty acids that react quickly with the alkaline catalysts during alkaline-esterification and produce soaps inhibiting the separation of ester from glycerin. This necessitates a first step of reducing the amount of

free fatty acids in the oil through acid catalyzed esterification following which alkaline catalyzed transesterification process converts the products of the first step to mono-esters and glycerol (Ramadhas et al, 2005) which enhances cost and reduces efficiency.

In 2003 the Government of India had set up a National Mission on biodiesel with plans to produce enough biodiesel using *Jatropha curcas* in order to achieve progressively increasing blending of diesel reaching upto 30% by 2020. By the end of the first phase of establishing country wide demonstration projects in 2007 the program was expected to become self-sustaining and ready for the next phase of commercialization of operations. The biodiesel blending was proposed to be made mandatory over larger geographical area of the country commensurate with the availability of biodiesel but it could not be given effect to for want of adequate production.

### **1.2 New National Biofuels Policy 2008**

Following this setback the Government of India announced a new National Policy on Biofuels in September 2008 revising its bio-fuel production targets while reemphasizing that it will remain confined to non-food feedstock to be raised on lands not suited for agriculture underlining its distinctiveness from current international approaches which could lead to conflicts with food security. The policy sets out an indicative target of 20% blending of biodiesels by 2017. The central feature of this policy is broadbasing of feedstock base to about 400 tree species that produce oil bearing seeds in India in order to exploit the full potential of the entire range of feedstocks available in this ecologically extremely diverse country and raising feedstock plantations not only on community and Government degraded forests and waste lands but also on private lands through the system of contract farming backed by a minimum support price mechanism and relief from tax burden. In addition the policy proposes a sound research and development back up and a top level steering committee at political level to ensure adequate budgetary support and forceful monitoring for speedy implementation.

### **1.3 Most suitable feedstock**

The significance of feedstock for biofuel production is extremely important for embarking any plans to use them on commercial scale. Equally important is the silviculture of the target species which not only determine its large scale cultivation but also underlines the factors responsible for its growth, development and successful dispersal beyond its bio-geographic zone. In the recent years there has been an intense search for tree species which can provide oil seeds without threatening the food security.



Primarily two types of oils are found in vegetation. One is the viscous liquid found usually in seeds which can be extracted just by crushing the seeds. The other is essential oil that vaporises quickly and is found in leaves and wood. The former, usually long chain alkyl esters have high calorific value, high cetane ratings and high viscosity, and make good biodiesels.

Of the species that contain vegetable oils the species that would fit in the National Biofuel Policy are only a few. The central requirement of the policy is that the oil must be non-edible and it should be possible to grow the species on lands that are unsuited to agriculture like wastelands. The edibility is linked to the toxicity contained in the seeds and thus we must limit our search to the species with high toxicity. Within this group of species then we choose species that have higher oil content and are gregarious by nature. The latter is important because only gregarious species would be able to yield high quantity of seeds when raised in dense plantations.

Being one of the mega-biodiversity hotspots, India is an extremely rich repository of floral bio-diversity and possesses a wide matrix of plant species having significant potential to yield bio-fuel. The data base of the Botanical Survey of India lists tree species which have significant oil content. The National Oilseeds and Vegetable Oil Development Board (NOVOD) have also conducted extensive research on species suited for biodiesel production across the country. From these databases the following fifteen species have been selected based on their land suitability requirements, non-edibility, vulnerability to browsing, suitability for a low intensity management system, seed yield, oil content and calorific value. Below some of these critical silvicultural aspects of these species have been discussed.

## **2. Major Tree Borne Oilseeds (TBOS) Suitable for Marginal Lands**

Under this section thirteen major tree borne oil seed species that are considered suitable for planting on marginal lands have been described briefly.

### **2.1 *Aleurites fordii* (Tung)**

Commonly known as Tung, the seeds of this member of family Euphorbiaceae are the source of Tung oil which is used in varnish, paint etc. It is native to China, Burma and northern Vietnam and in India the potential sites are the northeastern states specially Assam, Manipur and Mizoram and in Himachal Pradesh and Uttarakhand in northern India. It is not browsed by cattle as its leaves contain the toxin saponin. It grows well in subtropical climate with an annual rainfall of 640-1730 mm. The soil should be sandy or loamy, well drained and lime

free. Though it starts fruiting after 3 years, commercial production begins after 5-6 years and maximum production is reached in 10-12 years. Seed oil content is 49-65% and annual seed yield in the 10<sup>th</sup> year reaches about 1900kg/ha (NOVOD, 2008). Two or more harvesting should be done if maximum yield is desired as the fruits ripen at different times.

## **2.2 *Azadirachta indica* (Neem)**

Commonly known as Neem in India, this multipurpose tree belongs to the Meliaceae family. Neem grows in a wide range of ecosystems varying from tropical to near arid, and from sea level to 700 m elevation. It requires an annual rainfall of 300-1200 mm. It grows well on black cotton soil and on well drained deep and sandy soils. It starts fruiting in 3-5 years and reaches full bearing capacity at 10-12 years yielding about 2800kg/ha of seed (NOVOD, 2008) though it would depend upon the ecological conditions and seed genotype. Seed oil content lies between 30-40%. It is not browsed by cattle as its leaves contain the toxin saponin. (Daniel et al, 2007)

## **2.3 *Calophyllum inophyllum***

*Calophyllum inophyllum*, belonging to Clusiaceae family is a medium sized tropical evergreen tree native to East Africa, India, Southeast Asia, Australia, and the South Pacific. It grows well in regions with temperatures ranging from 18 to 33° C, annual rainfall from 1000 to 5000 mm, on sandy well drained soil. It is a hardy tree and can tolerate wind, salt spray, drought and short periods of waterlogged soils and has been widely planted throughout the tropics. Mature *Calophyllum* trees yield 100 kg nuts in a year yielding about 5 kg of oil (Friday et al, 2006) with an average of 300 surviving trees expected per hectare after a decade.

## **2.4 *Citrullus colocynthis***

*Citrullus colocynthis* is a small xerophytic plant of semi arid to arid regions of North Africa, Mediterranean Europe and northern parts of South Asia belonging to the family Cucurbitaceae. It thrives well in regions with annual precipitation of 380 to 430 mm, annual temperatures of 14.8 to 27.8°C and mildly acidic soils of pH 5.0 to 7.8. The fruits are edible and the seed oil content is 16.7% (BSI, 2004). Seed yields of 6,700 kg/ha (Duke 1983) is reported. It has many medical uses and can also serve as a fodder species.

### **2.5 *Diploknema butyracea* (Cheura)**

This species, belonging to family Sapotaceae, is native to the lower subtropical to sub-temperate Himalayan region of high rainfall ranging from 1000 - 2000 mm and is commonly called Cheura or the Indian Butter tree in India. Fruiting occurs after 7-8 years of planting. It is a multi purpose tree having a great economic value in respect of fodder, fuel wood, timber and other product and is also of considerable medicinal value. For this reason it is also called Kalpvriksha, which is Sanskrit for a tree of enormous multifarious utility. The average annual fruit yield is 100-250 kg per tree, seed constitutes 20% of the weight of the fruits and the seed oil content is 42-47% (NOVODB, 2008). An average of 300 surviving trees/ha can be expected in a Cheura plantation after a decade. (NOVODB, 2008)

### **2.6 *Garcinia indica* (Kokum)**

This tree, commonly called Kokum in southern parts of India, belongs to the family Clusiaceae and is indigenous to the evergreen forests of Western Ghats in southern and western India with annual rainfall ranging from 2500 to 4000 mm. It grows well on sandy, clayey, loamy and lateritic soils. Seedling origin tree starts bearing fruit after 7-8 years and grafted tree after 5 years. Seed oil content is 45.5% and the average annual seed yield is about 100 kg per ha (NOVODB, 2008) depending upon the availability of nutrition and moisture and the tree genotype. (NOVODB, 2008)

### **2.7 *Jatropha curcas***

Commonly called Jatropha, it belongs to Euphorbiaceae family and, though native of South America, it has long been propagated by the Portuguese in their former colonies in Africa and Asia. It is a fast growing small tree capable to producing good quantities of seeds over tropical to semitropical regions under semi arid to medium rainfall conditions. It is unpalatable to cattle on account of toxicity and is thus a good hedge plant. It starts yielding early and reaches nearly full productivity in about five years in well managed irrigated plantations. The seeds have high oil content ranging from 30 to 40% (NOVOD, 2008) and the amount of seeds produced ranges from about 2 tons/hectare/year to over 12.5tons/hectare/year (FAO, 2010). The seed yield depends on the water availability in the plantation area. Considerable difference is noticed in seed yield between irrigated and non-irrigated *Jatropha* plantations.

