STRATEGY FOR REHABILITATION OF DEGRADED LANDS AND IMPROVED LIVELIHOODS THROUGH BIODIESEL PLANTATIONS†

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Biofuels are gaining importance in the backdrop of increase in fossil fuel prices driven by reduced supplies and increased concern about environmental pollution. Considering the issues of rural poverty and water scarcity the efforts in the area of biofuel need to be looked along with other concerns. In this paper, the strategy for rehabilitating degraded lands using biodiesel plantations for improving livelihoods while protecting environment is discussed. The experiences of developing common property resources with the help of self-help groups (SHGs) and ensuring usufruct rights to the SHGs for harvesting seeds from the plantations are discussed. At the same time, lack of reliable scientific data to support various claims on biodiesel plants is explained. Preliminary results from research under way on Jatropha and Pongamia are also clarified. Different approaches for biodiesel plantations and oil extraction are looked into. Results from village-level case study on Pongamia pinnata seed collection from existing forests, oil extraction and Carbon trading are also discussed in this paper.

INTRODUCTION

Energy security has assumed greater significance than ever, as energy consumption, food production, improved livelihoods and environmental quality along with water availability are interrelated. Asian countries with dense population are more prone to energy crises than their other counterparts in the world. A strong nexus exists between overall development and energy consumption as well as the source of energy. Developed countries use more fossil fuel to meet their energy demand, whereas developing countries use lower energy as well as higher proportion of energy from renewable sources such as wood, coal, animal power, cow dung cakes, etc. (Karekezi and Kithyoma 2006).

Similarly, nexus between energy use for irrigation of water and agricultural output exists. Numbers of bore wells in India and energy consumption have increased dramatically over the last two decades. Groundwater now sustains almost 60% of the India's irrigated area. Even more importantly, groundwater now contributes more to agricultural wealth creation, than any other irrigation source (Roy and Tushar Shah, 2002). A recent study undertaken by ICRISAT in Rajasamadhiyala Watershed in Gujarat, indicated that not only number of open and bore wells increased from 357 to 508 within eight years, but pumping hours also increased from 5.25 to 10.4 hours per day, putting pressure both on energy and groundwater. Improved water availability in rainfed areas through watershed development not only improved family incomes, but also private investment in agriculture (Wani et al. 2003 and 2005).

In addition, farmers are also keeping additional diesel pump sets as stand by to cope with the prevailing power cuts (Sreedevi et al. 2006). Agriculture is now more dependent on mechanical and electrical source of energy than on human and animal power. During 1988-89 to 2004-05 farm power availability in Anantapur village in Andhra Pradesh, a predominantly dryland area, increased by 28%, while mechanical power use increased remarkably by 730% (CRIDA, 2004).

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. Countries like India have to maintain a delicate balance between food, fodder, water and energy security. All these are interrelated and need to be considered together. For example, India has to produce 200 million tonnes of food to feed its ever-growing human population. Water demand for food crops as well as for industries, human needs and

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environmental services are increasing. According to the prediction, by 2025 one third of the developing world would be facing scarcity of water (Seckler et al. 1998). Therefore, a careful consideration for sensible use is a must. Similarly, of 852 million poor people in the world, 221 million are in India and more number of poor reside in dry rural areas. Edible oils as well as productive lands will have to be spared for food.

Considering all these points, use of degraded common property resources (CPRs) along with low quality private lands with conservation and efficient use of rainwater strategies open up a new window of opportunities, for growing non-edible oil trees for improving livelihoods of rural poor (Wani et al. 2006a). The advantages of perennials are many as the greenery will protect the land from further degradation and generate employment in rural areas. The total number of species with oleaginous seed material from different sources varies from 100 to 300, and of them 63 belonging to 30 plant families hold promise (Hegde, 2003). Two species namely Jatrohpa curcas and Pogamia pinnata are favored in India, because of their contrasting plant characteristics and the species selected should match the site characteristics (**table 1**).

