SVERIGES
LANTBRUKSUNIVERSITET

MULTIPURPOSE TREE PRODUCTION SYSTEMS

**Joint IUFRO P1.09-00 and International Poplar Commission, FAO, Ad-hoc Committee on Biomass Production Systems
Workshop**

Beijing, China, Sept 5 - 7, 1988

Edited

C P MITCHELL

L SENNERBY-FORSSE

L ZSUFFA

Avdelningen för skoglig intensivodling
Institutionen för ekologi och miljövård

Rapport 46

Swedish University of Agricultural Sciences
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CONTENTS

FOREWORD

This workshop on Multipurpose Tree Production System of IUFRO P.1.09.00 "Integrated Research in Biomass for Energy" and IPC/FAO Ad-hoc Committee on Biomass Production Systems in Salicaceae" was organized around the themes of biodiversity, sustainability and economic development. A total of 21 papers were presented and 66 participants from 14 different countries attended. The Chinese delegation representing a large number of Universities and Government agencies from across China was very significant, as was that of the African countries (Zambia, Tanzania, Kenya and Ethiopia) supported by SIDA and guided by the Swedish delegation to a post-workshop study tour to view projects on soil erosion control. The presentations covered case studies and overviews of a wide range of industrialized and developing countries.

The topic of the first session included the selection of species and production systems for different economical and environmental conditions and purposes. In the second session the presentations focused on the need to consider long-term sustainability of the ecosystem when used for husbandry or when cultivated. The third and last session complemented the previous two by considering the "Socioeconomic aspects", of biological production systems such as their role in the social and economical patterns of the societies concerned.

The approach to reforestation has so far been oriented primarily towards economical profit. The restricted awareness and knowledge of natural resource management led to the complete destruction of many ecosystems or the replacement of natural forests by monocultures. Although production systems may vary considerably, from intensively cultivated woodgrass lots to extensively managed agro-forestry, one of the major concerns must be to establish a system that is sustainable and of complementary nature for both the ecological and the economical point of view.

Future forest or multipurpose tree production systems management will probably be essential to the survival and development of an acceptable living standard in human societies all over the world. As it may also arguably play a role in dealing with an emerging global CO_2 problem it is easy to agree with the request to "Think globally - act locally!" put forward by Clark and Munn in "Sustainable Development of the Biosphere" published by IIASA 1986.

Hopefully the wide spectrum of ideas and conceptions from the meeting, some of which are published in the present volume, will act as a stimulus to continue the important work to prevent further ecological destruction of forests and to spread the interdisciplinary knowledge of science and engineering of diversified and long-term sustainable production systems.

Uppsala, February 1989.

Lisbeth Sennerby-Forsse Chairman of the IUFRO/IPC Ad-hoc Committee workshop in Bejing, September 5-8, 1988.

SUSTAINABILITY

Moderator's report - Session on Long-Term Sustainability

Gustaf Sirén, Swed. Univ. of Agricultural Sciences, Uppsala

The session on sustainability concentrated on two main subjects.

1) Improvement and maintenance of sustainability of environmental components of the biosphere. Data and informative case studies were presented for exemplification of a variety of efforts in the fields of:

1.1 Sustainability of soils which was found to be improvable and maintainable by:
- avoiding mistakes like over-use of fertilizers, biocides, heavy-metal containing municipal sludges and continued soil compact ion
- Sufficient supply of organic matter either by addition of humus substances or by continued cultivation in order to optimize the sedentary root turn-over. Excellent examples of reclamation work were given from projects operating on the stress plateau.

1.2 Sustainability of water especially in open, steep terrains is of major concern in many countries. Surface erosion, mass movements, and fluvial erosion can however be efficiently controlled by reforestation which reduces runoff water speed and stabilizes river banks.

1.3 Sustainability of climate. In addition to a heavy reduction in the misuse of fossil fuel-based energy production, substitution of fossil fuel by biofuels was recommended. Goals were also quantified for assessing the scope of a world-wide reforestation campaign for restoring the CO_2 - fixing capacity of the vegetation of the world. During the initial steps of the re- or afforestation activities short-rotation energy forests should act as the main fixation agents of the surplus of fossil carbon until long-rotation tall timber stands have developed closed canopies. The economic burden should correspond to the pollution load and be carried by the users of fossil fuels. If this is not possible there is an alternative: 2% of the world's military budget. Developing countries should get a fair share of the reforestation budget.
The second main subject focussed on biological engineering.

2. This vast, versatile and heavily integrated subject concentrated mainly on:
- soil conservation
- multipurpose plant production systems
- industrial plantation systems.

All of these main fields of action were found biologically engineerable, offering a good potential for environmentally sound innovations for improving long-term sustainability.

SUSTAINABILITY OF SOIL

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ABSTRACT

Relative to geological time, soil properties are only stable for a very brief period of time. The continuous action of soil forming processes ensure this. The ability of a soil to maintain its physical, chemical and biological properties through time is termed its sustainability. Soil forming agents include: climate, relief, organisms (of which man plays an important role), parent material and time. In the long run climate is the most influential factor operating in the determination of soil type.

Examining Earth's natural history it is evident that changes in the natural environment occur irrespective of man's activities. However, we have seen the environmental influence of man increase tremendously over the last century. When discussing the environmental influence of man's activities it is important to distinguish between short term or instantaneous changes and those which occur over a longer period of time. For example, relatively slow accumulation of atmospheric levels of carbon dioxide, resulting from burning of fossil fuels, and man made particulate matter, may lead to a global rise in temperature (Greenhouse Effect). This longterm change in climate would lead to changes to the soils of the planet. Another environmental impact resulting from human activity and which has taken a relatively long time to show effects, results from the elution of sulfur dioxide. This air pollutant increases the acidity of rain water (acid rain). When the acidified rain falls on a weakly buffered soil the soil solution pH will drop and the concentration of toxic ions such as aluminum may increase to phytotoxic levels. Compaction of soil, or the disposal of sludge containing significant quantities of heavy metals on soil, represent instanteaneous changes to soil properties resulting directly from the activity of man.

The extent to which a soil's structure and nutrient status will be modified depends upon the inherent sustainability of the soil and the type, duration and frequency of cultural practices. Vegetation type, rotation length or crop period, irrigation and fertilization regimes, intensity and frequency of weed control and physical disturbance such as plowing and discing, represent factors with the greatest potential influence on soil characteristics. Drastic changes of the soil result from different kinds of erosion, often caused by man's misuse of land.

The maintenance of sustainable production levels is possible on many soils for many different crop species. To maintain soil structure, compaction must be kept to a minimum and the organic matter content should be sustained or if necessary increased. The best way to ensure that the humus content is sustained or improved is by selecting and growing productive crop species. This in turn means that nutrient status must be maintained near an optimum for the crop species and water must be available in sufficient quantities for growth and to avoid salinization. In semiarid and arid areas water conservation may in fact be the principle concern.

DEFINITION OF SOIL SUSTAINABILITY AND TIME PERIOD CONSIDERED

Soil sustainability is defined here as the ability of a soil to maintain its physical, chemical and biological properties through time. It implies the maintenance of a sustained production level of a specific land area for a long time. But is it a question of some generations of man or is it thousands of years? Looking at e.g. China, as one of the oldest cultures on Earth, it is known that some areas have been cultivated for at least 4000 years. But is it actually a question of the same soil? Some areas loose the top soil and the remaining soil is cultivated, some areas are flooded and the new sediment is used for agricultural production. Anyway, we must aim at sustained productions for thousands of years to come in those areas used for growing food-crops to-day. Still, relative to geological time, soil properties are only stable for a very brief period of time. The continuous action of soil forming processes ensure this.

SOIL FORMING AGENTS AND PROCESSES

Soil forming agents include: climate, relief, organisms (of which man plays an important role), parent material and time. In the long run climate is the most influencial factor operating in the determination of soil type.

Up till our own century all changes in the climate of our planet occurred irrespective of man's activities. E.g. it has been found that the content of carbondioxide has varied considerably. Pisias and Shackleton (1984) showed how the concentration of CO_2 appears to vary on time scales of 100 000, 41 000, and 23 000 years and it could be suggested that variations in CO_2 can play an important role in regulating the behaviour of climate, particularly on a longer time scale (McElroy, 1986). Irrespective of the causes, which are beyond the scope of this paper to explain, climate has changed with time and so the influence on soils has varied.

The influence of climate has been described by soil scientist for example through the different soil types occuring when moving from higher latitudes to lower latitudes, thus going from a humid, cold climate to semiarid and arid warm climates and further to wet, tropical climate. A simplified arrangement of soils shows arctic brown soils in the tundra of the high latitudes, the leached soils, podzols, brown earths and grey soils in the northern forest zone of the mid latitudes cool climates, the red and brown Mediterranean soils, cinnamon soils, red and yellow podzolic soils in the mixed forest zone of the mid latitudes warm climates, chernozems and chestnut soils in the steppe zone, grey-desert soils and desert soils in the semidesert and desert zone, ferralitic soils, ferrisols, ferruginous soils, vertisols and laterites in the tropical rain forest and decidous forest savanna zone of the low latitudes (Bridges,1970).

