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Improved Livelihoods and Environmental Protection through Biodiesel Plantations in Asia

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Abstract: Increasing energy demand and spiraling oil prices are the cause of financial strain on countries and also causing environmental degradation. Use of non-edible oil as biodiesel provides a win-win proposition for the densely populated Asian countries. Perennials such as *Pongamia pinnata* and *Jatropha curcas* have offered an excellent opportunity to remedy the problems of environmental protection and oil crisis. Strategies for rehabilitating degraded lands and improving livelihoods through biodiesel plantations based on field experiences are discussed.

Although technology, policy support, and the demand for biodiesel are increasing, the main constraint is supply of raw material. Validated and good quality data on agronomic practices, yield potential, diseases and pests occurrence, water requirement and management for block plantations are not available. There is an urgent need to undertake research on all aspects of biodiesel plantations.

Introduction

Energy security has assumed a greater significance than ever before as energy consumption, food production, improved livelihoods and environmental quality are interrelated. Asian countries with dense population are more prone to energy crises than are their counterparts in the developed world. A strong nexus between energy use for irrigation water and agricultural output exists. The number of borewells in India and energy consumption have increased dramatically over the last two decades. Groundwater now sustains almost 60 per cent of the India's irrigated area. Even more importantly, groundwater now contributes more to agricultural wealth creation than any other irrigation source.[1] During a recent study undertaken by ICRISAT in Rajasamadhiyala

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watershed in Gujarat it was noted that not only had the number of open and bore wells in a village of 1000 ha increased from 357 to 508 within eight years but pumping hours had also increased from 5.25 to 10.4 hours per day, putting pressure both on energy resources and groundwater.[2] In addition, farmers also keep additional diesel pumpsets as a stand by to cope with the prevailing power cuts. Agriculture is now more dependent on mechanical and electrical sources of energy than on human and animal power. During 1988-89 to 2004-05, farm power availability in Anantapur village, a predominantly dryland area increased by 28 per cent, while mechanical power use increased remarkably by 730 per cent.[3]

Any increase in food production calls for higher energy use in terms of irrigation and fertilizer, as further expansion of area under agriculture is limited. Areas that are left fallow or degraded and not fit for agriculture offer an opportunity for 'greening' through tree-based oilseeds (TBOs). The advantages of perennials are many for example, greenery will protect the land from further degradation and generate employment in rural areas. The total number of species with oleaginous seed material mentioned from different sources varies from 100 to 300 and of these 63 belonging to 30 plant families hold promise.[4] Two species namely, *Jatrohpa curcas* and *Pogamia pinnata* are favoured in India because of their contrasting plant characteristics and the species selected should match the site characteristics (see Table 1).

Jatropha is highly drought tolerant and is well suited to semi-arid conditions although it thrives in arid areas. It occurs mainly at lower altitudes (0-500m) in areas with an average annual temperature well above 20 ^{0}C but can grow at higher altitudes, tolerates slight frost, and up to 1000 mm rainfall.[5] *Pongamia* thrives well up to 1200 m altitude and rainfall of 500-2500 mm per annum. *Pongamia* withstands temperature from about -1^0C to 50^0C. Both plants can withstand drought but *Jatropha* sheds its leaves during the dry period (summer) while *Pongamia* retains leaves and is evergreen. Gall formation on leaves caused by mite in *Pongamia* is a major concern as it affects leaf area/ photosynthesis and it is widespread. *Jatropha* has an affinity for well-drained soils and is susceptible to collar rot disease in high rainfall humid areas or excessive irrigation or water logging conditions, while *Pongamia* can tolerate water logging, saline and alkaline conditions. Both the species are suitable for semi-arid tropics and are not grazed or browsed by livestock.

Table 1: *Jatropha vis-à-vis Pongamia*

Characteristics	*Jatropha curcas*	*Pongamia pinnata*
Ecosystem	Arid to semi-arid, up to 500 m altitude	Semi-arid to sub-humid, up to 1200 m altitude
Rainfall	Low to medium up to 1000 mm	Medium to high up to 2500 mm
Soil	Well drained soils	Tolerant to water logging, saline and alkaline soils
Nitrogen fixation	Non fixer	N_2 - fixing
Plant suitability	Wastelands, degraded lands, live fence for arable lands, green capping of bunds, shallow soils	Field boundary, river and stream banks stabilization, wastelands, tank foreshore
Plant habit	Mostly bush, can be trained as small tree	Tree can be managed as bush by repeated pruning but will affect yield
Leaves	Not palatable by livestock	Not palatable by livestock, used as green leaf mulch
Gestation period	Short, 3rd year	Long, 7th year
Yield	1.0 kg/plant	10 to 200 kg/tree
Oil content	27-38% in seed	27-39% in kernel
Protein	38%	30-40%
Fire wood	Not useful	Good as firewood, high calorific value 4600 k cal/kg