NON-EDIBLE OIL SOURCES FOR BIODIESEL

Jatropha is highly drought resistant and is well suited to semi-arid conditions, although it also thrives in arid areas. It is mostly found at lower altitudes (0-500 m) in areas with average temperature well above 20^{0}C, but can grow at higher altitudes and tolerates slight frost and grows well in conditions up to 1000 mm rainfall (Paramathma, 2004). Pongamia thrives well up to 1200 m altitude and in areas where rainfall is 500-2500 mm per annum. Pongamia withstands -1^{0}C to 50^{0}C. Both plants can withstand drought, but Jatropha sheds the leaves during dry period (summer) while Pongamia retains leaves and it is evergreen. However, water stress affects the crop productivity in Pongamia as well as Jatropha. Gall formation on leaves caused by mite in Pongamia is a major concern as it affects leaf area/ photosynthesis when it is widespread. Jatropha grows better in well-drained soils and is susceptible to collar rot disease in high rainfall humid areas or where there is excessive irrigation or water logging. Pongamia can tolerate water logging as well as saline and alkaline conditions. Both the species are suitable for semi-arid tropics as they are not palatable to livestock.

TABLE 1: JATROPHA VIS-À-VIS PONGAMIA

Characteristics	Jatropha curcas	Pongamia pinnata
Ecosystem	Arid to semi-arid, 0-500 m altitude	Semi-arid to sub-humid, 1200 m altitude
Rainfall	Low to medium	Medium to high
Soil	Well drained soils	Tolerant to water logging, saline and alkaline soils
Nitrogen fixation	Non-fixer	Fixer
Plant suitability	Wastelands, degraded lands, live fence for arable lands, green capping of bunds, shallow soils	Field boundary, nala (drain) bank 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 (with grafting it can be reduced)
Yield	1.0 kg plant-1	10 to 100 kg plant-1
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-1

Straight vegetable oils from Jatropha and Pongamia are also used directly in high rpm diesel engines for power generation and for pumping water (D'Silva et al. 2004). The use of blended fossil fuels with biofuels results in substantial reduction of un-burnt hydrocarbons by about 30%, carbon monoxide by about 20% and particulate matters by about 25%. Moreover, sulphur content in the emissions from the use of blended fuels is almost negligible (Francis et al. 2005).

SOURCES FOR BIO-ETHANOL PRODUCTION

In Brazil, since early 1970 bio-ethanol produced from sugarcane juice is used as a energy source for vehicles. In many countries, especially in India, molasses (a by-product of sugarcane after the extraction of sugar) is being used to produce ethanol, which is at present used for industrial as well as human consumption. The situation is similar in other developing countries in Asia, Africa and Latin America. Ethanol can be produced from cereal grains including maize, sorghum and starchy tubers such as cassava. In recent years, sweet sorghum stalks juice and cassava root tubers are emerging as viable sources for ethanol production.

Also, technologies are now being developed to produce ethanol from crop residues/ stovers (popularly termed as ligno-cellulose biomass) of cereal crops, including sorghum. The roots being rich in starch (about 70-85% on dry weight basis) cassava is rapidly becoming a preferred crop for biofuels in Asia (Thailand and China) sub-Saharan Africa (Tanzania and Nigeria) and Latin America (Colombia). Nigeria is a leader in the use of cassava for the production of ethanol, and now Tanzania is following in Nigeria's foot steps. Sweet sorghums are similar to grain sorghums, grows rapidly, have wider adaptability and high biomass producing ability, and have sugar rich stalks (Reddy et al. 2005). The juice extracted from stalks of sweet sorghums can be used for ethanol production. However, in large parts of South Asia and sub-Saharan Africa the use of sorghum grains (or any other rains) for ethanol production is not advisable, as food security will be compromised.

CURRENT STATUS OF BIODIESEL PLANTATIONS

Biofuels are gaining importance as a number of countries (developed and developing) have made mandatory policies for blending fossil fuel petrol with bio-ethanol and diesel with biodiesel. Demand for biofuels is expanding very fast as necessary policy support is there, demand exists, and technology to produce bioethanol and biodiesel are available. However, shortage of raw material to produce biofuels is becoming a major constraint (Wani et al. 2006b and Ortiz et al. 2006).

For meeting the growing demand for biodiesel developed countries are using edible oil seed crops such as soybean, rapeseed, groundnut, sunflower and cereals such as maize for bio-ethanol production. However, countries like India cannot afford to use edible oils for biodiesel or cereal grains for ethanol production.

