PAPER NO. 77-6532

TREE PLANTATIONS AS RESOURCES FOR RENEWABLE ENERGY PRODUCTION

by

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For presentation at the 1977 Winter Meeting
AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS

Palmer House Hotel
Chicago, Illinois
December 13-16, 1977

SUMMARY:

The interest in tree plantations has been stimulated sharply by energy crisis of the 1970's. This technology appears to have greatest potential benefit to the LDC's. U.S. research and development in the fields of pulp wood and biomass provides some hints of the potential of this technology.

American Society of Agricultural Engineers

St. Joseph, Michigan 49085

TREE PLANTATIONS

Introduction

Interest in tree plantations has increased markedly in the 1970's and arises from two major factors. In some areas the demands of the human population for fuel wood and building materials are appreciably greater than local supply with the results that forest lands are being degraded. In other areas the comparatively un-utilized forest lands are expected to be a resource for providing major energy supplies. Neither of these problems are fundamentally new crisis, but they have certainly taken on new dimensions of magnitude and urgency in the 1970's. Tree plantation themselves are comparatively well developed technologies in the production of rubber, coconut, tea, lumber and paper pulp. There has also been some technology developed for tree plantations as energy production units going back 30 or more years for Brazilian and West African railroad systems. In a word, tree plantation technology can be characterized as under-developed and major research and development investment seem to be justified.

The degradation of forest lands can hardly be quantified as we have meager forest inventories of ten, 20 or 40 years ago with which to compare the extent or quality of current forest lands. However, there is evidence of much recent and serious erosion across extensive areas of the Indian Sub-continent, Africa and Latin America. This evidence points quite directly to a relentless process of deforestation. Another sign with somewhat better documentation is the increasing price of fuel wood for household cooking; reported by Mr. Erik Eckholm to have increased from Rs 6 to Rs 20 per faggot in Nepal over a two year period. 1/ Mr. Eckholm also reports that some families in the LDC's spend a greater share of their income for fuel wood than the portion paid by the families of Europe for food. Perhaps there is no country that has exceeded the deprivation of forest lands that is evident in Haiti where the resultant chain of ill effects includes serious damage to the watersheds and reservoirs of the hydro-electric systems.

Unfortuaately, reforestation has not been enough to prevent degradation of much of these lands. Forestry projects were included in many of the developmental assistance projects of the 1950's and 1960's. Where such plantings received some protection, they resulted in good-looking stands of young trees,

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1/ Numbers refer to the items of the List of References.

but most of these projects have not established high production systems. Perhaps programs of replacement tree plantings have simply been inadequate in extent. However, it appears that only replacing native trees or only planting a new species will not produce adequate yield of fuel wood to meet the demand of raising population. The term tree plantations implying more comprehensive management appears to be imperative even to sustain present standards of living in most areas of the world.

There are also extensive areas of tropical rain forest that are unexploited for all practical purposes. Surveys of these forests have detailed at some length the fragile nature of the ecology and sensitive interdependence of the forest fauna and climate at the micro and macro level. In spite of the complication of maintaining ecological integrity, these forest areas attract attention as a resource to be used in collecting and storing the sun's energy to meet society's growing energy needs. It is hypothesized that tree plantation can be established and operated without adverse macro-ecological effects and with positive benefit to society.

Popular and scientific literature includes analysis of the problems, proposals and plans for the generation of needed technology. A few items report scientific or technical data on aspects of biology and product utilization. Research and development studies are underway covering essentially the complete range of production and utilization technologies. Unfortunatley, the research and investment in this area are significantly less than in agriculture. Also, the rate of growth of trees is comparatively slower and the processes of utilization are comparatively more complex than for food crops. Therefore, there is little reason to anticipate anything equivalent to a Green Revolution in tree plantation technology. This brief survey, or state-of-the-art assessment reveals, however, that the potential role of tree plantation technology would justify a higher level of R and D investment.

I. The Tree Plantations of the Railroads

The pioneering railroads of the U.S. rather quickly converted to coal because of its ready supply. However, in Brazil and East Africa the railroads burned wood up to the conversion to diesel in the 1950's. The rail system in Brazil and East Africa passes through extensive natural forest areas. However, managed tree production provided a lower cost fuel supply than occasional harvest of native regrowth. The significant point in this experience is that even when natural growth has little cost other than that of cutting and haulage, there is an advantage in managed planting and cultivation of forests. However, for 20 or more years these plantations have either been abandoned or converted to lumber production. There is practically no hard data of current value that can be gleaned from these old plantations.