The soil forming processes of special interest when considering soil sustainability are: leaching, podzolization, calcification, salinization and ferralitization. Of those processes leaching, podzolization and ferralitization implies a fairly slow but significant loss of nutrients downward in the soil profile. That loss must be balanced by addition of nutrients in order to maintain a sustained biomass production from plants grown on the soil. When calcification occurs, there is virtually no loss of nutrients to the drainage water. Therefore one can assume that it is possible to maintain the physical, chemical and biological properties of such a soil through time. The salinization process, on the other hand, could within a fairly short period of time lead to a deterioration of the productivity and thus that process is a severe threat to the sustainability of a soil.

THE DIRECT AND INDIRECT INFLUENCE BY MAN ON THE SOIL

Man influences the soil directly through activities leading to soil erosion, loss of humus, soil compaction, salinization and pollution. Since man, in our century, started to influence the environment on a global scale he has become a factor of long term influence on the soil in addition to his significant, often disasterous short term influence. For example, relatively slow accumulation of atmospheric levels of carbon dioxide, resulting from burning of fossil fuels, and manmade particulate matter, may lead to a global rise in temperature (Greenhouse Effect). This longterm change in climate would lead to flooding of low lying areas when icecaps melt, as well as desertification in some areas and also changes to the soils of the planet. Another environmental impact resulting from human activity and which has taken a relatively long time to show effects, results from the elution of sulphur dioxide.This air pollutant increases the acidity of rain water (acid rain). When the acidified rain falls on a weakly buffered soil the soil solution pH will drop and the concentration of toxic ions such as aluminium may increase to phytotoxic levels.

Compaction of soil, or the disposal of sludge, containing significant quantities of heavy metals on soil, represent instantaneous changes to soil properties resulting directly from the activity of man.

PERMANENT SOIL USE AT HIGH YIELD LEVELS

"Permanent soil use at high yield levels is possible, if a number of deterioration processes are avoided, resp countermeasures taken" (Finck 1988)

Let us look at the most serious threats to the sustainability of a soil and the countermeasures that could be taken.

Soil erosion

There is a widespread understanding of the soil deterioration process named erosion. Yet, water- and winderosion is to-day even more serious than ever in many areas of the world. Whether erosion is triggered by natural causes, like a change of climate, irrespective of man's activities, is a matter of continous debate (Hudson 1981). However, in some areas there is no doubt that the process is speeded up by man's misuse of the land. The cutting down of treees and the lack of reforestation programs, as well as overgrazing in sensitive areas inexorably will lead to serious loss of the fertile top soil.

The main remedy is to keep a continous vegetation cover on the ground. Protecting the soil surface from the impact of rain drops or the wind by mulching, is also effective (Hudson, 1981). The difficulties in coping with erosion varies with the climate, soil type and topography. In humid areas from temperate to tropical zones, the posssibility to cover the soil with vegetation is usually good. In semiarid and arid areas, water conservation of some kind is necessary in order to achieve a vegetation cover. E.g. "diguettes" in arid zones will, even on fairly level land, collect the sparse precipitation water and strips of vegetation can be established.

The effect of the vegetatin cover is multiple: the impact of raindrops is softened by the plants and the roots strengthen the coherance of the soil. The structure is improved directly by the roots and indirectly through the organic material, which is discussed further down. Through the improved structure the infiltration rate is increased with less surface run off as a result and more water stored in the soil, available to the plants.

Loss of humus

In order to achieve a sustained biomass production from a land area, the humus content of the soil must be kept at a high level. The content of humus in the soil is dependant of the quality and amount of the added organic material and the turn over rate. The equilibrium reached will be adjusted to the environment, crop types and sequences and the management including fertilization and tilling operations.

The loss of humus in a temperate climate is about 1-3 per cent per year and in a tropical climate it is in the range of 3-15 per cent per year (Fink, 1988).

The humus has a stabilizing effect on the soil aggregates and improves the nutrient and waterholding capacity of the soil. The list of beneficial effects of organic matter on the physical, chemical and biological properties of a soil can be made a long one, including soil aeration, increased soil temperature, mobilization of mineral nutrients and fixation of the atmospheric nitrogen (Finck 1988).

Most measures directed to keep up a high biomass production such as choice of suitable plants, adding of nutrients in quantities and proportions needed for high yields, are beneficial for the content of organic matter in the soil. Addition of crop residues and manure is essential. Naturally the amount needed for maintenance of a good soil fertility varies with environmental factors. If a generalized recommendation should be given it would suggest an addition of 2-4 tons organic matter per hectare and year. There are differences in the soil improvement effects of different organic matter. A mature compost is expected to have a longer lasting effect than for instance green manure. All organic matter added to the soil is a source of food and mineral nutrients for the soil organisms.

Soil compaction

There are considerable differences in susceptibility of different soil types to soil compaction. Soils with single grain structures (e.g. sandy soils) are resistant to compaction, whereas aggregated clay soils in a wet state are very susceptible. Soil compaction counter measures could be of technical nature and could also take the form of soil amelioration. The technical measures taken to minimize soil compaction include lowering of the pressure from the weels of tractors and machines e.g. by using broad tyres with as low air pressure as possible.

Many of the improvement effects of humus, mentioned above, will also counteract compaction. It is a matter of improving the soil resistance to pressure by increasing the structural stability. That is achieved by pH adjustment, addition of organic matter and thus maintaining a high activity of microorganisms and soil fauna.

Salinization

In arid areas with saline soils the farmer usually have no possibility to completely eliminate the surplus of salts. Thus cropping must be done with a certain level of salinity. Most important, however, is to avoid salinization processes of soils in the risk zone. This is in principle achieved by using the available water in a way that ensure a net flow of water downward in the profile to a drainage system. It is not only the lack of water which causes the plants to suffer in arid areas, but also nutritional disturbances. An excess of certain ions (eg sodium) can exist parallell to a deficiency in other nutrients. An analysis of the situation may show nutritional disturbances, and appropriate fertilization measures could be taken. However, unnecessary additions of ions must under all circumstances be avoided, so the fertilizer must be extremely carefully chosen or composed.

Pullution of the soil

There is only one effective counter measure when it comes to pullution by heavy metals and herbicides: Avoid pullution. There are no effective remedies if toxic amounts have been reached. Before phytotoxic levels are reached the food quality requirements have, in most cases, been passed.

Acidification

The acidification should be counteracted, by society, at the source of the problem. Thus cleaning of the smoke when burning fossil fuels, of any kind, is imperative. For a farmer in a humid climate liming could be used as a counter measure.

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THE USE OF POPLARS AND WILLOWS FOR EROSION CONTROL IN NEW ZEALAND

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INTRODUCTION

New Zealand is a mountainous country situated in the South West Pacific. It consists of two main islands, the North and South Island, and several small islands. The nearest continent is Australia some 1900 km to the west.

The country extends between latitude 34.5°S and 47°S, and is over 1600 kilometres in length, but only 320 km wide at its widest point. In total area covers 266,770 sq km.

Throughout the length of both islands runs a high mountain range with several peaks over 3,000 m high. Because of New Zealand's mountainous nature, rivers are short, with many rapids, flowing swiftly to the sea.

The climate ranges from warm-temperate in the north to cool-temperate in the south. Except for a small semi-arid region in the rain shadow of the Southern Alps of the South Island, the climate is oceanic with a rainfall of 1000-2500 mm per year. Rainfall is evenly distributed throughout the year, although short droughts can be experienced in summer. High intensity rainstorms can occur at any time of the year, eg, during cyclone Bola 300-800 mm fell over 48 hours.

Geologically the country is mainly sedimentary in origin, composed of mudstones and sandstones, the former being highly erodible. The mountain ranges consist mainly of fractured greywacke while the central volcanic plateau of the North Island is covered by deep erodible ash showers.

Before European settlement some 150 years ago, most of the country (66%) was originally in heavy forest and bush. The rapid exploitation of forest resources and conversion to farmland by burning and oversowing with grass seed brought about a wide expanse of exotic grassland covering some 7.3 million hectares, and grassland/scrub and grassland/forest associations covering another 4.3 million hectares.

This transformation of forest to agricultural land on country with steep slopes and erodible soils, subject to high intensity rainfall, coupled with ill-conceived management practices of periodic burning and overgrazing, has resulted in increased runoff and accelerated erosion which in some districts is of alarming proportions.

The seriousness of the problems of flooding and erosion resulted in central government legislation setting up a national authority to make provision for the conservation of soil resources, the prevention of erosion damage and the control of flooding. In all main river systems, Catchment Authorities were constituted to implement a programme of river control in the flood plains and erosion control in the hills and steepland headwaters. The system of ad hoc local authorities being responsible for soil conservation in the field, and a national authority being responsible for soil and water conservation policy, has served New Zealand well, but at present the government is reviewing existing environmental legislation and reorganising regional authorities to include soil and water conservation and river control along with other local and regional government functions.

For erosion control, soil conservation techniques such as pasture furrows, graded banks, grassed waterways, flood regulating and gully control dams and the use of improved plant materials - grasses, legumes and trees - have been adapted to meet the special conditions of the hill country farming system of New Zealand.