Non-edible oil seeds shrubs such as Pongamia, Jatropha and neem (Azadirachta indica) are explored for commercial production for biodiesel and sweet sorghum for ethanol. These crops not only can meet the oil demand for biofuel production, but can also green the wastelands in drought-prone areas, without sacrificing the food and fodder security as well as improve the livelihoods of the rural poor (Wani et al. 2006b).

Not much scientifically validated information is available for Jatropha and Pongamia, and many policy decisions are taken in to factor the environment. Both these plants are generally grown in isolation that too without proper agronomic management. However, due to escalating oil prices and race to achieve energy security, plant like Jatropha has become a wonder plant. Lot of claims on yield potential, water requirement and pest and disease tolerance are not based on scientific observations. It is important that science is applied to assess and harness the potential, and policy decisions are not taken in a "factory environment." The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) at Patancheru, India and several other institutes have initiated systematic research on biodiesel from non-edible sources and ethanol from sweet sorghum (Wani et al. 2006 a & b).

BIODIESEL PLANTATIONS

Seedling Management

Tree improvement programmes have mainly concentrated on few plants like Eucalyptus and Poplars, but no systematic efforts have been made in the past to improve tree borne oilseeds like Pongamia and Jatropha. The genotype and the environment influences yield, therefore, the source of seed assumes greater significance. Quality of the seedlings also affects survival, growth and yield and it is dependent on media and propagation technique.

Evaluation of seed sources

It is desirable to select seed source for multiplication from known plant population with favorable traits. In a study conducted at ICRISAT, samples were collected from various States of India for oil content (27.8% to 38.4%), according to seed weight (44g to 77g) and germination percentage (**table 2**). The seed source IJC-2 and IJC-6 were found to be promising in terms of oil content. A similar study is under way for Pongamia.

Nursery Techniques

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

Direct seeding: Seeds of Jatropha (sprouted) and Pongamia can be sown directly in the main field. The field should be ploughed and spots may be marked and enriched with FYM and DAP. Seedlings grown by this method will take time for establishment and will result in slow growth in the initial period. However, there should be enough moisture in the soil to support germination and seedling growth. Damage by birds and rodents to germinating seeds results in reduced plant stand. Frequent weeding is required to prevent the seedlings from competing with weed. Similarly, soil working around the seedlings will boost the growth and will improve the moisture and rainfall infiltration. Pongamia seedlings grown in this way can be grafted in-situ with a scion from high yielding tree after nine months.

Vegetative propagation (transplanting of pre-rooted cuttings/grafting): Jatropha can be multiplied by raising the cuttings in a raised bed and later transplanted in the main field. Multiplication of Pongamia by cuttings is difficult but grafting is easier. Cuttings of 2-3 cm thickness from the lower portion

TABLE 2: EVALUATION OF SEED SAMPLES OF JATROPHA FOR OIL CONTENT, TEST WEIGHT AND PERCENT GERMINATION

S. No.	Collection No.	Place of collection	100 seed weight (g)	% oil content	Germination (%)
1	IJC-1	Rajgarh	63.8	28.0	10
2	IJC-2	AP	68.2	38.4	90
3	IJC-3	Tamil Nadu (cape viridi type)	49.2	29.9	61
4	IJC-4	Tamil Nadu (Erode local)	44.0	28.6	85
5	IJC-5	Tamil Nadu (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

of the shoot, having 25-30 cm length may be prepared in the month of March, when plant 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 seed within a year of planting and growth is rapid. However, it has been observed that seedlings raised from seeds have better root system compared to cuttings. The plants raised through cuttings will be true to type and will have similar characteristics of the mother plant but are prone to damage by strong winds. To maintain the quality of plantations of Pongamia, there is a possibility 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, following the technique used for mango cultivation.

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 volume. Soaked seeds are sown at a row spacing of 25 cm and plant to plant 5 cm. The plants will be ready for transplanting in the main field six weeks after germination. The plants may be carefully uprooted from nursery beds, wrapped in wet gunny bag and transported to 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 bare root seedlings.