### **2.8 *Madhuca indica* (Mahua)**

Commonly known as Mahua, it belongs to the Sapotaceae family and grows over a wide range of ecosystems ranging from semi arid to evergreen with rainfall varying from 550-1500 mm annually on average. Ideal soil type is deep loam or sandy loam with good drainage but it has a wide range of tolerance. The Mahua biodiesel has a viscosity of 5.1 centistokes at 40<sup>0</sup>C with a cetane number of 53 and a calorific value of 44003kJ/kg. The tree yields between 20 to 200 kg of seeds per year with oil content in the range of 20-50%. An average yield of 800kg/ha can be expected in a Mahua plantation after a decade (NOVOD, 2008).

### **2.9 *Pongamia pinnata***

It belongs to the family Leguminaceae and grows over a range of ecosystems from semi-arid to sub-humid. It thrives well on medium to high (500-2500 mm) rainfall and is tolerant to water logging, saline and alkaline soils and is suitable for planting in pastures and for afforestation in watershed areas. Gestation period is longer than many other oil seeds species and the trees begin yielding after 5 to 7 years. The seed yield increases with increase in canopy size. Its flowers are a good source of pollen for honey bees and are used for apiculture in India. It also has medicinal properties. Mature trees yield 8 to 24 kg seeds/tree/yr and its oil content is 20-25%. *Pongamia* biodiesel has a viscosity of 5.81 centistokes at 40<sup>0</sup>C with a cetane number of 35.6 and calorific value of 19246 kJ/kg. An average yield of 6400kg/ha can be expected in a *Pongamia* plantation after a decade (NOVOD, 2008).

### **2.10 *Prunus armeniaca* (Wild Apricot)**

Formerly called *Armeniaca vulgaris*, it belongs to the family Rosaceae and is found in the dry temperate regions of North West Himalayas with average annual rainfall of 1000 mm. Ideal soil type is deep, well drained soil with a pH range of 6.0-6.8. It starts fruiting after 4-5 years, reaches maximum yield at 10-15 years and continues seeding till 50-60 years. The oil extracted from it resembles almond oil. The seed yield of a 10-15 year old tree is about 4 kg in a year and the seed oil content is very high at about 50%. An average of 400 surviving trees/ha can be expected in a *Prunus* plantation after a decade. (NOVOD, 2008)

### **2.11 *Schleichera oleosa* (Kusum)**

*Schleichera oleosa*, locally known as Kusum over many parts of South Asia, and belonging to family Sapindaceae, occurs in mixed deciduous forests of the South and South East Asia. An annual rainfall range of 750-2500 mm, maximum and minimum temperature ranges of 35-

47.5°C and -2.5°C respectively are suitable for growth. The fruits, seeds and young leaves of this plant are edible and used for medicinal and dye purposes. In India, this species acts as a host for the lac insect (*Laccifer lacca*). A mature tree yields 21-28 kg seed per year and the seed oil content ranges between 59-72% (ICRAF, 2010). A major drawback is that the growth of this tree is too slow for it to be cultivated for biofuel use. An average of 300 surviving trees/ha can be expected in a Kusum plantation after a decade.

### **2.12 *Simarouba glauca***

Native to central and northern America, it is a tropical evergreen tree belonging to family Simaroubaceae. It grows in area of rainfall ranging from 700 -1000 mm. It requires loamy soils, red loams and red laterites of 1m depth. The trees start fruiting 6-7 years but grafting can shorten the wait to 3 years. Average seed yield is 1 ton/hectare/year in the tenth year of plantation and the seed contains 60-70% oil. (NOVOD, 2008)

### **2.13 *Simmondsia chinensis* (Jojoba)**

The only species of order Caryophyllales of the family Simmondsiaceae is native to the deserts of North America and performs well in arid to semi arid conditions with rainfall of 450-650mm and soils that range from gravelly and rocky to well drained soil with silt and clay with a pH of 5-8. A 10 year old tree yields on an average 1 kg of seeds /year. The seed oil content is approximately 50% (NOVOD, 2008). Seeding begins from 4<sup>th</sup> year and can continue till 150 years. An average of 400 surviving trees/ha can be expected in a Jojoba plantation after a decade.

## **3. Oil Seeds from Natural Forests and Existing Plantations**

The new National Biofuel Policy of 2008 seeks to explore the full potential for biofuels in India not only from wastelands but also from natural forest and other private forest lands. The species of Sal and Rubber offering large existing resources that can be tapped have been described below.

### **3.1 *Shorea robusta* (Sal)**

Commonly called Sal it is a gregarious species belonging to the Family Dipterocarpaceae spread across vast stretches of forests in India, Bangladesh and Nepal and occurs in both dry and moist deciduous forests and in moist evergreen forests. A minimum temperature of 1-7°C and maximum of 34-47 °C with mean of 22-27°C and a mean annual rainfall of 1000-3000 is

generally observed to be suitable for its growth. Ideal soil is moist sandy loam with good subsoil drainage since it cannot tolerate waterlogging. Availability of soil moisture is an important factor determining the occurrence of *Shorea robusta*.

In India this species covers about 10 million ha of the forest area of the country (Gautam and Devoe, 2006) and the estimated total number of Sal trees in the country is about 968 million (FSI, 2009). The seed yield is up to 500 kg per ha (Gautam and Devoe, 2006).

The seeds contain 14.8% oil which is also edible and is used extensively in chocolate making and by tribes in central India as cooking medium. However, seeding period is immediately followed by monsoons and the primitive primary processing for de-winged of seeds, drying and packaging and the prevailing lack of good storage places enhances the free fatty oil contents of the seeds making them unfit for human consumption. Thus only a tiny fraction of the Sal seeds are actually used as food and a far higher proportion is used for non-food purposes. Hence, it should be possible to treat Sal seeds as largely non-edible and thus available for making biodiesel under the Government of India Biodiesel Policy after ensuring that the measures taken do not in any way effect the Sal seed collection for food by the local people and the tribes. Also the incomes generated by them from Sal seed collection and processing should be significantly enhanced from their current levels.

It is with this view that the authors propose that a small part of the Sal seeds from across the 10 million ha of Sal forests in India may be utilized for making biodiesel subject to the following caveats:

- (i) 30% of the seeds should be kept reserved for ecological purposes of regeneration, herbivory and transfer of nutrients to soil after decay.
- (ii) Atleast 25% of the seeds should be reserved for local consumption by tribal and other local people and, where necessary, any further amount for this purpose should be made available.
- (iii) 25% of the seeds should be reserved for chocolate and other high value foods so as to enhance the economic returns to the tribal people.