On this steep unstable hill country tree planting plays an important role with the main species used being *Pinus radiata* for reafforestation of the worst-eroded areas, and poplars and willows in less-eroded areas where continued grazing is still possible. This paper discusses only the role played by poplars and willows in erosion control.

PRINCIPAL REASONS FOR USING POPLARS AND WILLOWS IN EROSION CONTROL

Poplars and willows have been the most widely used trees for planting on unstable hillsides, under pastoral farming conditions, for the following reasons.

1. Easy vegetative propagation of clones of proven quality. New clones with superior characteristics such as improved pest or disease resistance can be multiplied rapidly by stem cuttings in Catchment Authority nurseries or by individual farmers.

2. Poplars and willows can be established from large unrooted poles in the presence of domestic stock (sheep, cattle) on grazing land.

3. Their early growth rate is superior to all cool temperate tree species other than a few eucalypt species. Height growth from poles varies from 1 to 4 m per annum for the first five years after planting, depending on soil fertility and moisture regimes.

4. The willows and most poplars are tolerant of flooding and periodically saturated soils. However some poplar species such as *deltoides* ssp. *angulata* and the Korean aspen x white poplar hybrid (*P. alba* x *glandulosa*) are difficult to establish from unrooted material in saturated clay soils.

5. Poplars and tree willows have extensive root systems capable of rapidly stabilising large soil masses and most can regenerate new trees from residual root systems and stumps whenever the tree has been damaged by live-stock, fire or erosion.

6. The fine fibrous root mat of willows has proven most effective for reducing bank erosion and channel scouring or deepening of streams and hillside waterways. Fine fibrous roots have also proven stronger and thus more effective in binding an erosion-prone soil mass together than the large rope-like roots of some poplar varieties.

7. Poplars and tree willows have a high evapo-transpiration rate during the growing season and are well known for their ability to dry out swampy soils.

8. Poplars and willows provide shade, shelter and supplementary fodder for stock. Foliage can be pruned and fed to stock during summer droughts since the prunings are similar in nutritive value to lucerne hay and are rich in nitrogen, potassium, calcium and zinc.

9. Timber from well-managed poplar trees is suitable for a variety of purposes. However, there is a large supply of *P. radiata* which has similar end uses, and thus poplars tend to be used only in small quantities, often by the farmer/grower. More recently, investigations have shown that the tree willow *S. matsudana* and several of its hybrids with *Salix alba* have sufficiently high basic density (400-480 kg/m^3) and wood strength properties that they could also be used for sawn timber production. There is also considerable interest in the growing of *Salix matsudana* and its hybrids with *S. alba* as short-rotation fuelwood crops.

PLANTING PATTERNS

The techniques of tree planting to reduce erosion on farmland have evolved into the following systems.

1. Close Planting

Trees are planted at minimum spacings of 3 x 2 m. The more actively eroding and unstable sites are planted with poplar and willow 1 m stakes and the remainder usually in *Pinus radiata*. This type of planting offers maximum protection and the most rapid stabilisation of the area. It is often linked to the construction of wooden or pole and netting debris-retention dams in stream channels. These areas may be planted and managed as farm woodlots with the dual purpose of erosion control and timber production.

2. Wide-spaced hillslope planting

On partly unstable areas, where stock are not excluded, 1-year-old trees or stakes are too vulnerable to browsing damage, so poplars and willows are planted as 3 m long unrooted poles at densities from 20-100 stems/hectare. Most hillsides do not require complete coverage, and poles may be planted only at strategic positions on unstable areas such as springs or seepages. Where possible cattle are withheld from grazing the area for two to four years and only sheep allowed in these paddocks until the poles are well established.

3. Change of slope planting

Often slips are initiated just below gently sloping flats or hill crests where downhill slopes become steeper, often due to seepage water from the flats flowing out over impervious layers. One or two rows of poplars or tree willows spaced some 8 to 10 m apart are planted in this change of slope area.

4. Pair planting

Pairs of willow and/or poplar poles are planted at intervals of 5 to 20 m along small streams or channels where runoff concentrates in heavy rainstorms. The poles are planted directly opposite each other. Willows in particular form an erosion-resistant mat of roots in the stream or gully, preventing scouring, maintaining bank stability and thus the stability of the hillslopes above.

5. Stream and Riverbank Planting

For streambank protection willows are planted in closely spaced lines along sections of the stream where bank erosion is likely to occur. Once established they prevent further undercutting of the banks. In meanders only the outside bends are planted. A similar planting pattern is used along the major rivers for stopbank protection. Here anchored tree willow logs are used to reduce scouring and assist the close-spaced plants to establish.

6. **Block Planting**

A block of willows and/or poplars is planted 4 or 5 rows deep across the streambed to create a strong point in gullies and streams and prevent degrading where small waterfalls are working back up the channel. They also trap silt and debris in the gully floor.

7. **Periphery planting**

In very unstable active gullies the direct establishment of plant materials is very difficult. Small rooted trees cannot withstand the soil movement. In these cases suckering poplars such as *Populus alba* and more recently *P. alba* x *glandulosa* and the black locust *Robinia pseudoacacia* have been planted along the more stable edges of the gully. If further movement occurs, these trees may be carried down to the gully floor where broken roots will send up suckers. When the gully bottom is sufficiently stabilised further planting on the gully bottom and up the sides can be undertaken.

8. **Shelter or Windbreak Planting**

Usually one row of poplars or willows are planted to shelter live-stock or crops or protect fields against wind erosion. Prior to the arrival in New Zealand in 1973 of the poplar leaf rust *Melampsora larici-populina*, the Lombardy poplar *Populus nigra* cv. 'Italica' was the most widely used clone for this purpose. Because of its high susceptibility to this leaf rust the clone has been replaced in the North Island by the fast-growing tree willow *Salix matsudana* and its hybrids with *Salix alba*, and by wider-crowned poplars such as the *P.* x *euramericana* cultivars 'Flevo' and 'Tasman'. Poplars and willows have been used extensively for horticultural shelter because of their ease of establishment and rapid growth rates. Spacings within the rows for farm and horticultural shelter vary from 1 to 4 m. At the wider spacings suitable small tree or shrub species are usually planted as fillers to provide bottom shelter (PM Handbook, Vol 1).

9. **Fence Line Planting**

In the past, poplar poles or two-year-old rooted trees were planted at 5 m intervals along proposed fence lines on unstable country. When planted 2 to 4 years before erecting the fence, the trees acted as fence posts. This system worked well but has since been replaced by the use of lighter and cheaper electric fencing through unstable areas.

On most farms a combination of several planting systems is required and erosion control work is usually carried out according to a farm plan prepared by a Catchment Authority soil conservator.

In most countries where poplars and willows are used for erosion control they are planted either as unrooted stakes or cuttings or one to two-year-old rooted trees. The practice of using unrooted poles in the presence of grazing animals is the most significant feature of poplar and willow planting in New Zealand and has led to some special problems in selection and propagation.

SPECIES SELECTION

The study of the various aspects of poplar and willow selection and cultivation in New Zealand is undertaken by the Plant Materials Group of the Soil Conservation Centre, DSIR (formerly the National Plant Materials Centre of the Ministry of Works). A poplar and willow nursery is maintained at the

Centre where the following work is carried out:

1. **Collection, identification and classification of all poplars and willows grown in New Zealand**

The poplar collection contains 349 imported clones, 81 clones selected from imported seedlots of pure species and 697 clones selected from interspecific hybrids bred in New Zealand between 1978 and 1985.

The willow collection contains 220 introduced clones, and 416 clones bred and selected in New Zealand. Certified material is distributed to commercial nurseries, catchment authorities and other government departments. Stock and stoolbeds of the larger nurseries are inspected for varietal control and incidence of disease at the request of the grower.

2. **Introduction and testing of promising hybrid clones and seedlots of pure species from overseas**

Introduced clones are released after two growing seasons in quarantine glasshouses and then undergo the same selection procedure as seedlings grown from introduced seed of pure species or hybrid seed from a small controlled hybridisation programme.

3. **Controlled hybridisation**

No introduced species has yet fulfilled all the requirements considered essential for erosion control trees and a controlled hybridisation programme is in progress to combine the most useful features of the introduced species into better adapted F1 hybrid combinations. Characteristics selected for in the hybrids include:

- High disease and pest resistance. At present this involves selection for resistance to *Melampsora* rusts and *Marssonina* leaf spot diseases. There are no serious insect pest problems in New Zealand, but several very damaging insect pests occur in the Northern Hemisphere. Since chemical control measures are rarely economic, all clones must be selected for resistance to the current range of pests and diseases in New Zealand. New introductions selected for resistance to pests and diseases overseas are also being imported.

- Ability to grow from stem cuttings. Poplars and willows are planted into pasture as 3 m-long poles, cut from 2 or 3-year-old shoots grown on stumps (stools) in specialised pole production nurseries. Alternatively, poplars and willows are established as rooted trees which have been propagated from 25 cm long stem cuttings. There is considerable variation in poplars between sections, species and clones for rooting ability.