Bare root seedling production of Pongamia is difficult as it has 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 color (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). DAP may be added @ 1.0 g per polybag of 2 kg weight. Good quality seeds having 80% germination should be sown with 1 seed per bag at 2-3 cm depth for getting higher rate of germination. One gram of mycorrhizae (mixed culture) may be placed below the seed at the time of sowing to enhance growth of seedlings. In a study, Jatropha seedlings treated with Mycorrhizae had higher plant height, girth and number of leaves compared to controlled plants, when sampled 85 days after sowing (**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 higher number of nodules, shoot and root weight, when sampled 85 days after sowing (**table 4**). Grading and root pruning is suggested to promote uniform growth of seedlings.

Field Management

Genotype and the environment (field condition) influence the survival and growth of the seedlings. There are several steps involved in management of the field. First, the field may be ploughed (deep tilled), followed by harrowing utilizing off-season rains or at the beginning of rainy season. Direct planting may be taken up in dug out pits in hilly and rocky areas where cultivation is not possible.

Spacing: A spacing of 3 m x 2 m or 3 m x 3 m spacing is desirable for intercropping and intercultivation. For hedgerow/boundary plantation of fields, the spacing should be 1 m x 1 m. For Pongamia blockplanting, a spacing of 5 m x 5 m or 6 m x 6 m is suggested. For avenue and field

TABLE 3: EFFECT OF MYCORRHIZAL INOCULATION ON GROWTH OF JATROPHA SEEDLINGS

Treatment	Height (cm)	Girth (cm)	Number of leaves
With Mycorrhizae	47	6.5	16
Without Mycorrhizae	35	5.9	12

TABLE 4: EFFECT OF RHIZOBIUM AND MYCORRHIZAL INOCULATION ON NODULATION AND BIOMASS OF PONGAMIA SEEDLINGS

Treatment	Nodule number/ seedling	Wet weight (g/seedling)		Dry weight (g/seedling)	
		Shoot	Root	Shoot	Root
No treatment (Control)	11.0	5.52	5.01	1.22	1.33
Rhizobium alone	19.0	5.95	5.35	1.32	1.79
Mycorrhizae alone	12.0	5.81	5.87	1.27	1.47
Mycorrhizae + Rhizobium	17.0	6.16	7.87	2.33	1.93
Mean	15.0	5.86	6.02	1.53	1.63
P< (0.05)	1.8	2.40	2.02	0.98	0.69

boundary planting, a spacing of 2 m to 4 m may be given from plant to plant.

Digging of pits: The recommended size of the pit is 30 cm x 30 cm x 30 cm for Jatropha and 45 cm x 45 cm x 45 cm for Pongamia. The pits may be dug well in advance of planting time.

Filling of pits: Refilling of the pits may be done by mixing 1.0 kg to 2 kg of FYM, 50 g of Di-Ammonium Phosphate (DAP). Methyl parathion (2% dust) @ 5 to 10 g or 5 g of thimmet granules per pit may be applied to protect the young saplings from termite damage.

Transplanting: Seedlings may be transplanted with the on set of rainy season, and the soil around the seedlings should be compacted. 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 with herbicides are 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 initial period. Irrigation once in a month during dry period will be quite beneficial for enhancing growth and productivity. Rainwater conservation techniques like planting on contour or staggered trenches will be advantageous in hilly, sloppy 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. Paddy husk of 5 cm thickness 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 needs to be standardized. Jatropha can withstand long periods of drought by shedding leaves, while Pongamia remains green during dry periods. However, water stress during growth period affects yield adversely in both the species. If possible, fortnightly irrigation is suggested to improve growth and yield.

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. Hence, organic manures (FYM/ Vermicompost) @ 1 kg plant-1 for Jatropha and 2 kg plant-1 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 @ 50 g and 100 g of urea and SSP per plant, respectively while for Pongamia DAP @ 100 g per plant may be applied.

Nutrient trials with Jatropha at ICRISAT farm revealed that application of 50 g urea +76 g single super phosphate per plant resulted in highest plant height after two years of planting. However, few trees which started yielding indicated that plants with 100 g urea + 38 g SSP per plant per annum yielded more than other treatments. Alternatively, oilcakes can be recycled as fertilizers to these plants to maintain the productivity of soil. The plants respond well to an 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: 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 also recommended by the growers. Supplemental irrigation resulted in early fruiting of Jatropha in first year along with good plant growth. Similarly, in a field study in Nalgonda, it is observed that Pongamia too has a liking for water and fertile soils. Pongamia grows mostly along the watercourses like streams and waterways (Mishra et al. 2004), 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 (Paramathma et al. 2004). Once in ten years, the plant may be cut, leaving one-foot height from ground level for rejuvenation in case of Jatropha. The growth is quick and the plant starts yielding in about a year. This will be useful to induce new growth and to stabilize yield. In a study of canopy management in North East Thailand, cutting of Jatropha at height of 50 cm from bottom was found reasonable to maintain a compact bush form. The end of dry season was found optimum 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 romote useful fruiting branches and to maintain a compact bush form (Sakaguchi and Somabhi, 1987).