Source: ICRISAT, 2005 unpublished data; Parmathma *et.al.*, 2004.

i) *Seedling Management*

Tree improvement programmes have mainly concentrated on a few plants like *Eucalyptus spp*. and Poplar (*Populus deltoides*) but no systematic efforts have been made in the past to improve tree borne oilseeds like *Pongamia* and *Jatropha*. As the genotype and the environment influences yield, therefore, the source of seed assumes greater significance. The quality of the seedlings also affects survival, growth as well as yield and this is further dependent on media and propagation technique.

Variability in Seed Sources

It is desirable to select the seed source for multiplication from known plant populations with favourable traits. However, no systematic efforts have been made to evaluate and document the existing variability in seed sources of both the plants. Since the last 2-3 years, a few researchers have started collecting seeds from high yielding trees of *Pongamia* and *Jatropha*. A preliminary study conducted at ICRISAT for samples collected in the states of India by various researchers and suppliers indicates great

Table 2: Evaluation of Seed Samples of *Jatropha* and *Pongamia* for Oil content, Test Weight and per cent Germination

Sl. No.	Collection No.	Place of collection	100 seed weight (g)	% Oil content	Germination %
Jatropha					
1	IJC-1	Rajgarh	63.8	28.0	10
2	IJC-2	AP	68.2	38.4	90
3	IJC-3	Tamilnadu (cape viridi type)	49.2	29.9	61
4	IJC-4	Tamilnadu (Erode local)	44.0	28.6	85
5	IJC-5	Tamilnadu (wild collection)	77.2	29.3	50
6	IJC-6	Rajasthan	69.5	34.8	78
7	IJC-7	Rajasthan	51.3	29.3	51
8	IJC-8	JNKV	72.6	34.7	-
9	IJC-9	CHRK-VSP	67.3	32.8	70
10	IJC-10	MONDC	69.2	31.8	-
11	IJC-11	CHRK-GBR	69.4	34.4	17
12	IJC-12	TFRI	66.5	33.5	-
13	IJC-13	Rajasthan	57.6	34.4	30
14	IJC-14	-do-	53.2	27.8	23
15	IJC-15	-do-	60.67	33.6	42
Pongamia					
1	P-1	Mumbai	233.2	30.4	90
2	P-2	Goa	132.7	21.3	90
3	P-3	Orissa	155.0	33.5	90
4	P-4	Bangalore	177.0	40.9	90
5	P-5	Adilabad	102.4	39.5	90
6	P-6	Adilabad (Behranguda)	105.2	32.9	90
7	P-7	Gurgaon	101.0	34.5	85
8	P-8	-do-	101.5	33.3	85
9	P-9	-do-	101.2	36.6	85
10	P-10	-do-	102.0	33.1	85

Source: ICRISAT, 2005 unpublished data.

variability in terms of *Jatropha* and *Pongamia* oil content, 100 seed weight and per cent germination (see Table 2). The seed source of *Jatropha* IJC-2 and IJC-6 were found to be promising in terms of oil content.

Nursery Techniques

There are several propagation techniques like direct seeding, cuttings, and nursery raising, which are discussed in detail below.

1. *Direct seeding:* One to two seeds of *Jatropha* and *Pongamia* can be sown directly in the ploughed and marked field. The main field should be ploughed and spots may be marked and enriched with FYM receiving the seeds. Twenty gram urea, 120 g single super phosphate and 60 g muriate of potash should be applied after establishment of the plant. Seedlings grown by this method will take time for establishment and

will have slow growth in the initial period. However, there should be enough moisture in the soil to support germination and seedling growth. Frequent weeding is required to prevent the seedlings from competing weeds and shade. Similarly, soil working around the seedlings will boost the growth and will improve the moisture and rainfall infiltration. *Pongamia* seedlings grown this way can be *in-situ* grafted with a scion from high yielding tree after nine months.

