Participatory Development of Agroforestry Ecosystems Including Oilseed Trees

A research report by associates of the CSAL Network

Introduction

Many issues have to be faced if the human species is to survive comfortably

- Continuing hunger and income inequalities in many countries, threatening violence
- The destruction of natural and agricultural ecosystems
- The finite supply of mineral oil
- Climate change/sea encroachment/extreme weather events, thought by many to be related to an increase in atmospheric 'green house gases'
- Desertification and rising water insecurity as plant life retreats
- Education systems that do not prepare young people for the local and global challenges they have inherited
- Obesity and related health issues related to the flawed production and misuse of food
- Well-researched illnesses that could be cured but are not
- Excessive urbanisation outrunning essential infrastructure
- Water management and sanitation deficiencies
- Pollution of the air, land, freshwater and oceans

There are also location-specific problems such as those created by political isolation, conflict, migration, and poor communication facilities. Most of these issues have impact on the less developed parts of the world. In the case of climate change, the less industrialized countries may well be the victims of the more industrialised ones. Paradoxically, the poorer countries that are most challenged by these issues may be able, with help, to contribute most to the implementation of long-term global solutions. This document suggests a way forward through research, education, and the application of shared knowledge to these challenges for social change.

The solution to many of these fundamental problems can be embodied in one set of activities: participatory development of agroforestry ecosystems, including oilseed trees .

Investment in this solution provides, primarily and virtually simultaneously:

- A renewable supply of Pure Plant Oil Biofuel (PPOB), which is a direct substitute for diesel fuel derived from mineral oil—a supply that will continue to produce for 100 and more years
- Stable agroforestry systems that support sustainable food production on marginal or degraded land
- The (re-) establishment of functional biodiversity on marginal land that has been degraded by over-farming or deforestation
- Land restoration and stabilization; reversal of desertification

It should be noted that the focus is on developing land that does not currently support conventional crop production. Investment in oilseed trees does not encroach on productive farmland or on the world’s diminishing primal forest cover. On the contrary, it extends food production into 'waste' or degraded land while adding to forest cover. Plantations can act as a nursery for forest regeneration (for instance along riparian areas) and as sanctuaries and corridors for threatened animal species.

There are significant additional benefits from the development of these ecosystems:

- Income and credit worthiness for rural communities from the sale of biofuels and the marketing of farm produce and by-products
- Money to invest in medical facilities, safe water, education, communication, and other infrastructure for producer communities
- A carbon sink to reduce emissions of greenhouse gases (After 8 years, 1 hectare of a typical oil tree plantation will have converted >40 metric tons of carbon into biomass, which is equivalent to over 140 metric tons of carbon dioxide.)
- Only a small fraction (<1%) of the sequestered carbon each year is returned to the atmosphere when the biofuel is combusted
- Reversing urbanisation through the provision of sustainable livelihoods in rural communities

Definitions

Oilseed trees are tree species that produce seeds that contain oil that is not normally harvested to supply an edible product. They produce a copious amount of seed in a determinate pattern (i.e., flowers, pod formation and pod maturation take place synchronously). They can tolerate and even prosper in the extreme conditions of marginal land. The oil has physical and chemical characteristics that permit its use as a substitute for, or in a blend with, diesel oil.

Marginal land is land that is of low fertility, and/or is in a low rainfall area, and/or which has been degraded by human activity or wind or water erosion, and, as such, cannot sustain commercially viable crop or livestock production. Examples are mine overburden, land that has been over-forested or over-cropped, areas where salt restricts plant production, and desert margins and areas where access to abundant irrigation water is no longer possible.

Pure Plant Oil Biofuel (PPOB): oil that is produced from oilseed trees or specific annual oilseed crops that can be used as a substitute for, or in a blend with, mineral diesel oil.