- Straight stem form. Since poles must be stacked in the nursery, on trucks and under helicopters, and in many cases are planted by ramming directly into saturated soils, stem straightness is an essential requirement for ease of handling and reduced costs during nursery production and planting, as well as for trees grown for timber.

- Vigour. Clones grown for soil conservation must possess rapid growth rates to effect rapid soil stabilisation and to place the foliage out of reach of domestic stock. Total growth is greatly affected by the widely differing photoperiod and temperature requirements of willows and poplars from different latitudes and altitudes; thus careful provenance selection is required to obtain clones capable of utilising the full growing season in the various regions of New Zealand.

- Fibrous root systems. Fine, fibrous roots are stronger and have a greater soil binding effect than large diameter roots. As part of the selection procedure assessment of fibrous rooting has been carried out on 1 to 3-year-old trees in the nursery.

- Unpalatability to the Australian brush-tailed possum (*Trichosurus vulpecula*). Poplar foliage, bark and buds vary greatly between and within species in palatability to possums. Establishment of palatable poplar and tree willow clones may be prevented or retarded by possum browsing.

- Early development of rough bark on the lower trunk. Poplar and willow species have barks of widely differing thickness and texture. Some varieties of *P. deltoides* develop a thick, rough bark within the first 5 years of growth, while other species such as *P. maximowiczii* may retain a thin smooth bark for 20-plus years. Cattle and horses often ring-bark smooth-barked trees causing severe damage or death. Poles may be protected by plastic netting sleeves for up to 6 years, before the tree bursts the sleeve allowing stock access to the bark.

- Resistance to wind damage. To minimise wind damage clones are selected for small leaves, strong flexible branches, narrow crowns and freedom from stem breakage in nurseries and field trials. Pliable branches are also preferred for willows planted for stream and river control since broken branches may re-establish downstream, causing channel blockages.

- Other characteristics which may be considered include: sex (male clones of willows are preferred for river-bank planting to prevent seedling establishment in the river bed); ability to tolerate acid, saline or low fertility soils; ability to produce sucker shoots from damaged root systems (most developed in aspen and white poplars); ability to grow on drier soil types (aspen); ability to grow on saturated, acid clay soils (some willows); and amenity values such as spring and autumn foliage colour, flower and bark characteristics and different tree forms.

POPLARS

In the past the silver poplar (*Populus alba*) and the Lombardy poplar *P. nigra* 'Italica' were the two most commonly used poplars in erosion control. Since 1973 *P. nigra* 'Italica' has been defoliated every year by *Melampsora larici-populina*, while silver poplar has been defoliated by *Marssonina castagnei* since 1985. At present, the following disease-resistant clones of poplar are being grown in pole production nurseries for erosion control planting.

Species	Clone	Date Released	% of total stools grown	
			1988	*(1984)*
Populus yunnanensis	Yunnan	?	7.4	(4.1)
P. x euramericana	I 214	1958	6.0	(5.0)
P. x euramericana	I 154	1974	2.2	(5.4)
P. x euramericana	Flevo	1974	27.3	(52.4)
P. trichocarpa	PMC 471	1978	3.9	(4.2)
P. alba x glandulosa	Yeogi 1	1979	4.2	(1.0)
P. alba x glandulosa	Yeogi 2	1980	1.0	(2.2)
P. x euramericana	Tasman	1980	15.8	(8.5)
P. deltoides x maximowiczii	Eridano	1980	21.3	(10.0)

P. x euramericana	Luisa Avanzo	1986	0.5	(-)
P. x euramericana	Veronese	1986	0.5	(-)
P. deltoides x yunnanensis	Kawa	1986	5.8	(-)

With the exception of 'I 214' these clones have proven resistant to the leaf rust *Melampsora larici-populina* which arrived from Australia in 1973 and caused a series of epidemics of leaf rust on the clones then in use. Clones used prior to 1973 included the *P. x euramericana* clones 'I 30', 'I 78', 'I 214', 'I 455', 'I 488'; and 'Robusta'. These proved so susceptible to the rust that large areas of pole production nurseries had to be replanted with new rust-resistant clones.

The above list of clones, except for Kawa, were introduced into New Zealand as cuttings and were not bred specifically for erosion control in New Zealand. They have several defects the most critical of which is the high palatability to the Australian brush-tailed possum (*Trichosurus vulpecula*) of the clones, 'I 154', 'Flevo', 'Tasman', 'Luisa Avanzo', and 'Veronese'. This problem of high foliage palatability to possums is being overcome as shown by the following changes in the ratio of palatable/unpalatable poplar clones grown in soil conservation nurseries since 1972.

	1972	1980	1984	1988
% Palatable poplars	93.6	86.8	78.5	55.5
% Unpalatable	6.4	13.2	21.5	44.5

From the current range of disease-resistant hybrid poplar clones under test, sufficient possum-resistant varieties will be available to replace all highly palatable clones during the next 5-10 years.

WILLOWS

Willows are widely grown in New Zealand for soil conservation planting. They are the most abundant exotic tree after *Pinus radiata* and have been used principally for river and stream bank protection. Since 1973 when the poplar leaf rusts arrived in New Zealand, the tree willow *Salix matsudana* and a group of *Salix matsudana* x *S. alba* hybrid clones have been used extensively for slope and gully stabilisation planting. In the last 15 years thousands of kilometres of kiwifruit shelterbelts have been planted in New Zealand using these same tree willow clones. The following willow clones are being grown in pole production nurseries for erosion control planting.

Species	Clone	Date Released	% of total stools grown - 1988	(84)
Salix matsudana	PN 227	-	20.2	(19.6)
Salix matsudana x *S. alba*	Cannock	1975	5.6	(6.8)
" " "	Aokautere	1975	29.4	(26.9)
" " "	Te Awa	1975	4.0	(6.0)
" " "	Tangoio	1980	7.7	(6.0)
" " "	Makara	1980	1.8	(5.0)
" " "	Moutere	1980	10.7	(9.2)
Other tree willows		-	9.5	(7.6)
Salix purpurea	Booth	-	2.5	(2.7)
Shrub/osier willows		-	8.6	(10.2)

In addition to the above willows, the crack willow *Salix fragilis* and to a lesser extent the golden willow *S. alba* var. *vitellina* are used for stopbank protection and river training work along major South Island rivers. The main problems with the tree willows in current use are their narrow genetic base and their high palatability to possums. Palatability problems are avoided as much as possible during the plant establishment phase by trapping and poisoning of possums, the use of repellents or the use of protective sleeves over which the animals cannot climb. An intensive breeding programme has so far failed to incorporate genes for leaf bitterness (possessed by shrub and osier willows) into vigorous hybrid clones of the tree willows *Salix matsudana*, *S. alba* or their hybrids, although several tree willow x shrub willow crosses have produced seedlings. The narrow genetic base of the existing clones has been widened by the recent introduction into New Zealand of new clones of *Salix matsudana* and *S. alba*, and by an interspecific hybridisation programme, including advanced generation crosses between these two species and their F1 hybrids.

A shrub willow selection programme aimed at producing improved clones for torrent control and bank protection planting has included a wider range of species. However, most emphasis has been placed on *S. purpurea*, which is well adapted to New Zealand conditions, and 21 introduced clones are under evaluation. Two clones, *S. purpurea* 'Holland' and *S. purpurea* 'Irette' have recently been released for bank protection planting. A further 44 shrub and osier willow species (134 clones) are under evaluation, more than half of which have been introduced in the last five years.

POPLAR AND WILLOW PROPAGATION AND ESTABLISHMENT

1. Type and size of planting material

In erosion control poplars and willows are planted principally as unrooted stakes and poles. The use of one-year-old rooted cuttings is now confined to the establishment of shelterbelts, woodlots and for riverberm protection/production plantations. The propagation of rooted stock follows normal nursery practice with cuttings lined out at 25 cm x 1 m spacing. At the end of the growing season trees are undercut with a U-shaped blade, lifted, pruned, root-trimmed and despatched.

For the production of poles, 235 ha of production nurseries have been established, principally by Catchment Authorities. These utilise the improved poplar and willow clones developed by the Soil Conservation Centre, and careful varietal control is maintained by the use of approved colour codes applied to poles on despatch.

A total of 417,000 poplar and 507,000 willow stools supplied Catchment Authorities with some 321,000 3-metre-long poles in 1988. Poles are normally grown on a 2 or 3-year-rotation and stools can provide 4 to 6 crops of poles before being replaced (usually by the arrival of improved cultivars). In some Catchment Authority areas crack willow *(S. fragilis)* poles are harvested directly from river-berm plantings for use in river control work, and in 1988 some 200,000 poles were harvested for this purpose.