2. *Vegetative propagation (transplanting of pre-rooted cuttings/grafting): Jatropha* can be multiplied by raising the cuttings on a raised bed and can be later transplanted into the main field. Multiplication of *Pongamia* by cuttings is difficult but grafting is easier. Cuttings of 2-3 cm thickness from the lower portion of the shoot and of 25-30 cm length may be prepared in the month of March, when plants shed most of their leaves. These cuttings are planted in nursery beds at a spacing of 30x30 cm or in polybags. Pre-treatment of stem cuttings with 300 ppm IBA (Indole butyric acid) solution for 5 minutes is desirable. Sprouting starts within 7 days of planting. Plants propagated by cuttings will normally produce seeds within a year of planting and growth is rapid. However, it has been observed that seedlings raised from seeds have a better root system compared to pre-rooted cuttings, which develop secondary and tertiary fine roots. Such seedlings are more stable during storms. The plants raised through cuttings will be true to type and will have similar characteristics of the mother plant. To maintain the quality of plantations of *Pongamia*, there is a possiblity of *in-situ* grafting. The rootstock may be raised directly by seeding in the pits (two to three seeds). The desirable scion material may be grafted on the rootstock when the seedlings attain pencil thickness. The technique needs to be standardized for *Pongamia* as followed in mango.

3. *Nursery raising: Jatropha* plant can be grown by two methods, namely bare root and container method (polythene bag). In the bare root method, nursery bed is prepared by mixing FYM, soil and sand in equal volumes. Soaked seeds are sown at a row spacing of 25 cm and a plant to plant distance of 5cm. The plants will be ready for transplantation in the main field six weeks after germination. The plants may be carefully uprooted from the nursery beds, wrapped in wet gunny bag and transported to the main field. Uprooted seedlings may be transplanted within 24 hrs. Before transplanting it should be ensured that enough moisture is available in the pit receiving the bare root seedlings. Bare root seedling production of *Pongamia* is difficult as it

has a tap root system and will get disturbed during lifting from nursery beds. Seedlings of both *Jatropha* and *Pongamia* can be grown in poly bags of mostly black colour (4" x 7", 150 gauge for 3-4 months old seedlings). The bags may be filled with equal parts of soil, sand and FYM (1/3, 1/3, 1/3). 1.0 g per polybag of Diammonium phosphate (DAP) may be added to 2 kg soil weight. Good quality seeds having 80 per cent germination should be sown with one seed per bag at 2-3 cm depth for getting higher per cent germination. One gram of mycorrhizae (mixed culture) may be placed below the seed at the time of sowing to enhance growth of seedlings. *Jatropha* seedlings treated with mycorrhizae in unsterlized soil + FYM mixture had higher plant height, girth and number of leaves compared to control, when sampled 85 days after sowing (see Table 3). Similarly, treatment of *Pongamia* seeds with *Rhizobium* and mycorrhizae, *Azatobacter* was found promising for improving seedling growth. *Pongamia* seedlings treated with *Rhizobium* and *Azatobacter* had a higher number of nodules, shoot and root weight when sampled 85 days after sowing (see Table 4). Grading and root pruning is suggested to promote uniform growth of seedlings.

ii) *Field Management*

Genotype and the environment (field condition) influence the survival and growth of the seedlings. There are several steps involved in

Table 3: Effect of Mycorrhizal Inoculation on Growth of *Jatropha* Seedlings in Nursery

Treatment	Plant height (cm)	Stem girth (cm)	Number of leaves
Inoculated	47	6.5	16
Non-inoculated (control)	35	5.9	12

Source: ICRISAT, 2005 unpublished data.

Table 4: Effect of *Rhizobium* and Mycorrhizal Inoculation on Nodulation and Biomass of *Pongamia* Seedlings in Nursery

Treatment	Nodule number/ seedling	Fresh weight (g/seedling)		Dry weight (g/seedling)	
		Shoot	Root	Shoot	Root
No treatment (Control)	11	5.5	5.0	1.2	1.3
Rhizobium alone	19	6.0	5.4	1.3	1.8
Mycorrhizae alone	12	5.8	5.9	1.3	1.5
Mycorrhizae + *Rhizobium*	17	6.2	7.9	2.3	1.9
Mean	15	5.9	6.0	1.5	1.6
LSD ($P \leq 0.05$)	1.8	2.4	2.0	0.98	0.69

Source: ICRISAT, 2005 unpublished data.

management of the field. First, the field may be ploughed (deep tilled) followed by harrowing at the beginning of the rainy season or by utilizing off-season rains. Direct planting may be taken up in dug out pits in hilly and rocky areas where cultivation is not possible.