After these needs are met the balance 20% or less seeds or effectively from about 2 million hectares of existing Sal forests may be utilized for biodiesel. Such an apportionment would be difficult to manage, given the past history of forest management in India. But the demands of climate change mitigation and adaptation would in any case require increasingly greater

sophistication in managing the crucial natural resource of forests and this apportionment would thus be in line with the future requisite changes in forest management strategies in India.

### **3.2 *Hevea brasiliensis* (Rubber)**

It is a fast growing tree commonly known as the Para rubber tree after the Brazilian port of Para and is one of the many members of family Euphorbiaceae the seeds of which yield good amount of oil. It is the major source of natural rubber and is native to the Amazon forests and is now widely cultivated in tropics across the world. In wild it forms part of the middle storey of the tropical rain forests and is tolerant of periodical flooding. It can be grown in humid lowland tropical conditions with mean annual temperature in the range of 23-35°C and mean annual rainfall between 1500 to 4000 mm. It does better in acidic soils. The ideal conditions are deep, well-drained loamy soils covered by natural undergrowth or a leguminous cover crop and protected from erosion. (Rubber Board, 2010)

The annual rubber seed production potential in India is about 150 kg per hectare and seed contain between 40 to 50% of oil (Ramadhas et al, 2005). Unlike many other oil bearing tree species rubber requires high maintenance and produces less quantity of seeds and would not be economical to raise rubber plantations for its seeds alone. The total area under rubber plantations in India is about 687000 ha, and assuming that seeds from a quarter of these plantations would be either used for other purposes like planting or not available for reasons of access or economics of scale, the authors propose that these existing rubber plantations over 0.5 million ha can yield significant quantities of biodiesel along with rubber under appropriate management and no planting on the identified marginal lands is proposed.

### **4. Different Agro-Climatic Zones of India and the species recommendation for each zone for raising biodiesel plantation**

In order to locate suitable lands for the above mentioned biodiesel species agro-climatic zonation of India by the Planning Commission of India (PCI, 2006) was used. Within each of these agro-climatic zones the availability of wastelands has been assessed using the wasteland database of the Land Resources Department of the Ministry of Rural Development (MoRD, 2000) of the Government of India which has been summarised in Table 1. Species recommendations have been made based on the agro-climatic suitability of the oil seed species and incorporated in the description of agroclimatic region below.

#### 4.1 Land Availability and Species Suitability in the Agro-climatic Regions of India

Using agroclimatic classification of the Planning Commission of India and wasteland data of the Ministry of Rural Development of the Government of India, the following analysis is presented for the fifteen agroclimatic regions of the country.

##### 4.1.1 Western Himalayan Region

This region spreads over the states of Himachal Pradesh and Jammu & Kashmir and Uttarakhand. There are four distinct sub regions within this region, namely, the subtropical low hills upto 800 m elevation, sub-humid mid hills upto 1800 m, the temperate high hills upto 2200 m and dry temperate very high hills with elevations in excess of 2200 m. The species suitable for planting here is *Prunus armeniaca* in the mid and high hills sub region and *Diploknema butyracea* and *Jatropha curcas* in the subtropical low hills.

The total available wastelands in this region is 11318300 ha out of which 15800 ha are gullied and ravenous land, 679100 ha are upland with or without scrub, 32900 ha are waterlogged and marshy lands, 816900 ha are under utilised or degraded notified forest land, 466200 ha are degraded pastures or grazing lands, 310800 ha are degraded land under plantation crop, 97400 ha are inland sand, 8700 ha are mining or industrial wasteland, 3708700 ha are barren or rocky land, 418100 ha are steep sloping area and 4763000 ha are snow covered or glacial area.

The land actually available for planting with biodiesel species would however be very limited. No lands are available for tree planting under the snow covered lands, barren and rocky lands, inland sands along the water bodies, and waterlogged and marshy lands. Degraded pastures and grazing lands in this region are also under huge pressure not only from the local villagers but also from migrant Gujjar tribe and only about 10% of these lands which are no longer in use because of severe degradation would be available which can be used for planting *Prunus* in higher reaches and *Jatropha* and *Diploknema* in lower hills. Only about 10% of lands reclaimed from the category gullied and ravenous lands would be available as these are essentially covered by huge quantities of debris and stones brought down by monsoonal streams which can be planted up by *Prunus armeniaca* in mid elevations and by *Jatropha curcas* in lower elevations. Large extents of lands under the category of degraded forests and uplands with or without scrub are suitable for biodiesel but the need for restoring these lands to their original ecological status would preclude diversion to biodiesel production except over about 10% which could be similarly planted with *Prunus*, *Diploknema* and *Jatropha*.



The categories of degraded lands under plantation, mining and industrial waste lands and lands on steep slopes offer opportunities for more lands for biodiesel and we assume about one third of these lands being available for planting *Prunus* in higher reaches and *Diploknema* and *Jatropha* on lower elevations.

The total land available under this region for planting biodiesel tree species is thus estimated to be about 443000 ha.

#### 4.1.2 Eastern Himalayan Region

This region covers all the seven states in the North East as well as the hilly regions in 3 districts of West Bengal and receives high rainfall of about 2500 mm and more. A total of about 7867100 ha of waste land is estimated to be available in this region out of which 1134300 ha are upland with or without scrub, 204100 ha waterlogged or marshy land, 3496700 ha under shifting cultivation, 1235700 ha are underutilised or degraded notified forest land, 435900 ha degraded pastures or grazing lands, 408700 ha inland sands, 132800 ha barren rocky lands and 815700 ha are snow covered or glacial lands.

No lands are available for tree planting under the snow covered lands, barren and rocky lands, inland sands along the water bodies, and waterlogged and marshy lands. Large extents of lands under the category of degraded forests are suitable for biodiesel, degraded pastures and uplands with or without scrub but the need for restoring these lands to their original ecological status or original use would preclude diversion to biodiesel production except over about 10% which could be similarly planted with *Prunus armeniaca*, *Diploknema butyracea*, *Aleurites fordii*, *Garcinia indica* and *Jatropha curcas*. The categories of lands under shifting cultivation offers the highest opportunities for biodiesel production in the region because increasingly shifting cultivation does not attract the younger tribal population in view of the low economic returns and very high level of physical human labour required for this form of cultivation compared to several other economic activities available to these younger people now. We assume about one third of these lands would be available for planting *Prunus* in higher reaches and *Diploknema*, *Aleurites*, *Garcinia* and *Jatropha* on lower elevations. The seeds from the existing natural rubber (*Hevea brasiliensis*) plantations raised on lands earlier under shifting cultivation are also a good source of biodiesel feedstock in the region.

The total land available under this region for planting biodiesel tree species is thus estimated to be about 1446000 ha.

#### 4.1.3 Lower Gangetic Plain

This region extends over 14 districts in the state of West Bengal and is characterised by highly fertile soil with a rainfall ranging between 1200 to 1700 mm. Species suitable for this region are *Calophyllum inophyllum*, *Jatropha curcas*, *Pongamia pinnata*, *Azadirachta indica*, *Madhuca indica*, *Shorea robusta* etc.

It is estimated that a total waste land area of 529400 ha is available in this zone out of which 116000 ha is upland with or without scrubs, 17100 ha is gullied or ravenous land, 188800 ha is waterlogged or marshy lands, 63500 ha is under utilized/ degraded notified forest, 37900 ha is degraded pastures, 79300 ha is inland or coastal sand and 13000 ha is barren rocky area.

No lands are available for tree planting under the category of barren and rocky lands and inland or coastal sands. More extent of lands under the category of degraded forests, waterlogged and marshy lands, gullied and ravenous lands, degraded pastures and uplands with or without scrub are suitable for biodiesel species but these are also generally ecologically fragile lands and have other existing uses by the poorer section of the people. This would limit the actual availability of to just about a quarter. In forest lands and on degraded pastures the preferred species would be *Shorea robusta* as it is also a species of the forests of the region and reforestation with this species would be an important step towards ecological restoration.