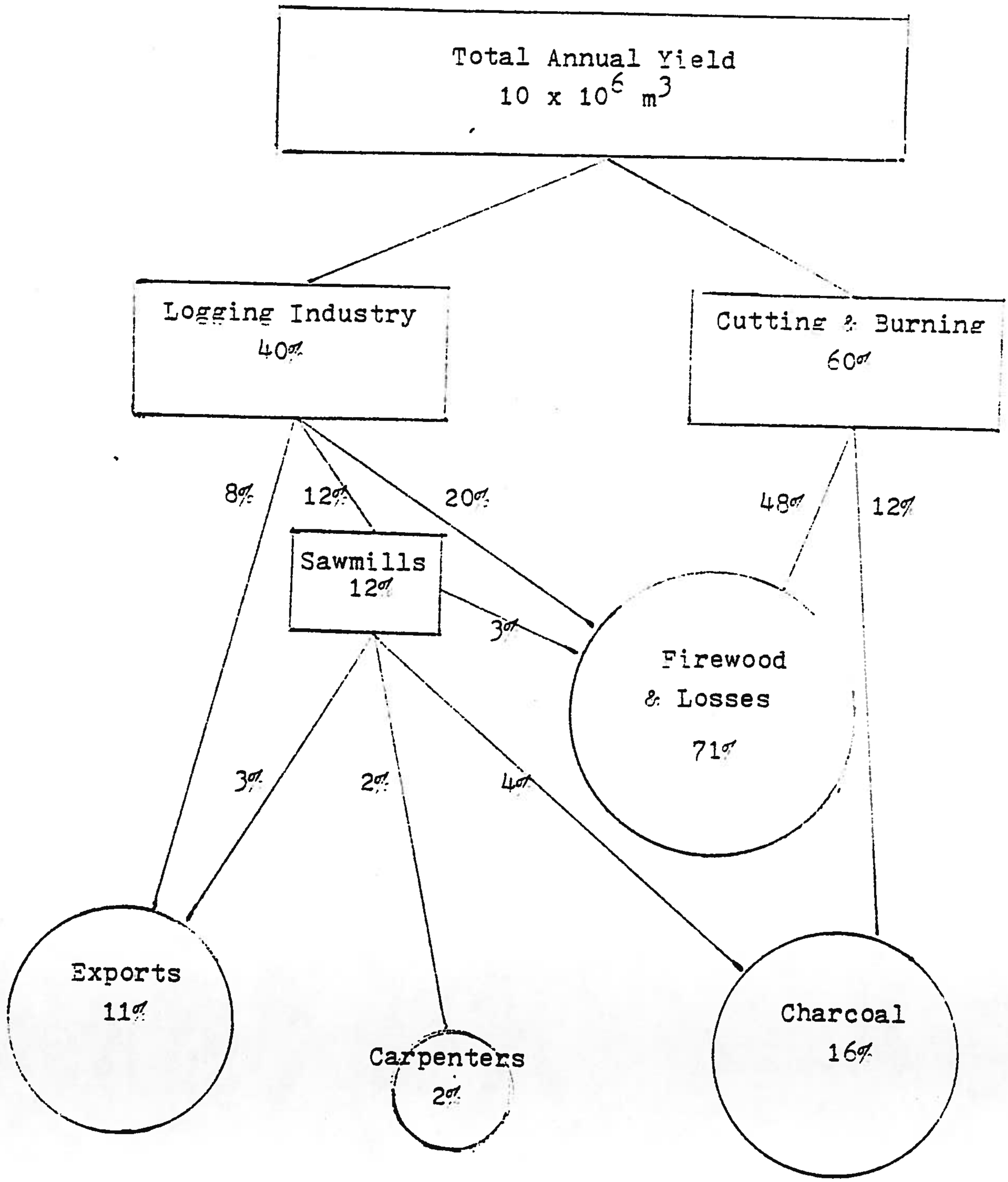
II. Current Use of the Tropical Forest - Ghana

Perhaps Ghana has looked at its forests as thoroughly as any country has considered this tropical resource. This nation uses its forests heavily for lumber production and for domestic fuel. An analysis by Dr. J.W. Powell, Director, University of Science and Technology, Accra, Ghana, graphically illustrates the conventional practice in utilizing the tropical forest. 2/ Dr. Powell noted particularly that 71% of c rrent forest production is consumed as firewood or burned as forest wastage. Dr. Powell hypothesized that the pyrolysis conversion of this quantity of wood would produce an improved fuel as compared to firewood and would also produce a fuel oil adequate to substitute for expensive imported fuel oil.