The Pongamia plants may be pruned initially to give stem a straight form and later lightly lopped for green leaf mulch. All side branches of tree 1/3rd from bottom may be pruned and top 2/3rd brancheson the plant may be retained. Periodical pruning can be carried out depending upon the vegetative growth of the plants. Diseased, dead, excessive, weak and lateral branches should be removed.

Insect pests: In 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 and capsule borer will damage the fruits (Paramathma et al. 2004). In 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 liter 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 liter of water or wettable sulphur @ 3 g per liter of water.

Diseases: In case of Jatropha, collar rot may become a problem in some areas in monoculture plantations, under irrigated condition or under severe water logging conditions and where there is excess soil moisture. The rot can be controlled by application of 1% Bordeaux drenching. Minor diseases such as root rot, damping off, powdery mildew and leaf spots are reported (Paramathma et al. 2004). There is no specific mention of diseases in case of Pongamia.

Harvesting: The flowering in Jatropha depends upon the location, agroclimatic conditions, fertility management and availability of water. Generally, it takes place from August to December in India. However, flowering and fruiting depends on 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 to physiological maturity (yellow capsule stage) from trees. 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. Rural women and unemployed youth can be employed for seed collection, which will help in improving 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 starts bearing from first year onwards and stabilizes from 5th year onwards. It gives economic yield up to 30-40 years. The expected yield from one-hectare plantation is near about 750-1500 kg under rain-fed and 1500-2500 kg under irrigated condition. Pongamia starts bearing at the age of seven years. A single tree yields 10–100 kg seed, indicating a minimum yield potential of 1000 kg ha-1, however, grafted seedlings starts bearing from third year. Irregular bearing has been noticed in Pongamia and yield may vary from year to year.

Storage and viability: The seeds should be dried to reduce the moisture content (5-7%) 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 the fields as an organic fertilizer or can be sold to prospective buyers.

Impact of Oilcakes on Crops Yield

Oilcake appears to be a very attractive proposition compared to oil itself, as it contains all the macro and micro-nutrients. It is an excellent organic fertilizer unlike inorganic fertilizers that supply one or two nutrients. Four kilograms of seed of Pongamia or Jatropha gives about three kilograms of oilcake, which is generally sold at Rs. 3 to Rs. 7 per kg depending upon the demand and supply scenario. The oilcake is mostly used for fertilizing plantation or commercial crops. An analysis of oilcake of Pongamia and Jatropha indicated presence of all the essential elements required for plant growth, and is found to be particularly rich in nitrogen and sulphur (**table 5**). On-farm experiments with Pongamia oilcake in Adilabad district of Andhra Pradesh resulted in 41-47% increased income from maize and soybean when compared to farmer's practice (**table 6**).

TABLE 5: CHEMICAL COMPOSITION OF OILCAKES VIS-A-VIS POPULARLY USED FERTILIZERS, ANALYZED AT ICRISAT, PATANCHERU, INDIA

Nutrients	Jatropha[1]	Pongamia[2]	Pongamia[3]	DAP*	Urea
Nitrogen (%)	4.91	4.28	6.14	18	45
Phosphorous (%)	0.90	0.40	0.72	46	0
Potassium (%)	1.75	0.74	1.07	0	0
Calcium (%)	0.31	0.25	0.96	0	0
Magnesium (%)	0.68	0.17	0.35	0	0
Zinc (ppm)	55	59	95	0	0
Iron (ppm)	772	1000	1053	0	0
Copper (ppm)	22	22	41	0	0
Manganese (ppm)	85	74	108	0	0
Boron (ppm)	20	19	43	0	0
Sulphur (ppm)	2433	1894	3615	0	0

Source of oilcake: 1 Coimbatore, Tamil Nadu; 2 Powerguda, Andhra Pradesh; 3 Tumkur, Karnataka
** DAP = Diammonium phosphate*