The following types and sizes of planting material are in general use:

Unrooted		Length	Diameter	Prepared from	Use
Wands		1 m	15-25 mm at base	1 yr old wood	Stream control
Stakes		1 m	20-40 mm at base	1 yr old wood	Gully control Scree stabilisation
Poles	- sheep only	3 m	40-60 mm at base	2 or 3 yr old	Hillside stabilisation
	- cattle	3 m	60-100 mm at base	wood	Gully control River control

2. **Method of pole production**

Stools for pole production are established from cuttings, the spacing varying from 1 x 1 m to 4 x 1 m depending on the clone involved, soil and climatic conditions and size of machinery available for interrow cultivation. Cuttings are grown into single-leader trees with the first harvest occurring at age two or three. Clones in current use, produce new crops of poles every two years, the number of poles varying between 2 and 4 per stool depending on spacing and stool vigour.

Poles are cut in winter, during June, July, and August, generally at heights of 25-50 cm above ground. Branches are trimmed off manually, and the pole topped just above the junction of the current and last years growth. This has been found to encourage sprouting from the top of the pole, particularly for poplars, and results in less dieback and subsequent infection by the silverleaf fungus (*Chondrostereum purpureum*).

Stumps or stools are either sprayed or painted with a fungicide/wound sealant mix to reduce infection by the silverleaf fungus. This fungicidal treatment is being revised by Dr A G Spiers of the Plant Materials Group as investigations of several new biological (fungal and bacterial) and chemical control methods are near completion.

Poles are planted as soon as possible after cutting, and when this is not possible they are stored vertically with their bases in running water to prevent drying out. Alternatively, they can be stored in horizontal stacks kept moist by irrigation sprays.

3. **Pole establishment**

Poles are delivered to field locations by truck and spread in bundles across hill sides, often by helicopter. Planting is carried out either by the farmer or a planting contractor using various types of pole bars or motorised soil augers and rammers. Cattle are excluded from the planted area for two to three growing seasons to allow root systems to establish. Sheep grazing is continuous but it is preferable that sheep are treated for external parasites and shorn before their return to the planted area. This reduces their tendency to rub on the poles and thus break the new roots near the soil surface. It either case it is necessary to check the poles for looseness and re-ram the topsoil, at least until the main growth phase occurs in early to mid-summer.

POTENTIAL UTILISATION OF TREES PLANTED FOR EROSION CONTROL

1. In most cases hill-country erosion control plantings are scattered with poor access; trees are unpruned, often multi-stemmed and prone to develop high proportions of tension wood and bacterial wetwood. Potential uses are limited to on-farm milling for fencing materials, firewood or lumber for on-farm use. However, it is possible to prune some clones grown from poles into an adequate form for timber or veneer production. Considerable research is needed to determine which clones develop the least tension wood and bacterial wetwood in this situation.

2. Where woodlots are established for stopbank protection on river bermland large quantities of poplar and willow wood can be grown for a variety of end uses. However, in New Zealand no suitably tended stands have been grown specifically for veneer or sawlog production and most material available (only in the South Island) is being utilised as a 10-30% mixture with *Pinus radiata* by a single mill producing medium-

density fibreboard. Two veneer mills have shown an interest in poplar but supplies of pruned logs are small and scattered.

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THE CONTRIBUTION OF BIOMASS TO SUSTAINED RESTORATION OF THE GLOBAL BIOSPHERE.

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Loosing the Paradise?

Although intellectually gifted, modern Man seems at present engaged either in an active destruction or maybe an in vain expected improvement of his own environment. The consequences are anyway the same for the two economic hemispheres, the Northern and the Southern as well as for their resources and development. The road toward the ruin is different, the end nonetheless looks dishearteningly similar. Life itself is threatened over large areas in both hemispheres.

The so called development is emptying their natural wealth and sterilizing large areas of their soil and land. In the southern economically underdeveloped hemisphere man-made evils are erosion, desertification and reckless destruction of the tropical forest. In the northern economically advanced hemisphere the change will develop into already foreseeable disasters caused by Man's shortsightedness regarding natural resources and his technological presumption. Heavy atmospheric pollution and climatic, edaphic and hydrological consequences of overlooked need of sustainability of the entire biosphere of the planet will however strike back sooner or later.

Summarizing the compound effect of the overuse of fossil fuels in the northern developed hemisphere and the vast deforestation, erosion and overgrazing of large areas combined with inoptimal migratory agriculture in the southern developing hemisphere it seems impossible to deny the risk of a severely worsened environmental development.

A doubling of the atmospheric concentration of CO_2 plus the trace gases will cause a warming of the climate with at least several degrees (Fig. 1, from Bolin et al 1986). - In addition an accelerated devastation of the tropical rain forests might heavily distort or enhance the expected global temperature development.

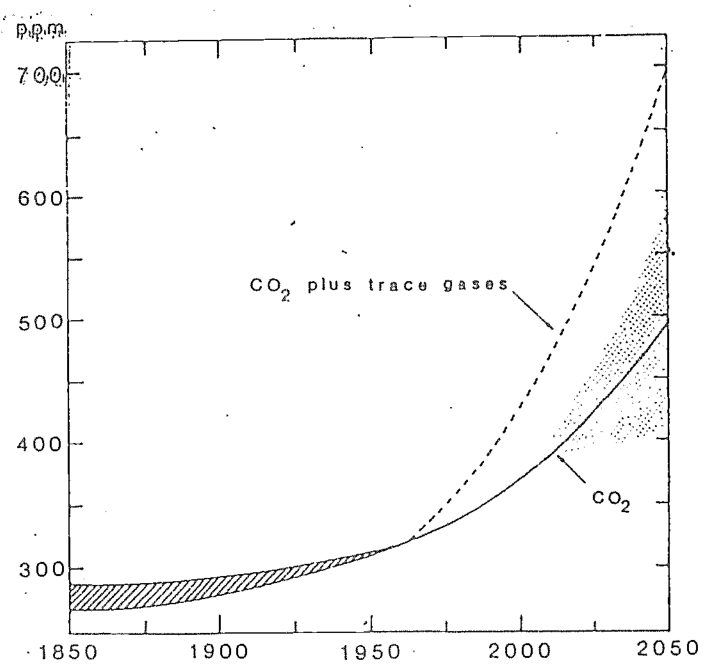

Fig. 1. Past and projected future atmospheric CO_2 and trace gas concentrations (based on (48)). The full line shows changes in atmospheric CO_2 concentration. Accurate data are only available from 1958 onwards. The earlier values are estimates based on a variety of sources of information, the most reliable of which are fossil CO_2 measurements made on bubbles in ice cores (e.g. (32)). While future concentrations are clearly subject to considerable uncertainty (indicated by the stippling), the full line shows a likely course of events. The dotted line shows the equivalent CO_2 concentration corresponding to the most likely CO_2 curve, and to trace gas projections given by Ramanathan et al. (36) and Dickinson and Cicerone (9). Only trace gas increases since 1965 have been considered (except for methane, these earlier changes were negligible). Since the trace gases considered have a greenhouse effect, their concentration changes can be converted to an equivalent CO_2 concentration change using appropriate models of their radiative effects. Only a single dotted line is shown, but the same relative uncertainty applies to the future CO_2-plus-trace-gas curve as to the curve for CO_2 alone. (Bolin et al 1986).

A warming process (see Fig. 2 from Jones et al 1986) simultaneous with the rise of CO_2-content has already started. Although some groups of scientists have accepted the foreseen rise of the average temperature as a blessing it seems easy to agree with those, who have a critical attitude to such a major change of our atmosphere in such a short time.

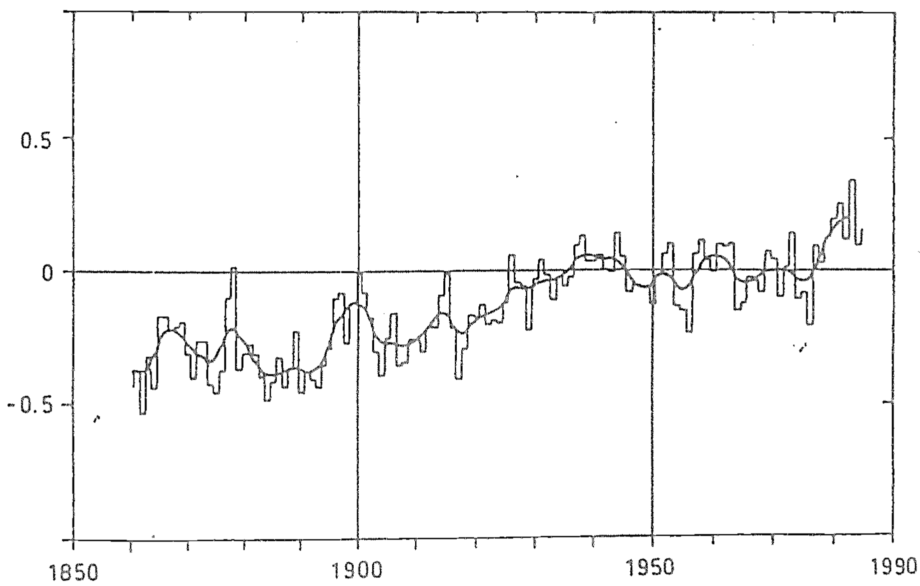

Fig. 2. Global mean annual surface temperature changes. Smooth curve shows 10-year Gaussian filtered values. (Jones et al 1986).