The Georgia Institute of Technology was commissioned to undertake a feasibility analysis of the pyrolysis process suggested by Dr. Powell. This analysis proposed a simple system and concluded that satsifactory economic performance could be expected. 3/ The capitol cost for a locally fabricated unit was estimated at $27,000. The operating performance for three-shift production was projected:

			Annual Basis
Charcoal	-	450 tons @ $100	$45,000
Oil	-	360 tons @ 52	18,720
		Total income	63,720
		Operating Costs	48,418
		Net before taxes	$14,381

Figure - Tropical Forest Utilization
Annual Wood Flow in Ghana



The pyrolysis process offers significant advantages over methane generation for recovering the stored energy of the tropical forest. The main advantage is the stable, dense form of the products--charcoal and oil. These products can be transported and stored facilitating their movement to population and industrial centers. Both the low density of methane gas and resulting transportation requirements combined with the long process cycle times are serious disadvantages to this process of recovering the energy of forest materials. In the case of both gas generation and fermentation for alchohol the thick dense limbs and trunks are the crux of the serious problems. Such parts can be mechanically reduced by chipping, chemically broken down, or processed by prolonged retention. These are all costly options. Scientific effort is being directed to each of these aspects, but the evidence provides no basis for anticipating these processes to be suited to harvesting tropical forest areas.

Direct combustion of forest and tree plantation material remains a viable prospect although it has not received as much attention during the last several years. Approximately 30% of the energy in fresh cut forest growth is consumed in drying the material for combustion, and it is this cost that has led to consideration of the other processes. However, the comparative simplicity of direct combustion for heat energy or in the production of electrical energy may yet result in this technology being the most practical concept. The determination of optimum site and performance economics for commercial steam or electrical generating stations would obviously depend upon road and terrain implications for transport as well as forest productivity, etc. Blankenborn and associates have shown that haul distances up to 2,675 kms for steam production and 387 km for electrical production will produce a net energy surplus from wood fuels. 4/

The state-of-the-art in respect to tree utilization can be characterized as rather speculative over quite a range of technologies. We cannot find a case for a particular tree plantation product required for processing or utilization or of particularly strong advantage in economic or technical terms. With this fact established, one can turn to the biology of the forest with somewhat greater freedom in search of potentials for maximum energy production.

III. Maximizing Forest Production of Energy

Trees are efficient multipliers of fossil energy as they utilize the sun's energy to store 27 energy units for one unit of petroleum used in culture and harvesting. 5/ For perspective Roller reported corn and alfalfa returned ten units of digestible energy for cattle per unit of energy input and corn or wheat grain was in the range of four to seven units of output per unit of input. Keener's calculations are based upon conventional practice and the research work reported in the following sections have a number of implications which could tend to increase the efficiency of energy recovery while reducing or at most marginally increasing the fossil fuel expenditure. In LDC's where intensive tree plantation management may be practiced with intensive labor use and minimal power equipment, one would expect considerably higher ratios between energy production and fossil fuel costs.

Intensive management of pulp wood production has progressively reduced the area required for a given harvest to about one-third of the productivity of a naturally regenerated forest. 4/ Such practices as prompt replanting of high producing species, timely thinning and planned harvesting have been documented for a variety of locations in respect to pulp wood production. Unfortunately, this data does not provide a handbook technology for solving the problem of those countries experiencing deforestation; Nepal, Haiti, etc. There are a few managed forests of eucalyptus in Brazil and India that offer some data pointing to even higher productivity ratios for managed tree plantations compared with unmanaged forests. But these few trials were set out as very tentative exploration of the potential of tree management under tropical soils and climates. In fact, relatively little is known about the growth characteristics and diversity of native tropical tree species in terms of the parameters relevant to evaluating their energy production potentials.

A number of U.S. scientists have initiated studies of forest biomass production. Some of the initial data is now available and it suggests that tree plantations could be high energy producers. It is also apparent that tree plantation management for maximum energy production will involve quite different practices from pulp or lumber production. If this data is substantiated in continued experimentation, the evolving technology will have a number of requirements for new machines and practices. At this stage, the data points to quite radical differences in tree plantation technology for equipment designers, resource managers and others.