Oilseed trees and annuals that provide biodiesel

There are many annual plants and tree species that have seeds containing oils of varying qualities and chemical constitution, and in a range of quantities. Not all have been fully investigated as providers of biodiesel in terms of quality and quantity. It is anticipated that candidates will undoubtedly emerge from research that intensified a few years ago and that will continue for many years. Annual oil-yielding species are valuable for generating cash flow and for intercropping during the gestation period of tree plantations.

There are a number of tree species ready, or close to ready, for international field operations, in particular:

Aleurites spp candle nut trees
Croton spp. (already the basis of an East African industry)
*Mellittia (Pongamia) pinnat*a (Pongamia) is grown extensively in India and Australia: as a legume, it contributes nitrogen to the soil
Moringa oleifera (drumstick tree, horseradish tree)
Xanthocerus sorbifolium (yellowhorn, chinese flowering chestnut), which adapts well to cold climates and produces nuts containing 60% oil, although fruiting is optimal only when fertilized

Annual oil species grown in a rotation in the aisles include:
Brassica spp (oilseed mustards, canola etc.)
Camelina (drought-tolerant)
soybean, peanuts (leguminous nitrogen providers, varieties adapted to marginal condition).
These crops are widely accepted as providers of biodiesel.

These species have most of the following characteristics:

- Assuming proper processing, the seed oil is suitable as fuel for electricity generation, and for all forms of diesel powered transport and for conversion to aviation fuel and other liquid fuels
- They do not compete with food crops for space and resources
- The oil content of the seeds exceeds 30%
- Yields that justify the investment of money and human resources
- Oilseed trees are determinate, i.e. they flower and set and ripen seed at the same time
- Seeds that are potentially machine-harvestable
- The technology needed to separate the oil from the seed and the seed from the husk (seed pod, hull) is simple and readily transferrable
- The storage qualities of seed and oil do not present a commercial constraint
- Ideally oilseed trees should be compatible with intercrops and unpalatable to livestock
- The husks and press cake have a commercial value in their own right (e.g. as stock food) or are suitable for recycling within a plantation
- Adapted to a wide range of climates and soil characteristics

Has this strategy of using trees for biofuel been tried before? Yes, but not on the scale required to have the desired impact

- Agroforestry is a successful method of enhancing and stabilizing the production of crops and livestock in the arid- and semi-arid tropics
- Functional oilseed trees are grown extensively in Australia and India and are beginning in East Africa
- The ability of oilseed trees to form the aisles of agroforestry systems has been demonstrated in India
- Participatory development of agroforestry including oilseed trees is practiced in temperate zones of East Asia, albeit not historically for biofuel[1]

What is needed to initiate this program on the scale required?

The knowledge and technology necessary to implement participatory development of agroforestry ecosystems including oilseed trees is currently sufficient to implement this process. This does not mean that we know everything. The authors have identified a list of questions that need to be addressed, internationally, or at least multi-locationally, via focused research, to secure the full potential of this initiative. Details follow in the next section of this document. (NB. Scientists are still finding ways of enhancing the productivity of rice, some 30-40,000 years since it was first cropped.)

There are potential research partners in less developed and more developed countries. Preliminary indications are that many will become partners and will provide essential resources including ample tracts of suitable land. Schools educating future leaders in agroforestry have the capacity and the opportunity to take the lead.

What is missing? The investment needed to take this project through its first years of development to the point where production units are functional and self-supporting but open to technological advancement and further expansion--i.e., 5-8 years depending on tree species and the vagaries of weather.

What forms will this investment take, and with what results? Initial investment will cover the start-up costs of land preparation, seed purchase, nursery establishment, and basic agricultural infrastructure - such as dams to store run-off water during the rainy seasons or to access and pump groundwater. A further tranche of investment will be needed to mechanise harvesting, and the processing and expulsion of oil. At this point the commodity is available for marketing locally and then nationally.