A spacing of 3m x 2m or 3m x 3m spacing is desirable for intercropping and intercultivation. For hedgerow/ boundary plantation of fields, the spacing should be 1 m x 1 m. For *Pongamia* block-planting, a spacing of 5m x 5m or 6m x 6m is suggested. For avenue and field boundary planting, a spacing of 2m to 4m may be given from plant to plant. Mixed planting of *Jatropha* and *Pongamia* and alignment of rows in the east-west direction is suggested. A spacing of 6m x6m for *Pongamia* and 3m x3m for *Jatropha* is desirable. The recommended size of the pit is 30 cm x 30 cm x 30 cm for *Jatropha* and 45cm x 45cm x 45cm for *Pongamia*. The pits may be dug well in advance of planting time. Refilling of the pits may be done by mixing 1.0 to 2 kg of FYM, 50 g of DAP and methyl parathion (2 per cent dust) @ 5 to 10g or 5g of thimmet granules per pit may be applied to protect the young saplings from termites' damage.

Transplanting

Seedlings having a plant height of 60 cm may be transplanted with the on-set of rainy season and the soil around the seedlings should be compacted. Normally, *Jatropha* attains a height of 60 cm in 60 to 75 days while *Pongamia* takes little longer time 90-105 days. The survival percentage will be more in case of plantation raised by seedlings compared to direct seeding. Seedlings are susceptible to competition from weeds in the first year. Therefore, weed control either manual or by herbicide is required during the establishment phase.

Irrigation and Moisture Conservation

Although *Jatropha* and *Pongamia* are hardy plants, even then they require adequate moisture in the root zone during the initial period. Irrigation once in a month during the dry period will be quite beneficial for enhancing growth and productivity. Rain water conservation techniques like planting on contour or staggered trenches will be advantageous in hilly, slopy and rocky areas where intercultivation and intercropping is not possible. Making ring basins around the plants and mulching (dust mulch/organic mulch) will conserve soil moisture and minimize irrigation needs. Tree loppings and straw is ideal for conserving the soil moisture in the basins. Creating surface roughness by intercultivation, etc. will enhance rainwater conservation and use. Irrigation needs vary with local soil and climatic conditions and need to be standardized. *Jatropha* can stand long periods of drought by shedding leaves while *Pongamia* remains green during dry periods. Irrigation during dry periods at fortnightly intervals during first year is suggested to improve growth and yield, if available. However, with appropriate soil moisture conservation techniques, *Jatropha* and *Pongamia* plantations in degraded common lands in Andhra Pradesh, Madhya Pradesh and Rajasthan showed 70 – 75 per cent survival after one year without any irrigation.

Manures and Fertilizers

It is often said that *Jatropha* and *Pongamia* do not need any nutrition. The plants may survive in soil having poor fertility but seed production will be very poor and will have only foliage. There are no systematic studies conducted on the nutritional requirement for *Jatropha* and *Pongamia* block plantations. However, based on experience with other plantations it may be seen that organic manures (FYM/Vermicompost) @ 1 kg/plant for *Jatropha* and 2 kg/plant for *Pongamia* and a fertilizer dose of 50 g of DAP for *Jatropha* and 100 g of DAP for *Pongamia* in the first year need to be applied at the time of filling the pits. In subsequent years, top dressing of *Jatropha* @ 50g and 100g of urea and SSP per plant, respectively while for *Pongamia* DAP @100g per plant is suggested. Alternatively, oil cakes can be recycled in these plants to maintain the productivity of soil. The plants respond well to addition of small quantities of calcium, magnesium and sulphur. Mycorrhizal associations have been observed in *Jatropha* and they are known to aid the plant growth under conditions where phosphorus availability is low.

Weeding

The basin should be kept free from weeds. Hoeing and weeding is essential during the establishment period. Around 2-3 weedings/intercultivations are enough to keep the field free from weeds and conserve moisture.

Irrigation

Jatropha was found to respond to irrigation and was also recommended by the growers.[6] Similarly, a field study in Nalgonda, revealed that *Pongamia* too has a liking for water and fertile soils. *Pongamia* grows mostly along the watercourses like streams and waterways,[7] while traditionally it is grown on field and farm bunds particularly around paddy fields.

Canopy Management

The flowering occurs at the terminal portion of the branches in *Jatropha* and along the branches in case of *Pongamia*. Therefore, efforts should be made to train and prune the plant in such a way that the number of fruiting branches increase. In *Jatropha*, the terminal bud should be nipped to induce secondary branches. Likewise the secondary and tertiary branches are to be pinched or pruned at the end of first year to induce a minimum of twenty-five branches at the end of second year.[8] Once in ten years *Jatropha* may be cut back leaving a one-foot height from the ground level for rejuvenation. The growth is quick and the plant starts yielding in about a years period. This will be useful to induce new growth and to stabilize yield. In a study of canopy management in North East Thailand, the cutting of *Jatropha* at a height of 50cm from the bottom was found reasonable to maintain a compact bush form. The end of the dry season was found to be the optimum time for cutting back as the plants go in dormancy after the fruiting season. Thinning twice after one and two months of cut back was recommended to promote useful fruiting branches and to maintain a compact bush form.[9]

The *Pongamia* plants may be pruned initially to give the stem a straight form and later lightly lopped for green leaf mulch. All the side branches of tree, one third from the bottom may be pruned and the top two third branches on the plant may be retained. Periodical pruning can be carried out depending upon the vegetative growth of the plants. The pruning should be done when trees shed leaves and enter into a period of dormancy. Diseased, dead, excessive, weak and lateral branches should be removed.