The coastal lands could be planted up with *Calophyllum inophyllum* and the other areas can be planted using *Jatropha curcas*, *Pongamia pinnata*, and *Azadirachta indica*. *Shorea robusta* and *Madhuca indica* may be used in degraded forests and degraded pastures.

The total land available under this region for planting biodiesel tree species is thus estimated to be about 105000ha.

#### 4.1.4 Middle Gangetic Plain

This region is spread over the whole of Bihar and 21 eastern districts of Uttar Pradesh. The alluvial plain zones of Bihar in this region has a dry to moist sub humid climate with a rainfall ranging between 1225 to 1275 mm whereas the plains in Uttar Pradesh receives an average precipitation between the range of 1025 to 1210 mm. The total available waste land in this zone is approximately 1119400 ha out of which 35400 ha is gullied or ravenous land, 224600

ha is upland with or without scrub, 289300 ha is waterlogged or marshy land, 190800 ha is saline or alkaline soils, 309700 ha is under utilised notified forest land, 6500 ha is degraded pasture, 39200 ha is inland sand, 17300 ha is barren rocky area and 3100 ha steep sloping land. The species suitable for raising biodiesel plantation in this zone are *Simarouba glauca*, *Simmondsia chinensis*, *Jatropha curcas*, *Pongamia pinnata*, *Azadirachta indica*, *Shorea robusta*, *Madhuca indica*.

No lands are available for tree planting under the categories of barren and rocky lands and inland sands. The categories of degraded forests, waterlogged and marshy lands, gullied and ravenous lands, degraded pastures and uplands with or without scrub can be used keeping in consideration the need for restoring these lands to their original ecological status. In forest lands and on degraded pastures the preferred species would be *Shorea robusta*, *Azadirachta indica* and *Madhuca indica* as these are species of the forests of the region and reforestation with these species would be an important step towards ecological restoration. On pastures the tree density would have to be kept low. In other places *Jatropha curcas* and *Pongamia pinnata* could be planted up. Overall about 25% of the lands under these categories could be taken up for biodiesel species if adequate care is taken that degraded forests are ecologically restored and degraded pastures continue to provide cattle feed with the choice of suitable species.

Saline parts of the land category saline and alkaline lands can be used for plantation of *Pongamia pinnata*, *Simarouba glauca*, *Simmondsia chinensis* and *Azadirachta indica* if the soil is properly treated first with gypsum and zinc sulphate. This requires higher investments but as much as three fourth of these lands are potentially available for biodiesel plantations.

The total land available under this region for planting biodiesel tree species is thus estimated to be about 298000 ha.

#### **4.1.5 Upper Gangetic Plains**

This zone is spread over 45 districts in the western and central parts of Uttar Pradesh. The climate is semi arid to sub humid with less than 1000 mm rainfall and soils are generally lightly calcareous alluvial sandy soils. Total available wasteland in this zone is 2048900 ha, 553300 ha out of which is waterlogged, 195000 ha are gullied or ravenous lands, 358300 ha is upland with or without scrub, 400000 ha is saline or alkaline land, 400000 ha is underutilised degraded forests, 28700 ha degraded pastures, 2500 ha degraded land under plantation crops, 31300 ha inland sand, 38900 ha barren or rocky area and 39700 ha steep sloping area. The species that would be suitable for this region are *Jatropha curcas*, *Azadirachta indica*,

*Pongamia pinnata*, *Shorea robusta*, *Madhuca indica*, *Simmondsia chinensis* and *Simarouba glauca*.

No lands are available for tree planting under the categories of barren and rocky lands and inland sands. The categories of waterlogged and marshy lands, gullied and ravenous lands, uplands with or without scrub are expected to provide about 25% of the available lands under these categories. In degraded forest lands and on degraded pastures the preferred species would be *Shorea robusta*, *Azadirachta indica* and *Madhuca indica* as these are native species that would be ecologically appropriate and would also permit grass growth below if planting density is kept low. In other places *Jatropha curcas* and *Pongamia pinnata*, *Simmondsia chinensis* and *Simarouba glauca* could be planted up. Overall about 25% of the lands under these categories could be taken up for biodiesel plantation taking care that the degraded forest are ecologically restored and forest used for grazing either continue to provide cattle feed or the communities using them no longer need access.

An important category of land in this region is the saline and alkaline lands which can be used for plantation of *Pongamia pinnata*, *Simarouba glauca*, *Simmondsia chinensis* and *Azadirachta indica* but requires higher levels of investments. Since most of these lands are privately owned finding a suitable mechanism for public investment in these lands to address the problem of salinity would be key concern. If this can be addressed then almost three fourth of the 400000 ha of these saline lands would be available for biodiesel plantations.

The total land available under this region for planting biodiesel tree species is thus estimated to be about 694000 ha

#### **4.1.6 Trans Gangetic Plain**

This zone is spread over the states of Haryana, Punjab and Ganganagar district of Rajasthan as well as the union territories of Delhi and Chandigarh. The climate is arid to semi arid with a pronounced winter season and an average annual rainfall ranging between 200 to 700 mm. A total area of 822100 ha is available as wasteland in this zone out of which 23000 ha is gullied or ravenous land, 224800 ha is upland with or without scrub, 82600 ha is waterlogged, 48800 ha is saline land, 111200 ha is under utilised notified forests, 94600 ha is degraded pastures, 21500 ha is degraded land under plantation crops, 192700 ha is inland sand, 4300 ha is mined area and 18400 ha is barren or rocky area. The major biodiesel tree species suitable for this zone are *Azadirachta indica*, *Pongamia pinnata*, *Jatropha Curcas*, *Simmondsia chinensis*, *Simarouba glauca* etc.

The lands under various categories of wastelands actually available for planting with biodiesel species would be similar to that described above for Upper Gangetic Plains except that the productivity would be significantly lower. The total land available under this region for planting biodiesel tree species is thus estimated to be about 156000 ha.

#### 4.1.7 Eastern-Plateau and Hills

This zone, the largest agro-climatic zone in the country, covers the whole states of Chhattisgarh and Jharkhand, fifteen contiguous districts of Orissa, four of Maharashtra, two districts of Madhya Pradesh and one district of West Bengal. Rainfall averages at 1350 mm annually and agricultural productivity is quite low. The total available wasteland in this region is 4587300 ha out of which 97300 ha is gullied land, 1881800 ha is upland with or without scrub, 3500 ha is waterlogged, 47600 ha under shifting cultivation, 2180400 ha underutilised notified forests, 25400 ha degraded pastures, 35700 ha degraded lands under plantation, 5900 ha inland or coastal sands, 31600 ha mining and industrial waste lands, 248600 ha barren or rocky area and 28800 ha of steep slope lands. The suitable species recommended for this area for biodiesel production are *Jatropha curcas*, *Pongamia pinnata*, *Simarouba glauca*, *Shorea robusta*, *Madhuca indica*, *Schleichera oleosa*, and *Azadirachta indica*.

With adequate financial and technical support to the tribals practising shifting cultivation and with assured food supply from the Public Distribution Systems as much as half of the lands under this form of cultivation can be utilised for biodiesel plantation. The categories of waterlogged and marshy lands, gullied and ravenous lands, uplands with or without scrub are expected to provide about 10% of the available lands under these categories. In degraded forest lands and on degraded pastures the preferred species would be *Shorea robusta*, *Schleichera oleosa*, *Azadirachta indica* and *Madhuca indica* as these are species of the forests of the region and reforestation with these species would be an important step towards ecological restoration. On pastures the tree density would have to be kept low to ensure that pastures must remain an important objective of the land management. In other places *Jatropha curcas* and *Pongamia pinnata*, *Simmondsia chinensis* and *Simarouba glauca* could be planted up. Overall about 25% of the lands under these categories could be taken up for biodiesel plantation if adequate care is taken that degraded forests are ecologically restored and degraded pastures continue to provide cattle feed.