[1] See http://www.worldagroforestry.org/downloads/publications/PDFs/B16990.PDF

The Technology of Participatory Development of Agroforestry Ecosystems Including Oilseed Trees

Researching regional sustainability of oilseed trees

This is a new industry. This means that there is no published or networked data, describing, for instance, what is a 'normal' reading for a leaf or sap analysis, or the number of day degrees below a specific temperature threshold needed to kill or temporarily sterilize a stand of trees. Therefore, input from a network of regional centers will be needed to resolve issues concerning plant nutrition, microbiology (soil microbes), insect and disease management, and pollination (see following list of topics). The identification and development of elite/adapted varieties will be an on-going activity internationally in collaboration with advanced science laboratories within the private and public sectors.

Research topics:

- Tree survival
- Vegetative growth - above ground ('biomass')
- Vegetative growth - below ground ('biomass')
- CO_2 /C sequestration
- Root development re soil structure
- Nodulation (*Pongamia*), mycorrhizal growth all species
- Nutrients in leaves/sap
- Nutrient content of soil (annual)
- Time of first flowering
- Flower visitors/potential pollinators
- Above ground and below ground pathogens, potential pests and incidence of beneficial organisms
- Pod and seed yield per tree
- Oil content and quality of seed by species/provenance
- Positive and negative impacts on environment
- Impact of topography and previous land use

- Impact of plantation on ambient temperatures
- Ability of oil trees to sequester heavy metals.

Experiments will focus on the regional sustainability of oilseed trees: evaluate survival and productivity of species selected for study on the basis of experience elsewhere. For example, plantings may include seed from +/- 5 provenances (about 100 trees of each genotype) collected from different climate zones within the home range of each species. The outcome of such multi-locational experiments will provide an indication of the adaptability of the candidate species to some given ecological zone. These experiments are the first step toward the long-term goal of identifying high-yielding feedstock varieties adapted to specific ecological zones. Early results from the evaluation of the regional sustainability of the selected species may well lead to the initiation of multi-species plantations. Here are the standard requirements for establishing these plantations:

- Full meteorological profile
- Comparisons to international bench mark sites
- Soil characteristics
- Water/irrigation profile
- Geospatial profile

Of course, a number of years are required to gather data pertaining to characteristics of the trees at their maturity. For the species listed in the above footnote, only Moringa will come into full commercial-scale production within five years. Two of the species produce 35% of their mature seed capacity in year 3, while others produce flowers and some seed in their third year and come into full maturity in year 5. The time span for project funding by typical donors may rarely exceed five years, requiring programs that link a series of donor-funded projects and/or a layering of grants, soft loans, and investments. Clearly, 'patient capital' is needed to accomplish these goals. Community Supported Agroforestry-based Learning (CSAL) programs, with their mobilization of capital contributions and private equity finance through Community Investment Trusts, can answer this need where there is adequate local initiative.

Researching best practice in oilseed tree plantations and agroforestry design

The potential for these research programs to advance the economic status of rural communities, small-scale landowners and farmers is an explicit goal and thus an important topic of proposals for funding. Large-scale plantations will invest in dedicated farm machinery and perhaps several expulsion mills. In contrast, networks of smaller farmers, who may wish to establish agroforestry farming systems that incorporate oilseed trees, will benefit from communal ownership of plant and marketing systems. Alternatively, they may wish to work through a contractor (employed by a cooperative) who harvests and processes their products. The same principles of plantation management, tree care, and harvesting apply in large and small enterprises. Both will benefit from technical input from the regional sustainability trials, specifically, trials matching tree species to habitat characteristics.

In conventional plantation silviculture, stand density is determined: 1) by species-specific factors, such as shade tolerance, branch structure and formation, and pre-commercial thinning and pruning schedules, and 2) business-related goals centred on wood quality, volume, and rotation length. Oilseed tree plantations are different:

The design of an oilseed tree plantation is approached according to the specific end use. Oilseed trees can be considered in the same way (1) as fruit or nut trees that are harvested annually, like olives, almonds, pecans, etc., or 2) as the tree component in agroforestry systems, or 3) as the permanent component in a mixed tree species stand that is sequentially harvested to remove (e.g.) 'cabinet' timber, building materials and/or firewood.