Insect Pests

In the case of *Jatropha*, insects such as leaf eating beetles, thrips, leaf hoppers, grass hoppers, caterpillars and leaf miner will feed on foliage. Shoot/stem borer and bark eating caterpillar will damage the stem. Blue bugs and green stink bug will be sucking on fruits while capsule borer will damage the fruits.[10] In the case of *Pongamia*, leaf miner, leaf galls, bark eating caterpillar and other pests are found. The pest may be controlled by spraying Endosulfan @ 3 ml per litre of water or any other pesticide recommended for that particular pest. The galls are formed due to the attack of mites and can be controlled by spraying Dicofol @ 5 ml per litre of water or wettable sulphur @ 3 g per litre of water.

Diseases

In case of *Jatropha*, collar rot may become a problem in some areas in monoculture plantations under irrigated condition. It is severe under water logging conditions and excess soil moisture. The rot can be controlled by drenching with 1 per cent Bordeaux mixture. Minor diseases such as root rot, damping off, powdery mildew and leaf spots are reported.[11] There is no specific mention of diseases in case of *Pongamia*.

Harvesting

The flowering in *Jatropha* depends upon the location and agroclimatic conditions. Generally it takes place from August to December in India. However, this flowering and fruiting depends on the site, soil moisture and climatic conditions. Fruits mature within two to four months after flowering. The ripe fruits should be harvested/plucked when it reaches physiological maturity (yellow capsule stage). There is no synchronized flowering and fruiting, which makes harvesting a labour intensive process. *Pongamia* flowers once in a year and takes about 8 to 10 months to mature. Pods can be easily harvested/collected after leaf shedding and before the new flush comes by shaking the branches. Rural women and unemployed youth can be gainfully employed for collection and will improve their livelihoods.

Processing and Handling

After collection the fruits are transported in open bags to the processing site. They are dried till all the fruits are opened and decorticated manually or by decorticators. It has been reported that direct sun drying has a negative effect on seed viability and the seeds should be dried in the shade.

Yield Potential

Jatropha plant begins bearing from first year onwards and stabilizes from the fifth year. It gives an economic yield up to 30-40 years. The expected yield from one-hectare plantation is near about 750-1500 kg under rainfed and 1500-2500 kg under irrigated conditions. *Pongamia* starts bearing at the age of 7 years. A single tree yields 10–200 kg seed, indicating a minimum yield potential of 1000kg/ha; however, grafted seedlings start bearing from the third year. Irregular bearing has been noticed in *Pongamia* and the yield may vary from year to year. However, no systematic data on yield from block plantations are available. In Maharashtra, where block plantations on *Jatropha* were undertaken in the 1980s without irrigation, a yield of 1000–1200 kg ha^{-1} was recorded.[12]

There is an urgent need to study the yield potential of both the plants with appropriate agronomic management practices in block plantations.

Storage and Viability

The seeds should be dried to reduce the moisture content (5-7 per cent) and stored in cool and dry place. At room temperature the seeds can retain high viability for at least one year. However, because of the high oil content the seeds cannot be expected to store for long time. Oil can be extracted using low cost expellers in the village itself and oilcake may be retained with the growers/ collectors for application to fields as an organic fertilizer or can be sold to prospective buyers.

iii) *By-Product: Oil Cakes as Source of Plant Nutrients*

Oilcake a by-product after extraction of oil appears to be a very attractive proposition as it contains all the macro and micro-nutrients and it is an excellent organic fertilizer unlike inorganic fertilizers that supply only few nutrients. Four kilograms of seed of *Pongamia* or *Jatropha* give about three kilograms of cake. The cake is mostly used for fertilizing plantation or commercial crops. An analysis of the contents of the cake of *Pongamia* and *Jatropha* indicated the presence of all the essential elements required for plant growth, particularly found to be rich in nitrogen and sulphur (see Table 5). Recycling of *Pongamia* cake in Adilabad district of Andhra Pradesh resulted in a 41-47 per cent increased income when compared to farmer's practice (see Table 6).