TABLE 6: RESPONSE OF SOYBEAN AND MAIZE TO THE APPLICATION OF PONGAMIA OILCAKE AND INORGANIC FERTILIZERS IN FARMERS' FIELDS IN ADILABAD DISTRICT, ANDHRA PRADESH, INDIA

Crop	Treatment	Yield (kg/ha)	Income (Rupees/ha)	Cost of fertilizer (Rs.)	Benefit (Rupees/ha)
Soybean	Farmer's practice (DAP 75 kg/ha)	900	10800	450	10350
	Pongamia cake (PC) (300 kg/ha)	1340	16080	1500	14580
	Recommended dose of fertilizer (RDF) 20 kg N/ha	1450	17400	250	17150
	50% RDF + 50% PC	1650	19800	1500	18300
Maize	Farmer's practice (DAP 125 kg/ha)	1200	6000	1125	4875
	Pongamia cake (PC) (1800 kg/ha)	2240	11200	4000	7200
	Recommended dose of fertilizer (RDF) 90 kg N/ha	2390	11950	1000	10950
	50% RDF + 50% PC	2560	12800	5000	7800

Similar studies carried out by Ngoma (1999), in Zimbabwe have revealed that application of Jatropha oilcake at the rate of 0, 0.25, 0.5 and 1.0 kg/sq. m resulted in cabbage yield 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 growth rates of tomato and total above ground dry matter with increased application rates of Jatropha and castor oilcakes. Henning (2000) is of the opinion that Jatropha plants can reduce the soil and water erosion when planted as live fence, and the oilcake 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 oilcake serves the interest of farmers as well as government as 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.

Plantation Management - Strategies for Livelihoods Enhancement

The focus is mostly on fine cereal – rice and wheat, rather than on the coarse cereals. A niche exists for promoting biodiesel plantations provided forward and backward linkages are ensured. In the initial phase, the government needs to act as facilitator and ensure a minimum support price. State Government of Andhra Pradesh (AP) has ensured a minimum support price of Rs. 6 per kg for Jatropha seed and is providing subsidy on irrigation and free saplings to the farmers in drought prone areas for encouraging biodiesel plantations as an alternative land use option. Buy-back for the output is ensured and the road transport corporation of the AP is willing to buy the entire quantity of biodiesel produced and experiments are under way in several states of India. Indian Railways are also looking for large quantities and demand from European Union is huge. The production needs to be enhanced and this requires favorable strategies where growers are not put to hardship and loss. One of the options of promoting livelihoods of poor is through promotion of plantation by user groups or SHGs on common pool lands like degraded forests, community owned lands, along the railway tracks, bund canals, tank foreshore, etc. The usufruct rights for harvests should be ensured to the groups who manage the plantations.

Decentralized extraction and centralized processing

In order to improve rural livelihoods and retain much of the capital in rural economy, deliberate measures need to be undertaken with necessary policy support. There is a need to promote and utilize the expellers available locally, as it will minimize the cost of transport of raw material and will generate employment in rural areas. This will also ensure availability of oilcake in rural areas and recycling of oilcake to the fields. There are examples of using straight Pongamia and Jatropha oil in high rpm diesel engines to generate electricity as well as to pump out water from wells. Electricity generation is also possible in remote areas using filtered oil directly, but all these require decentralized extraction (Wani et al. 2006a). Esterification and trans-esterification can also be promoted as an income-generating activity for unemployed youth by providing proper training, registration, financial and policy support. The processing facility can be created in a central location by pooling cluster of villages, which will minimize the cost of transportation and will reduce cash outflow.

Recycling of oilcake for production of biogas and compost

The oilcake offers an excellent opportunity for reducing the dependence on fertilizers and its marketing will generate additional income. The oilcake can be used for production of biogas before composting and both these two processes will improve nutrient availability to the crops during the season itself as fertilizer.