Some oilseed trees will usually be spaced in the ideal arrangement for harvesting, the end use being to maximize the harvest. This pattern may well create opportunities to intercrop the trees with annual seed oil crops such as *Brassica* spp, *Camelina*, sunflowers, and safflower. The key design factors in designing fruit and nut tree plantations are (1) ease of access for mechanical harvesters and seed collection bins and (2) rows running north-south or along contours for sloping-to-steep sites. Agroforestry models typically feature cash crops growing in the aisles (*Pongamia* is good for this), using annual crops or multi-harvest biomass crops such as Miscanthus, switchgrass, etc. Or there may be inter-row grazing of cattle and sheep, as for *Croton* and *Pongamia* in India, Africa, and Australia. If a long term goal is to grow dwarfed oilseed trees, a different cropping pattern will be most suitable.

Given the option to intercrop oilseed trees with annual oil seed crops, oilseed trees have a central role in an integrated spectrum of biofuel production. A primary objective of program for research on oilseeds is an integrated production system covering the trees, intercropped biomass, oil seed and marketable food crops (vegetables, maize, pigeonpea, cowpea, and many others), and livestock. Farmers will be presented with the options that match their land and ambitions.

Researching the processing of seed and its by-products

Market variability and irregular feedstock supply still tends to curb the growth of the oilseed tree biofuel industry in much of the world, even though dehulling and expulsion of oil from the seeds has been on-going in India and Europe for 100 years or more. The first diesel engine was fueled with Brassica oil. Many villages in India presently have dehullers and expellers. In the future, increasing official support for projects that produce non-edible oils from trees grown on marginal land will lead to the growth that is needed for stable feedstock supply and assured market access at profitable scales of turnover.

Processing the seed

Engineering advances in processing the seed as they come from the trees are facilitating industrial efficiencies. 'Expellers' squeeze the oil out of the seed through a cold press process, whereas 'extractors' employ a recoverable solvent to remove the oil. The solid shaft expeller is slowly replacing the traditional horizontal bar machines--a concept invented and patented by Valerius Anderson in 1901. The smaller, solid shaft machines are more efficient, and the operators do not need to be highly trained. The production cost of the new expellers is a little higher, but this may be offset by lower labor costs and the ability to process a wide range of feedstock, thus allowing for harmonizing of biomass crops. Scaling up may be accomplished either by procuring expellers with a larger capacity or by installing increasing numbers of similar machines.

Dehulling the seed poses less of a challenge but yet must be optimized. Suitable dehullers may not be available now for all of the species that are currently under study. Existing equipment used for *Pongamia* can be modified with advice from present operators in consultation with engineering contractors.

Safety issues arising from a seed processing facility are minimal. While there will be a variety of cleaners, grinders and other agricultural equipment involved, basic awareness and safety orientation will suffice to avoid injury. Hot spots may develop on press cone or frictional parts over time. These areas will be marked and operators will be trained to wear insulated gloves if contact or access to these areas is unavoidable. Equipment is properly guarded and shielded to eliminate open belts that can create pinch hazards. Noise protection will not be required in the crush plant. A hammer mill or final grinder may require an air cyclone to capture dust. Safety issues can be dealt with by training and supervision according to prevailing standards and laws.

By-products of seed processing

The primary by-products are the press cake left from the oil expulsion operation and the empty pods (husks or hulls). The husks, like those of edible seed such as pecans and walseed, are both a viable fuel for direct combustion and for lignocellulosic or pyrolytic feedstocks for conversion to liquid or gaseous biofuel. The hulls may well be most valuable if returned to soil as mulch or biochar. In India and Africa, the hulls are converted to biogas or are returned to the plantation as mulch for nutrient recycling and suppression of weeds.