Zavotkooski and Dawson sought maximum production of biomass from close spacing and studied intervals of .25 x .25 meters, .50 x .50 meters and .61 x 61. meters. 6/ They found that stagnation of growth set in at five years for the close spacing, and that maximum annual production was achieved for the larger spacing and at eight year harvest. The .61 x .61 meter planting yielded 7.5 - 8.0 Metric Ton per hectare per year of biomass production as compared with 1.2 - 3.4 for conventional practices. Nearly 50% by weight of the harvested biomass consisted of stems and needles which are comparatively higher in energy content. Crist and associates observed similar phenomena for Jack Pine and Eastern Larch. 7/

Isebrande and associates studied popular growth with attention to leaf area development. 8/ This group observed that plant population, fertilization and water were independent factors affecting leaf area. Leaf areas obtained were on the order of magnitude of grasses or that of the multi-layered tropical rain forest. Matthews has harvested 2-1/2 year old sycamore trees as a third crop from seven year old roots in the form of a whole plant silage. 9/ Sycamore silage can be utilized as a pulp feedstock, but the data also suggests that this system is a high-yielding energy production system.

Alternative Technologies

It is often a good practice in evaluating a technology to make some comparisons with the alternatives that appear to be available. One alternative is to search for tree, bush or plant species that might be higher energy collectors than the common lumber and pulp wood varieties. Another option is to follow a new strategy in breeding and development of conventional field crops with the objective of maximum energy production. A third alternative to tree plantation would be systems of mixed farming involving carefully managed tracts of food, fodder, energy, fiber and lumber production. This last alternative reduces to how much and what kind of tree plantations would be good management of available land resources and in a sense becomes a composite of the previous two queries.

There are few comparatively unknown plants that offer some potential for tree plantations--although it must be hostily acknowledged that there are many tropical plants which have little or nothing known about their growth characteristics. The Buriti Palm, for example, is a fast growing tree of the Amazon, Venezuela and the low land tropics. 10/ It grows well on swampy land and in soils poorly suited for agricultural production. The extensive adaptability of this tree suggests that a tree plantation technology based upon its culture, would have considerable benefit. However, before such a technology can be considered, it is necessary to determine more precisely the growth performance of this tree.

Lucaena offers somewhat more promise and is understudy in the Philippines as a multi-purpose tree crop. 11/ The wood is claimed to be a good firewood and produces excellent charcoal. The tree has a fast growth rate and will regrow from the cut stump. The tree is also rated highly for reforestation of steep slopes, some marginal soils and for droughty areas. However, it is also reported to be sensitive to some soil conditions, not to develop rapidly in its first few years, and to be poorly suited for higher elevations. Further study is expected to translate this qualitative description into harder data from which to evaluate this tree as a crop for plantation culture.

These two analysis suggest that a systematic search for suitable plant species and varieties should produce the identity and the cultural practices for an energy plantation system. Unfortunately, a realistic time frame for screening crop species, measurement of growth rates, varietal improvement and establishing high yield management practices should probably be estimated in a 10-30 year time frame. This fact indicates that a decision to establish energy plantations today requires considerable judgment and risk. The situation also demands that serious research planning get underway if tree plantations are to have any role in minimizing the "energy crunch."

The alternatives of energy plantations using sugar cane, sorghum and cassava appear more promising than tree crops simply because more is known about the production characteristics of these crops. Start-up time can be shorter and risks will be less, and both of these factors are of considerable significance to the LDC's in a serious bind on both the energy and foreign exchange accounts. Brazil is investing heavily in this option setting out on a target of substituting alcohol for 20% of its domestic gasoline requirement. 12/ That country is calling upon sugar cane based technology because it is on the shelf, but they are also embarking upon pilot work using cassava--a well-adapted crop. These two crops are probably not mutually exclusive for sugar cane has a higher water requirement and cassava has considerable adaptability to varying soil quality. The competitive performance parameters for tree plantation systems will probably be set within the next five years as Brazil establishes the fuel energy production system with these two conventional crops.

Sorghum is also a competitor simply because some varieties have high rates of photosynthetic activity and wide adaptability to soil, climate, and weather. Scientists have not succeeded in harnessing this photosynthetic efficiency to grain production as well for sorghum as for corn, but they have learned much about the physiology of the plant that could be used in establishing the crop as an energy producer. Research has been started in the U.S. toward that objective and may well establish this crop as a more productive and versatile crop than sugar cane or cassava in five years.