- Finally the CO_2 produced in the combustion process of all fossil fuels has one major controlable terrestrial sink only: The green forest-dominated vegetation cover of the world. Regrettably it has been severely reduced during the last decades. The present forest area is less than 3.9×10^9 hectares. In 1850 it was still about 7.5×10^9 hectares (cf. Buringh 1987).

The task and its scope

The author considers the rapid warming of the atmosphere a greater risk of catastrophe than the energy problems caused by reduced use of fossil fuels. Further uncontrolled development of the climate of the Earth must therefore be prevented. The possibility of an opposite development of the climate in form of an expected cooler period after 1990 the author considers a minor deviation caused mainly by colder winter climates in the Northern hemisphere. Carefully chosen countermeasures against the main disturbance factor should be both realistic and logical.

A conceivable approach would be to keep three separate tasks under control:

1. A consistent reduction of the present annual emission of carbon of fossil origin (Cfoss)* into the atmosphere seems a categoric imperative. The prime condition for this is a massive substitution of fossil fuel with energy saving industrial processes, hydro-electric, wind- and solar energy as well as renewable biomass fuels where energy is indispensable (cf. Goldemberg et al 1988).

2. The minimizing of the Man-caused flux of trace gases - a disgrace to the Mankind - needs to be initiated immediately globally, not in a few countries only, and carried out with perseverance until an acceptable minimum level is reached.

A controlled replacement of the present surplus of atmospheric CO_2 for retaining the climatic conditions at a wanted level, when the reduction activities have demonstrated their efficiency and practicability as a tool of global atmospheric control.

The annual flux of Cfoss to be reduced is of a magnitude of 5×10^9t as seen in fig. 3 (from Bolin et al 1986). The present drain of 1×10^9 t Cres* mainly from the ongoing devastation of the tropical rain forests can be reversed by a changed forestry policy and efficient reforestation activities in the next decades. About 50 % of the above surplus will be absorbed by the oceans.

*Cfoss = carbon of fossil origin

*Cres = carbon of recent biomass origin

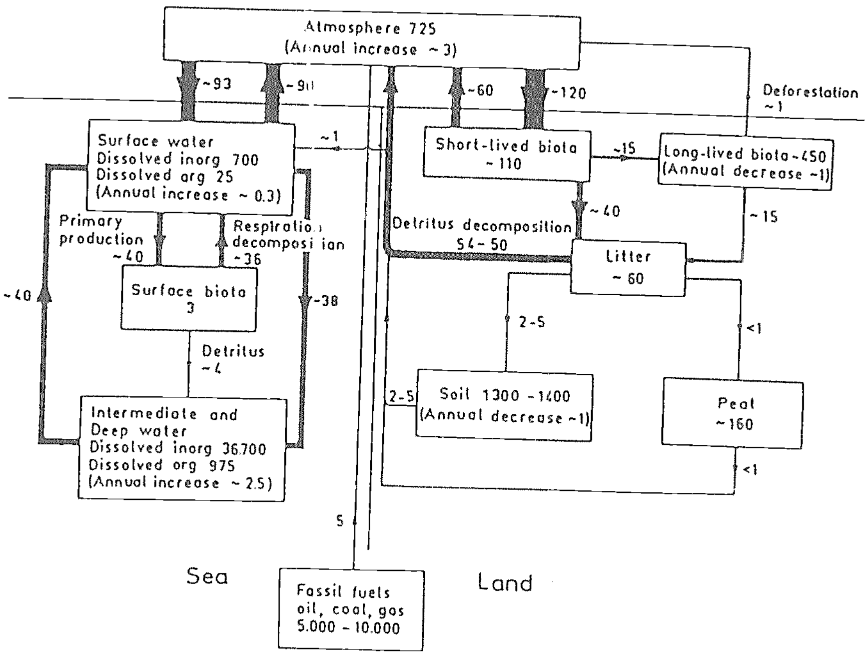

Fig. 3. Schematic diagram of the global carbon cycle. Approximate reservoir sizes are given in units of 10^{15}g C and fluxes between reservoirs in units of 10^{15}g C yr^{-1}, valid as of the early 1980s. Data from compilation by Bolin (1983) modified in accordance with most recent data (cf also Table 3.2). Although single numbers usually are given, there is considerable uncertainty about both reservoir sizes and fluxes. A complete balance is not achieved as later discussed in Section 3.7. (Bolin et al 1986).

A tentative calculus of the biological fixation of the surplus of CO_2 in the atmosphere caused primarily by overuse of fossil fuels is presented in tables 1a and 1b.

Table 1a. Assumed atmospheric surplus in 10^9 of C_{foss} from periods indicated below

Period	Total surplus of C_{foss}, 10^9 tons average annual, surplus x time
1990-2000	3 x 10 = 30
2001-2040	2 x 40 = 80
2041-2080	0,75 x 40 = 30
In total	140 x 10^9tC

Table 1b. An example of alternate methods applied for enhancement of biomass production for neutralization of the CO_2 surplus in the atmosphere (CO_2 expressed as C)

1. Increasing forest area (1.0x10^9ha) during 2000-2040 fixing at end 2tC/ha/yr	0.5x10^9x40 = 20x10^9tC*
2. Increased forest area during 2040-2080 fixing continuously 2tC/ha/yr	2.0x10^9x40 = 80x10^9tC
3. Lengthening of rotation in 10% of maturing forest of total forest area (0.4x10^9ha)x0.5tC/yrx80yr	= 16x10^9tC
4. Genetical, ecophysiological & silvicultural improvement (10%) in 25% of total forest area 0.5x10^9x0.2x40	8x10^9tC
5. Fastgrowing tree species 0.6x10^9hax2tC/yrsx40yrs	1.2x10^9tC
6. Fastgrowing tree species 0.6x10^9hax2tC/yrsx40yrs	9.6x10^9tC
In total	135x10^9tC

* The average productivity level seems low, but proposal depends on the low quality of soil available - after all misuse of soil.

A comparison of the table constituents indicates that the target of reducing the surplus of atmospheric CO_2 does appear within realistic frames. The difference (140-13<)$\times 10^{O}$tC during 80 years time seems negligable.

The energy content of the available part of annual removals from the forests will compensate part of the reduced fossil fuels during the two 40-year periods provided that the potential of advanced energy technology (cf Goldemberg op.c) will be fully employed during the first 40-year period when the contribution from the slow areal increase (40×10^6 ha/year only) of the biomass-production still is rather low. The role of energy forestry as producer of fuels may locally be important during the second 40-year period.

The total scope of the annual reduction of the remaining CO_2-flux plus replacement of previous Cfoss surplus needs to approach an equivalent amount of biomass-transferred Cres. This quantity must be semipermanently stored into

- viable new forests on afforestable productive land

- vital old forests by lengthening the rotation period within acceptable frames

- regenerated stands of genetical superiority and subjected to ecophysiological improvement measures

- fast-growing fuel-wood stands for direct substitution of the fossil fuels, until they can be replaced by climax species stands

- considerably lengthened life-time of woody structures for reducing the CO_2 emissions.

These goals can be achieved in different ways in the two economic hemispheres of the world.

The responsibility for a global climate deterioration is a case for the UN. For making the whole approach operational an authorized international core group should be elected to analyze the problems in detail and to prepare a reality-based global plan. The reforestation task of some 1.6 billion hectares in an 40 year long effort should be declared a global rescue operation for saving the common environment. Head-coordinators should be country-wise elected by competent ad hoc-committees. A chance of rescue does still exist, a high price however seems unavoidable.

For the desert countries short in water for biomass production a special programme for energy generation directly from the solar radiation or from the heat already converted from the radiation should be initiated (Fig. 4), (cf. Delin 1979). The immense energy quantities involved should not be overboked. Nor the supra conductors for long-distance transmission.