Oilseed cake (or press cake) has a high protein and carbohydrate content that make it ideal for stock feed. In the case of *Pongamia*, the seed cake also contains anti-feedant chemicals. This means that in Australia *Pongamia* cake is mixed with other feed components (grain, alfalfa, etc.) to a level that is not in excess of 30%.

The press cake is also a nutrient-rich fertilizer, feedstock for biogas converters, and a vermi-compost. The chemical composition of this commodity varies across species so that market and location-specific factors will determine how this opportunity is exploited. In all likelihood small-scale oilseed tree enterprises will retain it for recycling as organic matter, whereas larger enterprises will seek most profitable outlets for sales. As a rule, successful farmers return the nutrients that are removed from the soil each year by their crops, + 10%.

Stages in building agroforestry plantations

The process of forming agroforestry plantations is lengthy, as described in the following table. Field testing starts with testing the tolerance of potentially-suitable oilseed trees to variations in soils, climate, and biosphere, and systematically improving this tolerance for pertinent environments. Several schools in a given ecological zone may be engaged in this activity, using land that they own or control. Naturally, they will seek to discover whether their respective locations can apply the research results on suitable land at a commercially viable scale of PPOB output. This discovery clearly requires multiple layers of interdisciplinary analysis. If studies indicate feasibility, a start at mobilizing suitably large plantation lands and at creating an extension center (here called a PPOB Center) located on or near these lands will be practical steps forward. The goal is then to create this extension center as a for-profit PPOB producer. It will model the growing of oilseed trees for biofuel and demonstrate commercially-viable operations for processing PPOB.

A PBOB Center is an ideal Community Supported Enterprise to receive equity finance from a Community Investment Trust (CIT) of a CSAL program. This local private equity is likely to leverage additional capital from cooperating “impact investors” outside the local area. The PBOB Center might have a goal within, say, five years (depending on the oilseed tree species) to create a pilot oil-expulsion operation whose commercial results provide a solid basis for assessing profits to be obtained through scale economies from much larger investment. On this basis the PPOB Center will seek co-investors, which may be other private equity companies and established companies in the pertinent sectors of agriculture, forestry, mining, and energy.

Stages in the process of participatory development of agroforestry ecosystems, including oilseed trees for producing PPOB (pure plant oil biofuel)

Stages	Notes
Assessing the human and physical environment	
Define targeted physical environment(s) in terms of soil characteristics and climate and depth of groundwater	Contributes hard data to the Global Oilseed Tree Database
Assess quality of land in start-up areas in terms of erosion, fertility (ref to existing ground cover)	Contributes hard data to the Global Oilseed Tree Database
Assess development status in terms of physical and social infrastructure (roads, irrigation, schools...)	Plan with local leaders how to remedy key problems
Gauge willingness to cooperate of the communities nominated as start-up partners	If findings are negative, find other partners, other locations
Plan, construct, and procure agricultural hardware	Sheds, tractors, trailers, etc.

Plantation initiation and management		
	Match environment to tree species and whole agroforestry ecosystem	Ancillary input from PPOB Centers in consultation with all stakeholders; findings for the Global Oilseed Tree Database
	Procure seed	
	Set up nurseries (e.g., with schools or as income generation for women)	Key training facility; excellent centre of participatory technology development for the community
	Design multi-species plantations fitting site topography and mitigating degradation factors	Outcomes include protection of riparian areas, wildlife corridors, water retention, reduced erosion, clean rivers
	Install irrigation infrastructure and reticulation where needed	Outcome may include all-season production of foods, for which targeted funding may be available (e.g., WASH)
	Plant oilseed tree seed or seedlings	Ancillary input from PPOB Centers in consultation with all stakeholders
	Plant other aisle and resource tree seed or seedlings	Ancillary input from PPOB Centers in consultation with all stakeholders
	Initiate arable or other co-crop production	Keys to productivity and sustainability of the agroforestry ecosystem
	Implement sustainable rotation of aisle crops	Keys to productivity and sustainability of the agroforestry ecosystem
	Implement sustainable soil fertility maintenance through composting and mulching of weeds	Keys to productivity and sustainability of the agroforestry ecosystem
	Plan pollination strategy	Bees are necessary for oilseed production and, moreover, create secondary businesses
Processing		
1	Research and procure mechanical harvesting equipment	Requires training of local people, generates good incomes
2	Research and install dehulling and expulsion plant suitable for the selected oilseed tree species	Requires training of local people, generates good incomes
Social action		
	Promote secondary for-profit business, jobs, and incomes	Honey , soap, fertilizer, biogas, household uses of PPOB, motorbikes, etc.