Carbon trading

Although, carbon trading is possible the process of certification for the certifiable emission reductions (CERs) is costly as well as time consuming. To make the clean development mechanism (CDM) work for the poor, there is need to work out a simple mechanism, which could be operated as corporate social responsibility rather than getting the credits to neutralize the pollution. Adilabad district of Andhra Pradesh (AP) State in India is richly endowed with a good forest cover (47%), black soils (Vertisols) and substantial rainfall (1,100 mm). The district has a large presence of indigenous people, comprising Gonds, Lambadas and others. Powerguda, a remote tribal hamlet in the district became an environmental pioneer when it sold the equivalent of 147 tons of carbon dioxide in verified emission reduction (VER) to the World Bank in October 2003. The World Bank paid US $ 645 to Powerguda 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 (D'Silva, 2004).

The (VER) was calculated on the basis of 51 tons of Pongamia oil substituting for petroleum diesel over 10 years from planting of 4500 Pongamia plants in 2002 (**table 7**). The carbon income was utilized to provide "seed money" for raising nursery and planting of trees. The women's group has raised 20,000 seedlings of Pongamia and Jatropha from this income. Most of the 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 practices and income generating activities. The establishment of an oil mill to crush. Pongamia seeds into oil has helped the women to increase income through sale of oil and oilcake.

TABLE 7: CARBON CALCULATIONS FOR POWERGUDA VILLAGE, 2003-2012 *

Year	Oil yield (kg)	Trees	Total oil yield (kg)	C (t)	CO^2 eq (t)	Value (US$) (at 3%)	Discount value	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

** Carbon value is calculated at US$ 21 t-1 of carbon, or US$5.722t-1 of CO^2 equivalent*

Powerguda's example in carbon trading has been repeated in 20 other villages in Adilabad district. Recent study at ICRISAT by Nair (2005) Pongamia pinnata could sequester 17, 72, 331 and 347 kg carbon per plant at 5, 10, 15, 25 years of age, respectively, under natural conditions of Adilabad district.

There is no migration from the village, which can be attributed to increase in the level of income in each family. The improvement has come mainly from the agriculture (93%) and forest (7%) which translates to Rs. 27,821 (2002-03) from Rs. 15,677 (1999-2000). In 2003, the four groups of HGs in Powerguda had Rs. 5,52,000 as total savings, which worked out to Rs. 6,608 per household. Now, they are in a position to get loans from banks and are out of the clutches of moneylenders. 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 about the need for education for all. Powerguda action has inspired several neighboring villages to plant Pongamia/Jatropha trees on a large scale and there is a plan to sell one million ton CO^2eq from 100 villages in Adilabad.

Returns from plantations

Not much work has been done in large extent on these plantations and its economic returns. There is a need for research on an operational scale to identify plus trees and improved management techniques for higher productivity and economic viability. Several types of returns from growing and use of the products from Jatropha and Pongamia need to be carefully estimated (AFPRO, 2001). The economic returns may vary from place to place, depending on the climate, soil and management practices. The tangible benefits are from different main products like biodiesel and by-products like oilcake and glycerol. Besides economic benefits, there are innumerable in-tangible benefits like:

- Potential to produce a green fuel that will reduce carbon dioxide emissions and create much-needed rural jobs;
- Contribute greatly towards carbon sequestration thereby providing clean and green environment and possibility of carbon trading;
- Greening of waste and marginal lands, which have the potential positive impact on hydrology

- Alleviate soil degradation, desertification and deforestation and conserve soil and rainwater; and
- Improved ecosystem and environmental sustainability.

CONCLUSIONS

Biodiesel plantations offer an opportunity for converting fallow and unproductive lands into green oil fields as a renewable source of energy. Petroleum diesel is a major contributor to both greenhouse gasses (GHG) emission and other atmospheric pollutants. The use of biodiesel blends or neat fuel or green fuel will stop degradation of land and the environment and also improve the rural livelihoods. There is a need to conduct research in identifying improved plant types for higher returns from the plantations. Modification in the farm machinery is needed for making use of oil in-situ rather than depending on processing. This is likely to reduce the dependence on fossil fuel and ensure energy security in future.

Green cover over barren and unproductive lands will reverse the process of degradation caused by mostly water erosion. Fertility of these marginal lands will improve through recycling of nutrients from 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 third year onwards (Rao and Korwar, 2003). Employment generation from plantation, harvest and processing activities will reduce migration from 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 oilcakes will reduce the dependence on inorganic fertilizers and will pave the way for organic farming. Further, there is scope for earning carbon credits and the additional benefits can be passed on to the growers.

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