The total land available under this region for planting biodiesel tree species is thus estimated to be about 770000 ha.

#### 4.1.8 Central-Plateau and Hills

This zone is spread over 26 districts in the state of Madhya Pradesh, 21 districts of Rajasthan and 7 districts of Uttar Pradesh and is characterised by interspersed hills and plateau with excessive water run off. The plains of Rajasthan have a semiarid climate with a relatively low rainfall of 550 mm whereas the Vindhya and Satpura plateaus receive an adequate rainfall of 1130 and 1120 mm respectively with the Central Narmada Valley receiving an annual precipitation of 1300 mm. Out of the total area of 7923000 ha of wastelands in the region about 827400 ha is gullied, 3442800 ha upland with or without scrub, 9100 ha waterlogged, 148800 ha saline, 1400 ha under shifting cultivation, 2335200 ha underutilised degraded forests, 525700 ha degraded pastures, 42000 ha degraded land under plantations, 82800 ha inland sands, 38400 ha mining or industrial wastelands, 445300 ha barren or rocky lands and 24300 ha steep sloping lands.

This is a region with relatively lower population and cattle density and large parts of these lands can be utilised for raising oil seed species. Of the total wasteland, about 1/3<sup>rd</sup> each from gullied or ravenous land and upland with or without scrub would be available for planting and 25% of the total area from the lands affected by salinity, degraded forests and pastures would also be available for planting with species such as *Jatropha curcas*, *Pongamia pinnata*, *Simarouba glauca*, *Madhuca indica*, *Azadirachta indica*. Additionally, 10% of the total lands under inland sands, industrial wastelands and degraded land under plantations could be used for biodiesel plantation in this region.

The total area of wasteland available for biodiesel plantation in this zone is thus estimated to be 2190000ha.

#### 4.1.9 Western-Plateau and Hills

This zone covers 15 districts in the state of Madhya Pradesh and 22 districts of Maharashtra. The zone is considered to be low in agricultural productivity with a rainfall ranging between 600 and 1000 mm. The total available waste land in this zone is 5219300 ha out of which 586300 ha is gullied land, 2903400 ha upland with or without scrub, 8100 ha waterlogged and marshy, 17100 ha saline, 1369100 ha underutilised degraded forests, 24600 ha degraded pastures, 16800 ha degraded land under plantation crops, 2000 ha is inland sands, 4300 ha is mined area, 190300 ha is barren and rocky land and 97200 ha is steep sloping lands.

The land actually available for planting with biodiesel species is only a small part of these wastelands. No lands are available for tree planting under the inland sands, barren and rocky

lands, waterlogged and marshy lands and steep sloping lands. Larger portion of the lands under the category of gullied land, upland with or without scrub, utilised degraded forests and degraded pasture lands are suitable for biodiesel planting but there is a great requirement for reclamation of these lands to their previous ecological status or original use would prevent diversion to biodiesel production except over about 25% which could be planted with *Jatropha curcas*, *Pongamia pinnata*, *Simarouba glauca*, *Madhuca indica*, *Azadirachta indica* etc.

One third of the saline lands are potentially available for biodiesel plantations that can be planted with *Pongamia pinnata* and *Simarouba glauca*. The total area of wasteland available for biodiesel plantation in this zone is thus estimated to be 1220000ha.

#### 4.1.10 Southern-Plateau and Hills

The zone comprises of three south Indian states of Andhra Pradesh (14 districts), Karnataka (21 districts) and Tamil Nadu (13 districts). The climate is semi arid suitable for dry land farming with a rainfall ranging between 700 mm to less than 1000 mm. The total available waste land in this zone is 6747800 ha out of which 49800 ha is gullied or ravenous land, 2392000 ha is upland with or without scrub, 144700 ha is saline land, 3202600 ha is under utilised degraded notified forests, 30400 ha is degraded pasture, 25600 ha is degraded land under plantation crops, 13900 ha is inland sand, 21100 ha is mining or industrial wastelands, 800400 ha is barren rocky land and 66500 ha is steep sloppy lands. These lands can be used for raising biodiesel plantation with species such as *Jatropha curcas*, *Calophyllum inophyllum*, *Simmondsia chinensis*, *Pongamia pinnata*, *Schleichera oleosa*, *Azadirachta indica* and *Simarouba glauca*.

Out of the total area of wastelands, around 25% of the gullied and ravine lands, saline lands and upland with or without scrub, 10% of the degraded forests, degraded pasture, degraded land under plantation crops, inland sands, mined area and steep sloppy lands would be available for planting biodiesel plants. In degraded forest lands and on degraded pastures the preferred species would be *Pongamia pinnata*, *Schleichera oleosa* and *Azadirachta indica* as these species are native to the region and would help ecological restoration along with providing biofuels. On pastures the tree density would have to be kept low to ensure that pasture must remain an important objective of the land management.

The total available area of wasteland under this agro climatic zone would account to about 980000 ha.

#### 4.1.11 East-Coast Plains and Hills

This zone is spread over Andhra Pradesh (9 districts), Orissa (15 districts), Pondicherry and Tamil Nadu (15 districts). The zone is characterised by moist sub humid climate and coastal alluvial soil. The average annual precipitation ranges from 780 mm to 1300 mm. The zone has considerable area of wasteland affected from water logging and salinity. 3397500 ha of wasteland is available in this zone out of which 82600 ha is gullied or ravenous land, 1388300 ha is upland with or without scrub, 181800 ha is waterlogged or marshy area, 6900 ha is under shifting cultivation, 1147100 ha is underutilised degraded forest land, 67500 ha is degraded pasture, 25100 ha is degraded land under plantation crops, 113500 ha is inland or coastal sands, 10800 ha is under mining and industrial wastelands, 172200 ha is barren and rocky land, 14000 ha is steep sloping land and 187900 ha is saline coastal lands. *Calophyllum inophyllum* can be made use of in planting in the coastal wastelands of the area. Other potential biodiesel tree species include *Jatropha curcas*, *Pongamia pinnata*, *Simarouba glauca* etc.

In this zone, 25% of gullied/ravine land, waterlogged lands, saline coastal sands, upland with or without scrub, and 10% of degraded forests, degraded pasture, degraded land under plantations, inland or coastal sands, and steep sloping lands would be available for taking up biodiesel plantation.

This would account for a total biodiesel planting possibility of 590000 ha in this zone.

#### 4.1.12 West-Coast Plains and Ghats

This zone runs across the west coast along the Arabian Sea and is spread over the whole of Kerala and Goa as well as 6 districts of Karnataka, 6 districts of Maharashtra and 2 districts of Tamil Nadu. The presence of Western Ghats makes it an area of very high rainfall of 3000 to 4500 mm in coastal plains and from 900 to 2000 mm in the hilly regions. The total available wasteland in this zone is 7128500 ha out of which 119800 ha is gullied or ravenous land, 2972100 ha upland with or without scrub, 329900 ha waterlogged or marshy land, 418000 ha saline land, 12300 ha under shifting cultivation, 2194700 ha underutilised degraded notified forest land, 184300 ha degraded pastures, 118000 ha degraded land under plantation crops, 194700 ha inland or coastal sands, 41900 ha mining or industrial wastelands, 456200 ha barren or rocky area and 86500 ha steep sloping area. Natural Rubber (*Hevea brasiliensis*) is one of the major plantation crops in Kerala, the seeds from which can be procured in order to meet the biodiesel feedstock requirement. Other species suitable for this climatic zone are *Pongamia pinnata*, *Calophyllum inophyllum*, *Garcinia indica*, *Schleichera oleosa* etc.