Set up local and remote markets for excess food	Affordable transport fuel raises the profits from off-farm sales
Commercial set-up	
Prepare a detailed business plan for future investment	Short- and long-term plan, investment grade, that documents high expected profitability
Structure for-profit company with share issue	Local group participation transforms as local ownership, with opportunity for CIT and other outside PE investment
Negotiate buy-in or cooperative deals with sector partners	National or MNC oil company, other energy, forestry, mining …
Monitoring and evaluation of the launch	
Match achievements against expectations	Regular audits of outputs combined with subjective evaluation by community leaders
Monitor financial feedback into community	Annual survey of households and institutions to gauge effects on incomes
Scaling up following the launch	
Implement the business plan for future investment	The plan has monitorable targets for economic, social, and environmental goals
Structure ownership with fairness to all stakeholders	The stakes of initial shareholders are protected from dilution as capital is added
Promote business growth in the community and beyond	Cheaper local fuel supply helps to grow Sustainable Local Enterprise Networks

Assessing Results for Development

Social impact: job creation and rural development

Direct job creation will arise initially for nursery work and for the preparation of land and the planting of the trees at reclaimed and reforested sites. Much of this work is likely to be mechanized and usually will be based on no-till or low-till techniques. However, vegetative overburden must be cut back (and perhaps harvested for biomass and subsequent conversion to biogas) to promote seedling or sapling growth by allowing sufficient light penetration and reducing competition for nutrients and water. Further consideration may lead to the overseeing of perennial bee-friendly crops. They produce income and provide an essential service – the trees need bees to produce seed.

Care of the saplings (pruning, replacing, etc.,) as they grow through the vegetative stage will require further labour inputs. As with most agricultural crops, it is during harvest that need for labor will significantly increase, even though harvesting in large-scale enterprises will normally be mechanical in line with best international practices in gathering nut crops.

Transport and processing of the seeds and other biomass at crushing and oil-extraction/refining facilities will certainly add further jobs, with significant local impact especially after the full suite of biomass crops are brought online. There will be regular employment for drivers and mechanics as well as quality-control and process managers and other professional personnel.

Even while relatively small, an incipient PPOB biofuel industry may create a lifeline of jobs in surrounding rural communities. Especially where traditional rural industries producing unsustainable sources of energy are in decline, such as cutting forests for charcoal, this new industry may eventually restore both the environment and the incomes of those who have strong affinity for the land. This will tend to happen through the economic linkages that connect lower-cost energy with all forms of agribusiness and manufacturing opportunities in towns and cities.

The ultimate goal is to create sustainable industries that will ensure that communities in remote areas remain viable in terms of social services (particularly education and health) and the retention of young people close to their landed family units. Biofuels production with reforestation and land reclamation will allow many people to return to work, stabilizing their communities through higher incomes and underpinning the persistence of a rural way of life.

Environmental impact and protecting the Planet

The environmental impact of oilseed tree biofuel plantations is unambiguously favorable.

Land covered in trees intercepts and retains precipitation in the leaf litter and/or applied mulch. Soil surface organic matter also stops splash erosion. Water is returned to the atmosphere through the massive transpiration flow of forest biomass. Tree roots bind the soil and prevent sheet erosion. Contour planting and the careful planning of access tracks will contribute to the virtual elimination of soil erosion, even where starting with degraded hillsides.