However, while sorghum, sugar cane and cassava offer exciting potential in the short-term, they save serious limitations on the longer term. Sugar cane requires considerable water, cassava harvesting requires a friable soil, and sorghum like any other crop will have sensitivities to nutrient, acidity and other conditions. The world would be ill-advised to become excessively dependent upon one source or process. The dangers of a "corn blight" can best be avoided by diversity. Thus, one can foresee both niches of comparative advantage and niches of non-competitive performance for tree plantations. At this stage though, it is quite impossible to assess quantitative descriptions to the various alternatives.

Summary

There are two situations in the LDC's where tree plantation technology is needed. There are extensive areas such as Nepal, Haiti and some regions of Africa where forest resources are being rapidly degraded by excessive cutting. There are other extensive tracts such as the Amazon valley from which man reaps very little benefit, yet the forests harvest vast quantities of sunlight and store it as energy. In both cases, intensive tree culture would improve society's well-being.

The optimum intensity of tree cultivation cannot be firmly established from the existing research for tropical and sub-tropical lands. Promising lines of research have been established which suggest growth rates of twice the intense management of the U.S. and would result in annual production of 8.0 Metric Tons per hectare per year for harvest at six-year intervals. Some other more esoteric lines of biomass research which are being pursued are also challenging for their possibilities to yield even higher rates.

Tree plantation management programs will be soil and climate specific and relatively little is known about the growth rates and optimum management for project sites. At this stage, we do not have data on the native varieties. The question of optimum land use and the establishment of the experimental variables may be set according to domestic priorities for grain production, timber and/or energy. In fact, some alternative energy sources such as sorghum, sugar cane, and cassava may yet displace tree crops as raw material with resulting definition of land use priorities.

Harvesting and utilization systems are in about the same state-of-the-art as are tree plantation systems. Pyrolysis appears to have the greatest potential where storage of fuel is a requirement. However, direct combustion is also a viable energy utilization system. Prototype research is now being conducted in U.S. and in the LDC's which will produce harder data over the next 2-5 years.

The literature includes many projections of total system performance which suggest major economic benefits for LDC's from tree plantations alone or as a part of a larger development program. These calculations include bold assumptions regarding performance factors, and such assumptions are themselves the subject of considerable debate. Simply to illustrate these projections of benefits, the following is quoted from a recent report of the Georgia Institute of Technology: 3/

"Thus a further step from simply recovering energy from agricultural and forestry wastes would involve the combination of direct biomass energy production with agriculture and the introduction of this combined concept into the Third World. It can be shown that the potential for this concept is outstanding and could, if properly implemented, insure the development of many LDC's to a prosperous, stable condition otherwise practically unattainable. The application of this concept, using highly organized, labor-intensive farming methods (including conventional, nontill, and "organize" practices) could produce a year-round, perpetually renewable source of biomass for energy production and food and could generate the continuous need for many, many new jobs. By proper selection of the primary energy-food crops, "energy-food plantations" could be made to yield a blend of products tailored to meet a country's needs as it develops toward a more industrialized society.

"To illustrate the potential of the concept, a simple 100,000--acre plantation (that is, about a 12.6-mile by 12.6-mile tract) could produce the energy equivalent of 500,000 tons of coal per year, perhaps 54,000 tons of corn, and 60,000 tons of peanuts.

"A more capital-intensive plantation of the same size but including processing plants to produce methanol, ammonia fertilizer, and also a thermoelectric plant could typically produce:

- 50,000 tons methanol/year
- 120,000 tons anhydrous ammonia/year
- 17,000 tons char/year
- 12,000 tons pyrolytic oil/year
- 80,000 kilowatt hours/year

In addition, the 54,000 tons of corn and 60,000 tons of peanuts would go a long way toward correcting the imported food deficit.

"To put the above numbers in perspective, in 1973, Ghana consumed a total of 4.1×10^{13} Btu's or the energy equivalent of 1.64×10^{6} tons of coal. Of this, 2.9×10^{13} or 70% of the total was imported. Likewise, Ghana imported 15,500 tons of wheat and 267,000 tons of rice. Thus, it can be seen that the production of energy and food, using the method described, could have a profound effect insstabilizing Ghana's economy and meeting its own needs in a socially beneficial way."

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