Table 5: Chemical Composition of Oilcakes analyzed at ICRISAT, Patancheru, India

Nutrients	*Jatropha*[1]	*Pongamia*[2]	*Pongamia*[3]
Nitrogen (%)	4.91	4.28	6.14
Phosphorous (%)	0.90	0.40	0.72
Potassium (%)	1.75	0.74	1.07
Calcium (%)	0.31	0.25	0.96
Magnesium (%)	0.68	0.17	0.35
Zinc (ppm)	55	59	95
Iron (ppm)	772	1000	1053
Copper (ppm)	22	22	41
Manganese (ppm)	85	74	108
Boron (ppm)	20	19	43
Sulphur (ppm)	2433	1894	3615

Notes: Source of oilcake: [1] Coimbatore, Tamil Nadu.
[2] Adilabad, Andhra Pardesh.
[3] Tumkur, Karnataka.
* DAP = Diammoium phosphate.
Source: ICRISAT, 2005 unpublished data.

Table 6: Response of Soybean and Maize to the Application of *Pongamia* Cake and Inorganic Fertilizers

Crop	Treatment	Yield (kg ha^{-1})	Income (Rs. ha^{-1})	Cost of fertilizer (Rs.)	Additional income over farmer'spractice (Rs.ha^{-1})
Soybean	Farmer's practice (DAP 75 kg ha^{-1})	900	10800	450	-
	Pongamia cake (PC) (300 kg ha^{-1})	1340	16080	1500	4230
	Recommended dose of fertilizer (RDF) 20 kg N ha^{-1}	1450	17400	250	6800
	50% RDF + 50% PC	1650	19800	1500	7950
Maize	Farmer's practice (DAP 125 kg ha^{-1})	1200	6000	1125	-
	Pongamia cake (PC) (1800 kg ha^{-1})	2240	11200	4000	2325
	Recommended dose of fertilizer (RDF) 90 kg N ha^{-1}	2390	11950	1000	6075
	50% RDF + 50% PC	2560	12800	5000	2925

Source: Source: ICRISAT, 2004 unpublished data.

Similar studies carried out by Ngoma (1999) in Zimbabwe have revealed that application of *Jatoropha c*ake at the rate of 0, 0.25, 0.5 and 1.0 kg/sq. m resulted in cabbage yields of 16.8, 23.6, 22.8 and 35.8 kg, respectively and the crop was free from pest and diseases. Tasosa *et. al.* (2001) have recorded a significant difference in the growth rates of tomato and the total above ground dry matter with increased application rates of *Jatropha* and castor cakes. Henning (2000) is of the opinion that *Jatropha* plants can reduce the soil and water erosion when planted as live fence and the cake obtained after oil extraction can help in building the organic matter content of the soils of Sahelian countries. Substitution of oilcakes with fertilizers is likely to improve the fertility of the soils in the long run and the soils will overcome the widely observed deficiency of several nutrients like N, P, Zinc, Boron, Sulphur, etc. Further, it will reduce the dependence of farmers on external input (fertilizers). Recycling of the cake serves the interest of farmers as well as of the government as the huge subsidy paid on fertilizers to industries can be reduced. The amount saved on subsidy of fertilizers can be used for encouraging biodiesel plantations in rural areas for ensuring energy, food and livelihood security.

iv) *Plantation Management – Strategies for Livelihoods Enhancement*

In the semi-arid tropical region, large numbers of poor people reside and most of them are landless and marginal small landholders. Biodiesel plantations could be successfully utilized to improve livelihoods on a sustainable basis and to rehabilitate the degraded lands and protect/ improve the environment.[13] There is already a good market demand globally for biodiesel with spiraling fossil fuel prices and the increased awareness of the adverse impact of global warming. Good policy support from the national governments also exists, e.g. in India and Thailand where governments have extended good support for enhancing production and use of biodiesel. Technological options to process biodiesel using multi-feed stocks also exist. However, the missing factor or the fourth wheel to run the biodiesel car is an assured supply of raw materials.[14] There is an urgent need to enhance production and supply of *Jatropha* and *Pongamia* and other non-edible oils to be used as biodiesel. In densely populated countries of Asia as in Europe edible oils cannot be used for biodiesel production as already these countries are in short supply of edible oils for human consumption. Similarly, to achieve oil security most of the developing countries would not like to sacrifice their food security. The proposed strategy is to bring vast areas of degraded and low quality lands under biodiesel plantations.