Downstream environmental impact is also favourable: reduced soil erosion, reduced turbidity and sedimentation in streams and rivers, lower risk of flash-floods, and the concomitant positive impact on the health of riparian strips. Trees shade creeks and streams, cooling summer water temperatures and supporting aquatic life.

Dense stands of well-established oil trees change the local albedo and may transpire sufficient water to increase local rainfall. The local environment is cooled through increased cloud cover and through the latent heat needed to evaporate water. These effects increase human comfort and may reduce energy consumption expended on air conditioning. They also recycle water to the extent that previously-ephemeral springs and streams run longer or even perennially. A plantation of sufficient area in an arid or semi-arid zone can affect local climate to the extent that small-scale irrigated or rain-fed crop production may follow.

Trees increase soil fertility through nutrient recycling and provision of an improved habitat for soil organisms. It is anticipated that mycorrhizal associations will bring phosphorus closer to the surface. One species under study (*Pongamia*) is a leguminous nitrogen fixer. This property may encourage some farmers to intercrop biofuel trees and plant them along field boundaries.

Tree plantations provide refuges and food for birds and other natural enemies of insect pests. In some regions oil tree plantations and associated riparian areas can provide wild-life corridors through which migratory species can move in relative safety.

The roots of oilseed trees that are planted on mine tailings or overburden are important because they stabilize (bind) the top 2-3 yards of unstructured 'soil'. This reduces the risk of slumping and slipping and the resultant risk of damage to land, houses, and sources of potable water.

Eventually, Africa and other 'frontier' regions may contribute significantly to reducing global greenhouse gas emissions through carbon sequestration. The below- and above-ground biomass of oil trees is a carbon sink. Whilst the seed oil produced by a tree is combusted in diesel engines, the amount of carbon dioxide emitted in that combustion is, on a per-tree per-annum basis, less than 1 per cent of the carbon dioxide absorbed by that tree. Even if the oilseed tree biofuel industry never becomes a major contributor to the struggle against global warming, a country’s encouragement of this industry will demonstrate its determination to address long-term climate issues.

Bio-remediation: *Pongamia* is believed to sequester a range of metals, such as copper, manganese, and arsenic, which are toxic to other plants when present in excess in the soil. This observation is based on pot experiments and needs to be tested in field conditions. The results of such observations will be of considerable interest to environmental scientists.

Benefits of international cooperation in research

The CSAL Network intends to maximize the benefits of international cooperation and exchange, using its networks of teachers, students, scientists, and the managers of PPOB Centers and the businesses thereby created. These benefits will derive from visits to the home ranges of candidate species, starting in Africa, Australia, India, Indonesia, so as to understand their environment, their ecological role, and the constraints under which they have evolved, including humans, other plant species and micro- and macro- wildlife.

These visits will permit:

- A review of plantation design and harvest methods

- Compilation of the database of production bench marks and identifying information voids
- Oil expulsion and processing technology
- A review of PPOB in the market place
- Engine testing of PPOB for efficiencies
- Labor and workforce economics

The formation of a **Global** I**nformation Exchange Network** as an activity of the CSAL Network will permit scientists who are new to this field to access information that would take them years to discover on their own. Here are examples of subject areas that could be accessed in a **Global Oilseed Tree Database,** which CSAL programs collectively could maintain:

- Issues concerning bees: species, pollination, retention

- The pH, macro- and micro-nutrient requirements and acceptable ranges of these bee species

- The availability of Rhizobium and species (for *Pongamia*) and Mycorrhiza for all tree species

- Optimizing plantation design for tree and aisle crops

- Optimizing harvesting operations and the most appropriate harvesters

- De-hulling, expulsion, and filtering protocols and equipment

- Further processing and storage protocols

- Development of novel planting systems involving hormonal treatments for early and prolific flowering