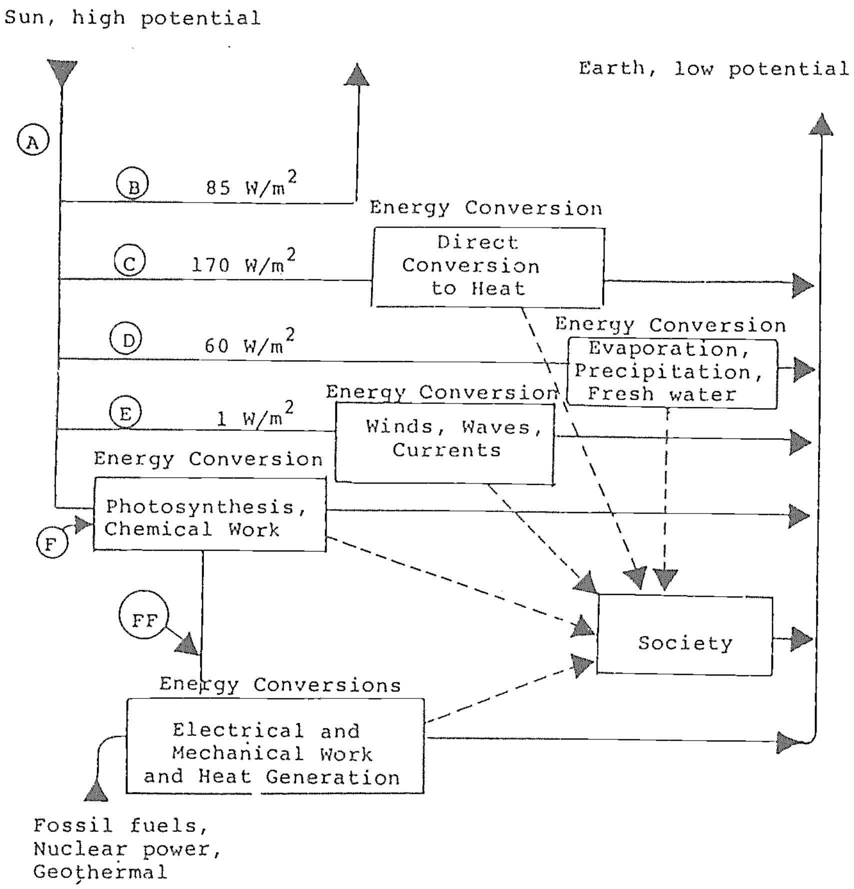

Fig. 4. Flows of energy which also have a high potential may be transformed into different kinds of useful work. However, the potential decreases during this process. Many of those energy transformations constitute resource inputs to our society such as the synthesis of food and fiber and the creation of fuels. It may be seen that the transformation of fossil fuels, geothermal energy and nuclear power is about 0.02-0.03 $W./m^2$ at present, which makes such transformations minor in comparison to other transformations taking place within the system. (From Delin 1979, fig. 15): The quantity of solar radiation converted into heat represents a considerable resource irrespective of its level of entropy (Delin 1979).

The costs of the restoration of the developing atmospheric pollution-disaster should be shared to the benefit of all nations between producers and consumers. Because of negligence of cleaning the combustion gases the consumer countries should pay the main load of the restoration costs. The economic burden should cover all costs for education, research, vocational training, seed and plant material, the machinery needed, transports as well as the aff-or reforestation costs. The quantities of polluting combustion gases and particles to the air should be the main principle of cost-sharing. A simplified calculus could be based on average annual consumption in the past, at present and in the near future.

The other alternative, e.g. 10 % of every nations annual military budget would be simplier to calculate, and maybe easier to get accepted. Every year of delay will worsen the situation and add to the increasing restoration costs.

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BIODIVERSITY

Joint IUFRO P.1.09.00 and IPC/FAO Ad-Hoc Committee Workshop

Multipurpose tree production systems

Moderator's Report - Session on Biodiversity

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The trends that we are currently facing are: over-exploitation and utilization of natural resources especially forest resources; decrease of forest coverage; and deterioration of environment as the human population increases and industry and consumption are fast developing. These trends have broken the equilibrium of agriculture and agro-ecology and given rise to the problem of high cost investment to agriculture. In order to meet the increasing various needs of humanity and improve the environment, the multi-purpose tree biomass production system has been developed in the last decade.

The first part of this session mainly focused on how to use the multi-properties of biomass to meet human needs. The following topics have been discussed:

1. How to select, maintain, introduce, improve and use abundant biological genetic resources. Almost all of the presentations involved this concept. Dr. Zsuffa

from the Faculty of Forestry, University of Toronto, Canada proposed a set of clear and practicably-valuable criteria for tree ideotype and improvement programmes. Drs. Debell and Weisgerber of Germany, professors Tu Zhongyu and Zhu Zhaohua of China presented their achievements in Populus, Salix and Paulownia, respectively. A number of clones that are fast growing, easily propagated, high biomass-producing and adapted to a wide range of locations, have been selected. Mr. Zheng Shikai reported a successful example of introducing Alnus and Acacia into south China indicating the importance of the international exchange of multi-purpose genetic tree material. Dr. Farmer emphasized an important point in his presentation, i.e. the rule of factor 'C' in tree genetic improvement programmes. It can be described as the influence of parents' existing conditions on their progenies.

2. Short rotation technique is an important component of multi-purpose tree biomass production systems. Dr. Debell's report on woodgrass and Dr. Weisgerber's inspiring results in short rotation experiments not only revealed a bright future for short rotation techniques in the development of forest biomass production, but also provided us with useful

techniques, abundant data and valuable experience in short rotation plantation management.

3. Agroforestry generates a variety of model systems for multi-purpose tree biomass exploitation and utilization. Mr. Cai Mantang and Professor Zhu Zhaohua presented an agroforestry model in south China and a model system of crop-*Paulownia* interplanting, respectively. Agroforestry systems play an important role in the protection of the agro-ecological environment, rational exploitation of soil resources, satisfaction of human needs and development of social economy. It should become one of the most important alternatives in development of agriculture, animal husbandry and forestry, especially in developing countries.

4. All the participants were highly interested in Dr. Zsuffa's proposal of international research cooperation in multi-purpose tree biomass production systems. A series of researches, as Dr. Zsuffa proposed, should be carried out worldwide in the aspects of tree improvement, culture techniques, biotechnology and product processing, utilization and marketing.

In summary, what we should always keep in mind is to fully exploit and use the multi-forms of biological materials to satisfy the human diversity requirements of environmental improvement and social economic development.

BIOLOGICAL ENGINEERING 1

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USA

The approach to reforestation in the first several decades of the twentieth century has been largely guided by the pursuit of single-sector and short-term profitability at any price, justified by the technocratic concept of "consumer needs". This was further complicated by the lack of a good interdisciplinary knowledge of the science and engineering of natural resource management. These led to the replacement of genetically diversified natural forest by, for example, plantations consisting of row upon row of trees belonging to a very small number of different species. These species are chosen for their rate of growth and consist mainly of conifers, poplar or eucalyptus. The complete lack of diversity in monoculture plantations makes them particularly vulnerable to attack by pests: that is, by pathogenic insects and fungi. Proliferation of the bark-beetle Scolytidae, for example, generally haphazard and localized among naturally diversified conifers, assumes disastrous proportions in spruce plantations that have spread so extensively over France over the last decades that the international natural resources management community became seriously alarmed about it. One of the results of the systematic introduction of monoculture plantations is a significant alteration of the soil structure including a reduction in porosity of upper soil horizons, making them less and less permeable. The water cycle is so modified that there is a two-fold or three-fold increase in runoff. Loss by evaporation increases because pine needles retain a large amount of rainwater. Coniferous forests are therefore naturally drier than broadleaved woodlands, other conditions being equal. Soil fauna are also affected. The number of earthworms is smaller by a factor of between 100 and 500 than under broadleaved trees. Decomposers are also affected and a marked reduction in bacteria occurs, particularly in the microorganisms involved in the nitrogen cycle. The current practice of reforestation with conifers in temperate and even in tropical regions would seem to constitute an astonishing perseverance with mistaken methods on the part of the authorities responsible for forests in the various countries involved. Science is badly needed in the decision-making process for natural resource management.

There is absolutely nothing wrong with using genetically superior material. In this lecture we will discuss breeding parameters so far found useful in the biological components of our reforestation systems and land-rehabilitation systems under consideration. Superior trees are being produced in major government and industrial laboratories all over the world. Micropropagation of superior genotypes will soon accelerate the genetic improvement of forest yields. Vegetative propagation via organogensis and embryogensis is at the forefront of planting stock production. Everyone in this business is aware and speaks of the danger of monoclonal plantations. Species and genotype "mixing" is often talked about, in laboratories anticipating the mass production of single genotypes. But "mixing for what purpose?" is the question. The errors occurred because there was a lack of the broad knowledge of what it took ecologically to sustain long-term balance and productivity. The correct approach is to biologically engineer the inter-connecting units of our production system to ensure sustainability.

Let us first define the term "production system". We are all familiar with agricultural production systems and timber forestry production systems. They each involve the use of some selected species of pre-specified use. They are managed. The agricultural systems are managed at much higher intensity traditionally than forestry systems. The two, however, are in a sense extremes of a complete continuum of production systems. The products of a production system can be soil erosion control, fertility improvement, watershed replenishment, or material (protein, fibre, energy and others) production. Depending on the socioeconomic boundary conditions and the history of a site(part of a larger watershed unit), desirable production systems can be biologically engineered. The biologically engineered systems we encounter most frequently in this IUFRO group include:

1. soil conservation systems,

2. multipurpose tree production and agroforestry systems,

3. industrial plantations.

The last decade and a half saw the rapid development of production techniques of high-value feedstocks from the biomass base. Modern and traditional genetic engineering have been combines with modern agricultural know-hows to produce low-cost and high-volume biomass for energy, chemicals, and structural material (Shen 1986). We no longer should restrict our view of products of the land to food and timber. And the new discipline of biological engineering become increasingly more important.

In what follows we will discuss the foundation of biological engineering, and then outline the methods of biological engineering, and draw a number of conclusions regarding the breeding parameters to be considered for component species of biologically engineered production systems.