The land actually available for planting with biodiesel species is a small part of these wastelands. No lands are available for tree planting under the barren and rocky lands. Larger portion of the lands under the category of gullied land, inland or coastal sand, steep sloping lands, and degraded pasture lands are suitable for biodiesel planting but there is a great need for reclamation of these lands to their previous ecological status or original use would prevent diversion to biodiesel production except for 10% of the land. Upto 25% of lands in degraded forests can be used for raising biodiesel species provided the species selected are native to those forests like *Pongamia pinnata* and *Schleichera oleosa*.

Steep slopes can be planted with *Schleichera oleosa* while the coastal sandy areas may be planted with *Calophyllum inophyllum*. Also, *Calophyllum inophyllum* and *Garcinia indica* may be planted in the waterlogged areas and *Pongamia pinnata* in the uplands with or without scrub occupying 25% of the respective land categories.

The total area of wasteland available for biodiesel plantation in this zone is thus estimated to be 1420000 ha.

#### **4.1.13 Gujarat-Plains and Hills**

This zone covers the whole of Gujarat, Dadra & Nagar Haveli and Daman & Diu. This is a drought prone zone with a mean annual precipitation of 828 mm. The zone has a total wasteland area of 4313600 ha. Of this 101300 ha is gullied or ravenous land, 2180200 ha upland with or without scrub, 266400 ha waterlogged or marshy, 764400 ha saline, 550500 ha underutilised/ degraded notified forest land, 38800 ha degraded pasture, 7800 ha degraded land under plantation crops, 20700 ha inland or coastal sand, 5000 ha mining or industrial wasteland, 392700 ha barren or rocky land and 48800 ha steep sloping land. The drought resistant species which are suitable for this zone are *Azadirachta indica*, *Pongamia pinnata*, *Jatropha curcas*, *Madhuca indica* and *Simmondsia chinensis*.

No lands are available for tree planting under the barren and rocky lands, and waterlogged and marshy lands. About 50% of mining and industrial waste lands, 25% of uplands, degraded forests, degraded lands under plantations and degraded pastures, and 10% of the remaining lands are available for biodiesel.

However, it has to be ensured that the species planted within forests should be exclusively native species like *Pongamia pinnata*, *Madhuca indica*, and *Azadirachta indica*. On saline lands *Pongamia pinnata* and *Simarouba glauca* can be planted. *Calophyllum inophyllum* may

be planted in the coastal sandy areas while *Citrullus colocynthis* may be planted in the inland desert areas.

The total area of wasteland available for biodiesel plantation in this zone is thus estimated to be 790000 ha.

#### **4.1.14 Western Dry Region**

This zone is formed of the hot desert in the 9 districts of the state of Rajasthan. The climate is arid with a very scanty rainfall of 200 mm which makes the zone very low in productivity. In this zone out of total wasteland area of 6510200 ha majority of area i.e. 3896800 ha covered by inland sand area followed by an area of 13,05,000 ha of upland with or without scrub. An area of 7,03,400 ha lies as degraded pasture, 2,14,300 ha is underutilised or degraded notified forestland, 1,92,900 ha as barren or rocky land, 1,50,400 ha saline or alkaline land, 1,650 ha steep sloping land while 5,500 ha lies waterlogged. Very little area in this region would be available for biodiesel tree cultivation on account of extremely low productivity. Only about 10% each of the degraded forests and degraded pastures can be taken up for this purpose with *Citrullus colocynthis* and *Simmondsia chinensis*.

The total land available under this region for planting biodiesel tree species is thus estimated to be about 90000 ha.

#### **4.1.15 Island Region**

This zone is located in the union territories of Andaman & Nicobar Islands and Lakshadweep Islands. The natural vegetation of the zone is comprised of tropical wet evergreen as well as littoral and swamp forests. The average annual rainfall of Andaman & Nicobar Islands is 3000 mm and that of Lakshadweep is 1600mm. The total available waste land in the Island zone is 48187 ha out of which 35132 ha is underutilised or degraded notified forestland while 8961 ha lies degraded under plantations and 1878 ha is waterlogged. The inland sand and coastal area covers another 1711 ha while degraded pasture covers 505 ha.

On account of the ecologically sensitive nature of these islands we propose only planting of multipurpose *Garcinia indica* over about 10% of the degraded forests and 50% of degraded plantations. The total land available under this region for planting biodiesel tree species is thus estimated to be about 7000 ha only.

*Jatropha Curcas* will be planted in all climatic zones except the Himalayan hill region and waterlogged and marshy areas considering its adaptability to different climatic and edaphic conditions. One of the major drawbacks in raising biodiesel tree species is the long time it takes to give appropriate yield. Most of the tree species comes to full bearing only after 6-8 years of planting. One way to overcome this economic hindrance is to plant Castor (*Ricinus communis*) as an inter crop wherever possible with the main biofuel tree species other than *Jatropha Curcas*. Castor will give seed yield from the first year itself and this way the farmers can get quick economic returns in the initial years of planting until the tree species comes to full bearing. This, however, can happen only on small scale where intensive care by farmers and irrigation is possible.

### 5. Estimation of biodiesel yield

As discussed for different agro climatic zones above the total area of wastelands and other marginal lands available in these 15 zones is estimated to be 11199000 ha. The oil bearing tree species described above, except Sal and Rubber, can be raised over these identified lands. No plantations of Sal and Rubber are proposed to be raised specifically and only a part of the seeds from the existing natural forests and plantations of these species (effective area 2 million ha for Sal and 0.5 million ha for Rubber) would be utilized for producing biodiesel for reasons already explained in paragraphs 3.1 and 3.2 above. For the rest the authors propose equal spread of the species over the available lands in suitable agri-climatic zones. For example, in the West Coast Plains and Ghats zone the available marginal and wastelands are estimated at 1420000 ha and the species considered suitable are *Pongamia pinnata*, *Calophyllum inophyllum*, *Garcinia indica*, *Schleichera oleosa* and *Hevea brasiliensis*. Since no new plantations of Rubber (*Hevea brasiliensis*) are proposed to be raised the total available area is considered fit to be utilized for raising the remaining four species to equal extents.

Similar assessments have been made for each zone and then the area to be brought under each species is summed up over all zones. Per hectare seed productivity data is then used to assess the total species wise seed yields in the tenth year. Wherever the available productivity data indicates a range of values the least value has been adopted to account for the inevitable poor quality of management when activities are taken at such a large scale in India as also for the fact that only marginal lands of low productivity are proposed to be utilized. When only one value is given the average productivity is considered half of this value for the same reason. Seed oil to biodiesel conversion factor is taken as 0.9.

With these assumptions the total quantity of biodiesel produced annually in India ten years from now is estimated at 8.83 million tons. The projected demand of diesel for the year 2020 is 111.92 million tons (TERI, 2006). Thus with the current technology and the restrictions on the use of cultivable lands for growing oil seed bearing trees we should only expect about 8% blending with the internally produced biodiesels. For reaching its blending targets of 17% by the year 2017 India would need to reduce its diesel demand drastically or rely on imports. A drastic reduction in energy demand does not appear plausible. Technological breakthrough in the production of lignocellulosic liquid fuels may offer a good alternative to large scale imports but in the absence of such a technological advance imports are the only choice.

## 6. Biodiesel status in China

China's economic growth in the 1990s resulted in a rapid increase of petroleum consumption and led to serious air pollution problems. China became a net oil importer in 1993 and world's second largest importer in 2004. From 1990-2004, China accounted for 26 percent of the growth in global crude oil consumption (EIA, 2006a). China's total diesel demand in 2005 reached 109.72 million tons (NBS, 2006) and crude oil demand in China will more than double from 2004-2020 (EIA, 2006).