Collector's Model

In many Asian countries already a large number oilseed trees exist as avenue plantations or in forest areas. For example, in India *Pongamia pinnata* and *Azadirachta indica* trees are commonly grown as avenue plantations on common lands as well as on riverbanks. At present the seeds from these trees are not commercially used to the possible extent. The production needs to be enhanced and this requires favourable strategies where growers are not put to hardship and loss. One of the options in promoting livelihoods of the poor is through the promotion of plantations by user groups or Self-Help-Groups (SHGs) on common pool lands like degraded forests, community owned lands, low quality lands not suitable for annual food crops production, railway setbacks, canal embankments, tank foreshore, etc. The usufruct rights for harvests are ensured to the groups who manage the plantations but the right on land is not extended. Through assured market demand the landless people in groups (SHGs) could handle collection from the decentralized plantations and earn their livelihoods. This strategy along with the strategy to develop/rehabilitate degraded lands through biodiesel plantations could ensure an efficient use of existing natural resources for promoting a win-win solution through biodiesel plantations.[15]

Decentralized Extraction and Centralized Processing

There is a need to promote and utilize the expellers available locally as this will minimize the cost of transport of raw material, and will generate employment in rural areas. This will also ensure an availability of cake in the rural areas and the recycling of cake back to the fields. There is a possibility of using oil directly in the irrigation pumpsets and it can be blended directly with diesel up 10 per cent for use in farm machinery. Electricity generation is also possible in remote areas using filtered oil directly but all these require decentralized extraction. For esterification and biodiesel production a centralized processing facility can be created, which will minimize the cost of transportation and ensure strict quality adherence.

Recycling of Cake for Production of Biogas and Compost

The cake offers an excellent opportunity for reducing the dependence on fertilizers and its marketing will generate additional income. The cake can also be used for production of biogas before composting and both these processes will improve nutrient availability as fertilizer to the crops during the season itself as well as reduce pressure on energy demand for domestic use.

Carbon Trading by Women SHGs

The associated benefit with biodiesel plantations is small income for the rural communities through carbon trading. Under natural conditions *Pongamia pinnata* was observed to sequester 17, 72, 331 and 347 kg carbon per plant at 5, 10, 15, 25 years of age, respectively in a study carried out in Adilabad district.[16] Adilabad district of Andhra Pradesh (AP) State in India is richly endowed with a good forest cover (47 per cent), black soils (Vertisols), and substantial rainfall (1,100mm). The district has a large presence of indigenous people, comprising *Gonds*, *Lambadas*, and others.

Powerguda, a remote tribal hamlet in the Adilabad district, became an environmental pioneer when it sold the equivalent of 147 tons of carbon dioxide in verified emission reduction as carbon replacement to the World Bank in October 2003. The World Bank paid US $ 645 to Powerguda women SHGs to neutralize the emissions from air travel and local transport by international participants attending its international conference in Washington, USA held on 19-21 October 2003. This was the first time that the multilateral agency made a direct payment to an Indian village for exporting environmental services.[17] The emission reduction was calculated on the basis of 51 tons of *Pongamia* oil substituting for petroleum diesel over 10 years from the planting of 4500 *Pongamia* plants in 2002 (see Table 7). The carbon income was ploughed back by the women SHGs for raising a nursery and planting of *Pongamia* trees. The women's group are able to raise 20,000 seedlings of *Pongamia* and *Jatropha* from this income every year and generate further income through sale of seedlings. Most of seedlings are sold to the forest department, but some are also planted on field boundaries, farm bunds and community owned lands. The women are also members of the forest protection committee formed to protect the nearby forest under the government's Community Forest Management project. Other village activities include social networking, watershed management, improved agricultural pratices and income generating activities. The establishment of an oil mill to crush *Pongamia* seeds into oil has helped the women to increase income through the sale of oil and oilcake.

Table 7: Carbon Calculations for Powerguda Village, 2003-2012[1]

Year	Oil yield (kg)	Trees	Total oil yield (kg)	C(t)	CO2 eq (t)	Value (US$)	Discount value (at 3%)	NPV
2003		3,600	410	0.32	1.17	6.72	1.00	6.72
2004			494	0.39	1.41	8.09	0.97	7.85
2005			590	0.46	1.69	9.66	0.94	9.08
2006	0.5		1,125	0.88	3.22	18.43	0.91	16.77
2007	1		3,600	2.81	10.31	58.97	0.88	50.71
2008	1.5		5,400	4.21	15.46	88.45	0.85	51.89
2009	2		7,200	5.62	20.61	117.94	0.82	96.71
2010	2.5		9,000	7.20	26.43	151.24	0.79	119.48
2011	3		10,800	8.42	30.92	176.90	0.76	134.45
2012	3.5		12,600	9.83	36.07	206.39	0.73	150.66
			51,219	40.13	147.29	842.79		644.32

Note: [1]Carbon value is calculated at US$ 21 t^{-1} of carbon, or US5.722t^{-1}$ of CO_2 equivalent
Source: D'Silva *et.al.,* 2004.