- Small-farm plantation model for tree propagation

Modeling macroeconomic results for development

To the extent that CSAL programs will be funded by national and international official agencies, there will be demand for assessment of impact on national and global development goals. This demand for macro-analysis and measurement can be addressed through model-based scenarios that start with the assumption that over time an oilseed tree biofuel industry becomes big enough in a given country or region to replace a significant percentage of its use of fossil fuels. Such scenarios can be made for particular countries or regions of interest. Further, the results will be enhanced if the calculations are done for the world as a whole in a model that incorporates sectoral as well as macroeconomic linkages through international trade and capital flows. Such a framework allows analysts to include strategic aspects of planning such as competitive responses to innovations by oligopolistic producers of fossil fuels.

Over the past forty years, following the quintupling of oil prices of 1971, many Computable General Equilibrium (CGE) models have been built to explore such questions. Early contributions were Project Link, led by the late Lawrence Klein of the University of Pennsylvania, which incorporated the Armington model of trade linkages. Later the Sachs-McKibbon model, built for the World Bank, demonstrated how new generations of computers can expand systems of open-economy macroeconomic models to include detail on environmental constraints and outcomes.

CGE models cannot be formally estimated as systems but rather build on the user's assumptions about structural parameters and dynamics, typically derived from partial-equilibrium measurement. If the user believes in the assumptions that he has put in, based on available empirical tests, then he may well trust the results. The CGE model is built to be user-friendly and 'transparent,' but, as the saying goes, 'some assembly is required,' which specialized consultants such as the Millennium Institute can provide at a price.

Conclusion: the opportunity to change the future

Visualize a region that is large and landlocked with undeniable evidence of encroaching desertification. It has an area of 1.5 million square kilometres, or twice the size of Texas, with a population of 15 million, of which 40% is urban. The population of rural areas thus averages less than 2 people per square kilometre. Only 4% of the land is classed as arable (suitable for cultivation). The north of the region is arid or close to desert, so that the rural population has been forced further and further south and is denuding the few remaining riparian forests. One of the region's major problems is a shortage of firewood. Another is the cost of energy. The region consumes 600,000 metric tons of diesel fuel each year. How can an agroforestry ecosystem with oilseed trees help?

Projections with Pongamia as a representative species: applying conservative production estimates,

- One mature tree can be expected to produce 20 kg of pods per year. The dehulled seeds weigh 9 kg and will yield about 3 kg of oil.
- One hectare of trees planted at 200 trees/ha in an alley crop farming system will therefore produce 600 kg of oil. Reduce this estimate to 500 kg to allow for inefficiencies of one sort or another.
- Ten thousand hectares is perceived as a commercial unit. It could produce 5,000 MT of oil a year – that is over 5 million litres.
- Eleven such units, using only 1100 sq km (0.22% of the land of this region), would supply 10% of the region's annual diesel fuel requirement, help to feed the population, supply firewood and construction material, and contribute to pushing back the desert.
- Once started by this pilot, why would this investment process stop? In time this region could be self- sufficient in energy and maybe food as well. And why wouldn't other regions with comparable opportunities follow a similar path? After all, this model is already working in India and Australia.

While the needed capital investment to take this program to commercial scale is large, and inevitably will enrol participation by the big energy companies of the world, the trees will live and produce for many decades. Thus, investment into such an enterprise would have a profound influence for the long term. Clearly there would be no reason to stop planting – especially as better-adapted varieties will appear as a result of research, and production methods will improve over time. Oil and other energy companies will compare this open-ended lifespan to a fossil-fuel extraction enterprise where the venture lifecycle may be only 20 to 30 years.

Indeed, there is no reason to be wary of big numbers for capital costs. Rice production in Asia and wheat production across Europe and America are much larger endeavours, but no one there thinks about challenging the feasibility of these industries. Moreover, they only produce food and employment, while the PPOB industry will produce food + energy + other essential commodities + environmental restoration. As Sir Fazle Hasan Abed, founder of BRAC, has opined, "Small is beautiful, but big is necessary."