In the last one decade China has laid great emphasis on biofuels and quietly emerged as the world's third largest biofuel producer during the past decade. At roughly one million tons, China was world's third largest biofuel producer in 2005 (USDA, 2006). In 2006 the National Development and Reform Commission (NDRC), China's chief planning agency, set a target of meeting 15 percent of transportation energy needs with biofuels by 2020. With 20 percent of the world's population and 10 percent of its arable lands, plans for rapidly increasing biofuel production in China have spurred domestic debate about its implications for food security since the primary feedstock for ethanol in China, which comprises the bulk of the country's biofuel production, has been wheat and corn.

Concerned over it, China's Central Government banned the use of grain-based feedstocks for biofuel production in June 2007, and reoriented the country's bioenergy plans toward perennial crops grown on marginal land. Since then *Jatropha curcas* has emerged as a potential biodiesel feedstock due to its claimed adaptability to the diverse growing conditions on China's abundant marginal lands. Much of the focus on *Jatropha curcas* production has been in Southwest China, where research on the plant began comparatively early and unused land is more readily available.

In Southwest China, provincial governments have ambitious plans to undertake large scale *Jatropha* plantations on marginal land much of which is wild. The State Forest Administration (SFA) has set a target of 13 million ha of biodiesel plantations by 2010 (SFA, 2006).

However, these ambitious targets for increasing biodiesel production through raising *Jatropha* plantations on a vast scale in the subtropical parts of China have not yet yielded results that were projected. If one were to go by the outcome of *Jatropha* based national biodiesel plans in India there are few reasons to be overly optimistic. Just as has been argued for India in this paper the authors would suggest a serious relook at China's biodiesel feedstock policy and make attempts at broadbasing it. Among the species suggested for India at least three should do well in parts of China. These are *Aleuritis fordii*, *Simmondsia chinensis* and *Prunus armeniaca* all of which are native to the various parts of China. In addition, *Simarouba glauca* should also perform well in the Yunnan, Guangdong and Guansi provinces.

The Chinese Academy of Forestry has already identified more than 1400 species that have significant biodiesel potential. One of the more promising of these is the Chinese pistachio which grows wild over large parts of China and has an oil content of about 40%. The species, however, has a long gestation period of about 12 years. Research into its silviculture and management is needed to effectively shorten the seeding period of this very promising species.

## 7. Conclusion

For vast continental sized countries like India and China with widely differing ecological conditions no one species can be relied upon to meet the huge national demands of biodiesel. In the case of *Jatropha* its ability to survive across very diverse climatic and soil conditions has been taken to indicate its suitability as the national species of choice in India. But, as India's National Mission for Biodiesel discovered, the survivability of *Jatropha* is a poor measure of its suitability as a seed source for biodiesel production because even though it may survive adverse conditions it yields very little seeds in the absence of moisture and on poor soils.

Long gestation has been seen as deterrence in the case of most biodiesel species and one of the main reasons for preferring *Jatropha* has been its early seed production. This premium on shorter gestation is as much on account of the urgency to produce biodiesel as the attraction short rotation crops hold for low income farmers. But the reality is that the physiological ability to produce seeds is quite different from ability to produce seeds at scales which are commercially viable. Trees, particularly those that are expected to grow wild conditions over

vast marginal lands in the absence of irrigation and intensive management common in horticultural plantations would take longer in coming to a commercially viable seeding stage. It would thus be advisable if the countries wanting to make biodiesel a significant part of their energy security and climate change mitigation plans factor longer gestation periods of about 10 years which would offer them a far wider choice of species and surer chances of meeting their targets. This would in effect mean that while planning for tree based biodiesel production that does not threaten food security, using marginal lands and little water, returns from the planting should not be expected sooner than a decade. Since biodiesel productivity differs from country to country and many countries with low population and large extents of productive lands can produce larger quantities of biodiesel at lower economic, social and ecological costs, imports of biodiesel may also be a good option in a limited number of cases. For successful biodiesel production appropriate planning and management is as crucial as making the right choice of species for planting.

But irrespective of the measures taken by these two countries it is unlikely that they would ever be able to produce enough to meet the domestic demand. The possibilities of technological breakthrough in the production of lignocellulosic liquid fuels offer a hope, but in the absence of such a technological advance, imports of gigantic proportions from other developing countries appears to be the only choice. Experiences of past indicates that import of biodiesel in such large quantities could create severe adverse ecological and socio-economic consequences for the producing country, particularly if it happens to be a developing country with either inadequate governance or following ecologically unsustainable policies. No too long back many European countries had to cancel their orders for palm oil when it became obvious that the imports were leading to large scale destruction of rain forests in the exporting countries. So if countries like India and China decide to rely on imports of biodiesels for fulfilling their blending needs they need to develop appropriate strategies in coordination with international bodies like the FAO well in advance to minimize negative ecological and socio-economic effects on the exporting economies.

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**Table 1 Estimated Wasteland and Marginal Lands Available in Different Agro climatic zones of India**

Agro Climatic Zone	Type of Waste lands (sq km)													Total wasteland (sq km)
	Gullied and/or Ravinus Land	Upland with or without Scrub	Waterlogged and Marshy Land	Land Affected by Salinity/Alkalinity Coastal/Inland	Shifting Cultivation Area	Under utilised /Degraded Forest Land	Degraded Pasture s/Grazing Land	Degraded Land under Plantation crop	Sands-Inland/Coastal	Mining /Industrial Wastelands	Barren Rocky/Stony Waste/Sheet Rock Area	Steep Sloping Area	Snow Covered and/or Glacial Area	
<b>Western Himalayas</b>	158.99	6791.98	329.83	1.36	0	8169.78	4662.05	3108.3	974.3	86.88	37087.45	4181.29	47630.76	113182.97
Himachal Pradesh	121.89	2056.5	15.69	1.36	0	4589.98	4278.17	2457.59	105.04	85.66	3858.04	1529.67	12559.42	31659.01
Jammu & Kashmir	21.25	4495.3	246.5	0	0	2491.66	267.51	640.56	869.26	0.31	32821.5	1685.42	21904.97	65444.24
Uttarakhand	15.85	240.18	67.64	0	0	1088.14	116.37	10.15	0	0.91	407.91	966.2	13166.37	16079.72
<b>Eastern Himalayan region</b>	0.18	11343.52	2041.89	0	34967.15	12357.25	4359.12	9	4087.08	0.73	1328	19.63	8157.73	78671.28
Arunachal Pradesh	0	3326.78	41.47	0	3088.08	1416.67	2134.99	6.07	309.43	0.3	1262.36	7.93	6732.17	18326.25
Assam	0	843.72	1633.56	0	8391.48	3112.71	2217.85	0	3764.54	0.43	54.88	0	0	20019.17
Manipur	0	1.32	324.6	0	12014.06	608.64	0	0	0	0	0	0	0	12948.62
Meghalaya	0	4190.63	14.87	0	2086.77	3612.11	0	0	0	0	0	0	0	9904.38