The pioneering work of extracting oil from *Pongamia* seeds, exporting environmental services to the World Bank and improved income level has given the people a sense of pride and has put the village on the map of the world. Women's involvement in nursery raising, plantation, carbon trading has triggered the social capital development and social cohesion. Today, the women are able to manage their finances, are sensitized about health and nutritional issues such as HIV, etc. and need education for all. There is no migration from the village and this may be attributed to an increase in the level of income in each family. The improvement has come mainly from agriculture (93 per cent) and forest (7 per cent) which translates to Rs.27,821 (2002-03) from Rs.15,677 (1999-2000). In 2003, the four groups of SHGs in Powerguda had Rs. 5,52,000/- as total savings, which worked out Rs. 6,608/- per household. Now, they are in a position to get loans from banks and are out of the clutches of moneylenders. Powerguda action has inspired several neighboring villages to plant *Pongamia/Jatropha* trees on a large scale and this has been repeated in 20 other villages in Adilabad district.[18]

Returns from Plantations

Not much research work has been undertaken on these plantations and their economic returns. Several types of returns from the growing and the use of products from *Jatropha* and *Pongamia* need to be carefully estimated. There is a need for research on the operational scale to identify plus trees and improved management techniques for higher productivity and economic viability. The economic returns may vary from place to place depending on the climate, soil and management practices. The tangible benefits, include the market prices of different products like diesel and by-products like cake and glycerol while intangible benefits are many. Besides tangible benefits, there are innumerable intangible benefits like:

- Potential to produce a green fuel that will reduce carbon dioxide emissions as biodiesel will be recirculating atmospheric CO_2 through the process of photosynthesis.
- Greening of waste and marginal lands, which has positive impact on hydrology.
- Alleviate soil degradation, desertification and deforestation and conserve soil and rainwater.
- Improved ecosystem and environmental sustainability.

Conclusions

Tree based oilseeds offers scope for rehabilitating degraded lands and improve livelihoods in developing countries. Green cover over barren and unproductive lands will reverse the process of degradation caused mostly by water erosion. The fertility of these marginal lands will improve through recycling of nutrients from the deeper layers, addition of leaf litter, nitrogen fixation (*Pongamia*) and carbon will be sequestered unlike fossil fuels. Studies have shown that *Jatropha* returns 19 kg N ha^{-1} $year^{-1}$ through litter fall from the third year onwards.[19] Employment generation from plantation, harvest and processing activities will reduce migration from the rural areas, which is a big concern in most Asian countries. Participation of women SHGs in managing the plantations will boost their livelihoods and will empower the women. Recycling of cake will reduce the dependence on inorganic fertilizers and will pave the way for organic farming. Further, there is scope of earning carbon credits and the additional benefits can be passed on to the growers.

As necessary market demand, government support and technologies to process do exist, however, the potential cannot be tapped mainly because of insufficient availability of feedstock. Biodiesel plantations for rehabilitating degraded lands, and increasing income from low quality lands provides a win-win situation for protecting the environment, increasing income, and generating employment opportunities in rural areas. However, the lack of scientific information about suitable management practices as well as identification of high-yielding accessions and lack of high yielding cultivars on a large scale holds back development in this area. There is an urgent need to undertake detailed research for development of management practices, high-yielding cultivars, mass multiplication techniques, suitable development models for increasing supply of raw material for biodiesel production. The by-product cake after extraction of oil is a potential source of valuable plant nutrients as well as organic matter for improving the soil quality of tropical soils, and is a good source of energy through biogas for meeting the domestic energy needs. In conclusion, the development of biodiesel plantation provides win-win situation and needs targeted investments towards research and development aspects for ensuring the supply of raw material.

Endnotes

1 Roy and Shah, 2002.
2 Sreedevi *et.al.*, 2006.
3 CRIDA, 2004.
4 Hegde, 2003.
5 Paramathama *et. al.*, 2004.
6 Reddy, 2005.
7 Mishra *et. al.*, 2004.
8 Paramathma *et. al.*, 2004.
9 Sakaguchi and Somabhi, 1987.
10 Paramathma *et. al.*, 2004.
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16 Nair, 2005.
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