Mizoram	0	0	0	0	3761.23	310.45	0	0	0	0	0	0	0	4071.68
Nagaland	0	1596.46	0	0	5224.65	1582.99	0	0	0	0	0	0	0	8404.10
Sikkim	0	1073.11	0	0	0	1060.57	0	0	0	0	10.34	0	1425.56	3569.58
Tripura	0	286.87	0.11	0	400.88	588.18	0	0	0	0	0	0	0	1276.04
West Bengal	0.18	24.63	27.28	0	0	64.93	6.28	2.93	13.11	0	0.42	11.7	0	151.46
<b>Lower Gangetic Plain</b>	171.72	1160.14	1888.23	131.25	0	635.57	378.69	0	793.63	0	130.04	4.54	0	5293.81
West Bengal	171.72	1160.14	1888.23	131.25	0	635.57	378.69	0	793.63	0	130.04	4.54	0	5293.81
<b>Middle Gangetic Plain</b>	354.84	2246.43	2893.15	1908.45	0	3097.25	65.11	16.29	391.77	16.62	173.08	31.37	0	11194.36
Uttar Pradesh	246.72	824.91	1712.5	1907.94	0	394.12	42.05	15.13	171.15	0	0	0	0	5314.52
Bihar	108.12	1421.52	1180.65	0.51	0	2703.13	23.06	1.16	220.62	16.62	173.08	31.37	0	5879.84
<b>Upper Gangetic Plain</b>	1950.5	3583.36	5533.86	4000.64	0	4000.64	287.94	25.16	313.1	7.51	389.41	396.92	0	20489.04
Uttar Pradesh	1950.5	3583.36	5533.86	4000.64	0	4000.64	287.94	25.16	313.1	7.51	389.41	396.92	0	20489.04
<b>Trans Gangetic Plain</b>	230.02	2248.03	826.4	487.98	0	1112.36	946.02	215.7	1927.93	42.8	184.12	0	0	8221.36
Chandigarh	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Delhi	12	7.6	2.6	19.4	0	21	0	0	0	0	79	0	0	141.60
Haryana	49.5	988.42	238.3	285.63	0	732.52	721.65	134.12	465.01	13.72	105.12	0	0	3733.99
Punjab	168.52	339.44	352.01	173.29	0	353.29	113.71	81.58	619.67	26.89	0	0	0	2228.40
Rajasthan	0	912.57	233.49	9.66	0	5.55	110.66	0	843.25	2.19	0	0	0	2117.37
<b>Eastern Plateau and Hills</b>	973.25	18818.76	35.27	3.82	476.74	21804.22	254.35	356.51	58.81	316.68	2485.89	288.21	0	45872.51
Chhattisgarh	230.95	5849.78	1.9	0	369.99	2746.27	32.31	225.03	22	49.1	991.95	36.69	0	10555.97
Jharkhand	451.05	3268.41	18.22	0	45.45	10363.4	141.91	78.64	1.46	167.61	515.83	65.73	0	15117.71

Madhya Pradesh	132.82	999.95	0	3.62	0	768.02	34.5	0	0	6.85	179.51	44.08	0	2169.35
Maharashtra	0	1481.93	0	0	0	1937.87	0	0	0	80.59	86.34	0	0	3586.73
Orissa	88.58	6720.37	15.15	0.2	61.3	5816.32	10.83	52.84	35.35	12.53	608.72	137.17	0	13559.36
West Bengal	69.85	498.32	0	0	0	172.34	34.8	0	0	0	103.54	4.54	0	883.39
<b>Central Plateau and Hills</b>	8273.77	34427.77	90.74	1488.22	13.91	23352.1	5256.56	419.88	827.88	384.01	4452.82	242.73	0	79230.39
Madhya Pradesh	1947.56	20368.74	16.41	0.49	0	12357.82	192.81	398.74	0	62.08	1199.9	76.95	0	36621.50
Rajasthan	4620.85	13189.38	1.29	1209.05	0	10392.74	5063.75	21.14	827.88	57.77	2870.11	165.78	0	38419.74
Uttar Pradesh	1705.36	869.65	73.04	278.68	13.91	601.54	0	0	0	264.16	382.81	0	0	4189.15
<b>Western Plateau and Hills</b>	5863.22	29034.35	80.94	171.04	0	13691.19	245.71	167.98	19.84	43.36	1903.43	971.6	0	52192.66
Madhya Pradesh	4244.42	8096.39	33.41	158.7	0	5146.49	52.36	107.98	2.57	24.38	746.02	35.31	0	18648.03
Maharashtra	1618.8	20937.96	47.53	12.34	0	8544.7	193.35	60	17.27	18.98	1157.41	936.29	0	33544.63
<b>Southern Plateau and Hills</b>	497.79	23919.81	8.63	1446.79	0	32026.16	303.84	256.16	139	210.99	8003.89	665.35	0	67478.41
Andhra Pradesh	153.13	11336.16	0.5	283.32	0	16172.26	37.84	12.42	13.5	66.76	4659.46	324.2	0	33059.55
Karnataka	301.14	7564.29	8.13	119.57	0	6832.71	97.46	61.52	16.13	76.5	2254.45	40.97	0	17372.87
Tamil nadu	43.52	5019.36	0	1043.9	0	9021.19	168.54	182.22	109.37	67.73	1089.98	300.18	0	17045.99
<b>East Coast Plains and Hills</b>	826.25	13883.16	1817.93	1878.51	68.31	11470.89	674.63	250.71	1134.55	108.28	1722.01	140.19	0	33975.42
Andhra Pradesh	539.55	8920.48	1034.52	319.94	13.8	6065.52	671.45	40.49	451.2	32.12	536.81	64.76	0	18690.64
Orissa	97.24	1638.31	363.95	51.29	53.98	4197.75	2.6	141.09	177.14	22.92	965.37	70.71	0	7782.35
Pondicherry	0.83	2.97	3.66	13.1	0	0	0	0	17.89	0	0	0	0	38.45
Tamil Nadu	188.63	3321.4	415.8	1494.18	0.53	1207.62	0.58	69.13	488.32	53.24	219.83	4.72	0	7463.98
<b>West Coast Plains and Ghat</b>	1198.49	29721.29	3299.42	4180.39	122.82	21947.01	1842.79	1179.53	1946.91	418.55	4562.11	865.22	0	71284.53

Goa	0	292.83	41.02	0	0	71.99	2.47	32.19	0	110.73	58.55	3.49	0	613.27
Karnataka	1112.95	19138.67	2642.36	3437.08	122.82	16948.25	680.28	493.12	1817.9	295.17	2965.76	219.11	0	49873.47
Kerala	0	357.93	136	0	0	609.3	3.99	25.65	27.87	0.49	146.46	140.49	0	1448.18
Mahe (Pondicherry)	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Maharashtra	81.57	8967.02	480.04	239.32	0	2948.1	1156.05	627.43	60.36	0.88	1343.67	453.28	0	16357.72
Tamil nadu	3.97	964.84	0	503.99	0	1369.37	0	1.14	40.78	11.28	47.67	48.85	0	2991.89
<b>Gujarat Plains and Hills</b>	1013.39	21801.89	2663.59	7643.85	0	5505.24	387.83	78.32	207.35	49.66	3297.44	487.31	0	43135.87
Gujarat	1013.39	21786.72	2656.26	7637.34	0	5443.02	387.45	78.32	188.42	49.66	3293.39	487.31	0	43021.28
Dadra and Nagar Haveli	0	13.38	0	0	0	60.62	0.25	0	0	0	0	0	0	74.25
Daman & Diu	0	1.79	7.33	6.51	0	1.6	0.13	0	18.93	0	4.05	0	0	40.34
<b>Western Dry Region</b>	331.92	13050.81	54.88	1504.28	0	2143.6	7034.03	0	38968.38	68.69	1928.91	16.5	0	65102.00
Rajasthan	331.92	13050.81	54.88	1504.28	0	2143.6	7034.03	0	38968.38	68.69	1928.91	16.5	0	65102.00
<b>Island Region</b>	0	0	18.78	0	0	351.32	5.05	89.61	17.11	0	0	0	0	481.87
Andaman & Nicobar Islands	0	0	18.78	0	0	351.32	5.05	89.61	17.11	0	0	0	0	481.87
Lakshadweep	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00

Source: The above estimates have been made using data from Planning Commission of India and Ministry of Rural Development