The Foundation of Biological Engineering

Biological engineering is build on an understanding of the long-term sustainability requirements of a site - typically part of a larger watershed system. A biologically engineered system system must satisfy at the same time the following:

1. physiological requirements of the plants involved,

2. symbiotic requirements of the plant and the micro-organisms in its rhizosphere,

3. physico-chemical requirements of the cycling of nutrients and water - two inseparable components of the material flow, and

4. the external constraints.

the conceptual units in a biologically engineered system are shown in Table 1. For any production system all of these units must be considered as interconnecting parts of the system. The above-ground and the below-ground biomass are those contained in the plants (both woody and herbaceous are included in most systems) the physiological requirements of which are to be satisfied and sustained by the overall biologically engineered system. Units 2 and 4 are self-explanatory, except it should be pointed out that the soil and anything on it -- cover, mulch, etc must be treated as one unit. The externalities (Unit 5) considered are characterized by solar insolation and its average periodicity, precipitation and its average periodicity, temperature, humidity and wind. They provide the ultimate boundary conditions on transpiration and evaporation patterns which our production system has to perform within.

Table 1 Conceptual Units to be Considered in a Biologically Engineered Production System

Unit	Description
1	Above and Below-ground Biomass
2	Rhizosphere and its associated micro-organisms
3	Soil and its Cover
4	Water and Nutrient
5	The Objective Externalities

The physiological requirements include the phenological phase of the plants and the photo period of the plants, the symbiosis of each plant (in a typical system, several components compliment each other for soil cover, layering of canopy, soil fertility improvement, nutrient transfer, stress reduction, hydrology, and greater economic return) with its rhizosphere, and the amplitude of the species and clones involved.

The physical requirements of the system include the preservation of moisture in the surface and sub-surface layers of the soil, the appropriate movement of the water/nutrient system (unit 4) through Unit 3, and the hydrology of the below-ground system.

The Strategies of Biological Engineering

Knowing the biological and physico-chemical constraints of a set of plant-site combination, the strategy is to extend the boundaries of our limits and to conserve our resources. Typically the critical resources are water and nutrients. if the seasonal change of precipitation is very large, care must be taken to design a bio-physical total system that stores the water for use over a period of time. Effectively we want to design storage systems that average out the daily availability of water to our plant population. This is usually accomplished through modifications of ground cover, complimentarity of canopy types, complimentarity of species (including the plant rhizoshpere as part of the species component in the consideration) components for permeability control, complimentarity of species and age class components for litter mineralization control, engineering of the micro-topography for the improvement of water infiltration, reduction of ground water runoff, and replenishment of ground water reservoirs.

If the externalities are such that erosion is a big problem, the bio-physical total system must check erosion. This can be accomplished by both engineering of the micro-topography again to compliment a well-designed biological barrier to erosion. The contour hedgerow system being designed for the mid-hills of Nepal and North Eastern China (Shen, 1986) are good examples. Other examples for the tropical mountains are described by Behmel and Neumann 1981, and Benge 1980. A handbook on plant materials for soil conservation using the new Zealand experience was recently compiled (van Kraayenoord and Hathaway, 1986).

Utilization of plants which service different regimes of hydrology is an effective method of improving the underground water cycle. This is usually accomplished through the use of deep-rooted, medium-rooted, and shallow-rooted plant populations. This approach is often consistent with the labour economics as well. Shallow-rooted population can be obtained from reforestation planting stock in the form of cuttings, and medium and deep-rooted population can be obtained from reforestation planting stock in the form of seedlings. Table 2 illustrates some useful combinations of components of production systems. The individual functions of the components in the system beyond hydrology are also listed. Here we use cuttings and seedlings as the example components for considerations at planting time. Two example geographical areas including latitude levels of 27.5 N (Mid-Hills, Nepal) and 41.5 N (Northeast, China) are considered in the illustration.

The classification of land in terms of its limiting factors is the fundamental database needed by any government in planning for reforestation and any other land use. These factors include slope, soil depth, soil properties and their distribution, erosion, water table and climate. The degree of each limitation usually varies from place to place within one site.

The actual level of the water table before an engineering strategies are taken must be considered. There are cases in which the water table is actually higher, say by a third of a meter, above the ground. A successful practice in this case is to construct ditches and use the ditched-up soil material to produce bunds above the water table on which woody plants can be established (Lu, 1988).

Table 2 Examples of Species Components for Maintaining Hydrologically-Connected Upper and Lower Soil Strata

Components	Geographical Area	
	Nepal (Mid-Hills)	China (Northeast)
Seedlings	Alnus Nepalensis (Nitrogen Fixer)	Hippophae Rhamnoides (Nitrogen Fixer and Fruit Producer) Pinus Sylvestris (Erosion Controller)
Cuttings	Populus hybrids (Cutting Producer & Erosion Controller)	Populus hybrids (Cutting Producer & Erosion Controller)

Biological engineering is built on a comprehensive understanding of the overriding features of a site. Specific biological processes, microbiological processes, and topographical engineering are employed to satisfy the most critical requirements of the total productions system.

Indigenous consumption of the products of production system and overall economic incentives are important factors contributing to the success of locally accepted production systems. Multipurpose tree production systems for South America, Africa, and Asia can be biologically engineered to yield a number of major and minor products, some of which have reasonably high potentials for community commercialization:

1. reforestation planting stock,

2. all-season protein and roughage feed for animals

3. construction material,

4. energy wood,

5. medicinal bark and herbs,

6. silk, honey and wax,

7. food, fruits and

8. conversion of bare hills to productive land.

Multipurpose and multi-component tree production systems are designed with the benefits of biodiversity in mind. Tropical forests are examples of natural production systems high in biodiversity and they contribute genetic materials which confer disease and pest resistance upon economic products of the forest (Repetto 1988). Insect predators and parasites found in tropical forests control a very large number of agricultural pests (Myers 1984).

The knowledge base needed for biological engineering can be obtained from two sources: areas advanced in agriculture and forestry (examples include the U.S., China, Sweden, Finland and several other European countries) and developing countries in Asia, Central and South America and Africa. In the latter Nepal presents the extremely challenging situation in terms of slopes, altitude, and lack of nutrients.

In addition to considerations discussed above, the design and engineering of an ecologically sustainable production system require that attention be paid to the following areas:

1. biodiversity of species and clones be maintained within one locality,

2. complimentary benefits that can be obtained from biodiversity be emphasizes. These include economic as well as ecological benefits.

3. the chemistry of the system products (e.g. lignin, resin, tannin and other components) be examined critically for potential high-value use. Here is should be emphasized that the chemical makeup of the biomass is a function of age, and that the largest change in chemistry often takes place for temperate species during the first dormant season.

The immediate objectives of biological engineering are sustainability and biodiversity (see Figure 1). Sustainability ensures economic and ecological benefits. Biodiversity ensures the preservation of the gene pool that may be required for the biology component of strategies to maintain and increase sustainability.

	Objectives	Products
		ECOLOGICAL MANAGEMENT
Biological	SUSTAINABILITY	
Engineering	BIODIVERSITY	
		ECONOMIC DEVELOPMENT

Figure 1 Objectives and Products of Biological Engineering in Examples Dealt with in this Paper

Breeding Parameters

The major breeding parameters to be considered for the system plant components can be determined from biological engineering considerations. These typically include:

1. ecophysiology,

2. capability of utilizing the full growing season -- this may be accomplished by using companion clones which complement each other for this as well as other purposes.

3. crown architecture for adaptation in different density regimes,

4. juvenile vigour and relation between growth curve and plant spacing -- clones grown for soil conversion must possess rapid growth rates to effect rapid soil stabilization and to replace the foliage well out of reach of domestic stock,

5. relation between lignin chemistry and the occurrence of dormant periods,

6. the ability to use biological control for disease and pathogens, and

7. the physical and biological requirements of potential production systems involving the plant (This is how the genotype-environment interaction is realistically quantified).

Action Plan

Each successful system of industrial plantations, multipurpose production and agroforestry systems, and soil conservation systems possess necessary attributes to meet the requirements of sustainability, productivity, and environmental and socioeconomic benefits. The biological and engineering criteria for model systems must be developed.

The locations and infrastructure resources for model-system development and demonstration must be identified.

The gaps in knowledge pertaining to biologically-engineered model systems as defined above must be identified and research designed to establish the necessary database.

Attributes for ideotype planting stock suitable as components of biologically-engineered production systems must be established and revised as production system design improves.

Using the above-established considerations world-wide cooperative projects in each watershed categories and biodiversity regimes must be designed and carried out.

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CHINESE-SWEDISH SOIL CONSERVATION COOPERATION PROJECT IN MIZHI, SHAANXI PROVINCE, CHINA.

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ABSTRACT

The 530 000 km^2 Loess Plateau in north central China is one of the worst eroded areas of the world. 1.6 billion tonnes of silt run into the Yellow River every year. The average erosion in the hilly and gully areas reaches over 100 tonnes per hectare annually. This causes poor soil, ecological destruction and a constant threat of flooding of the river in the densely populated plain along its lower reaches.

Besides several projects funded by the FAO the Swedish SIDA has recently (1986) started a programme on soil conservation at the Shaanxi Research Institute for the Loess Plateau Control (SRILPC) in Mizhi County, Shaanxi Province. The Institute was established in 1979 with support from FAO/UNDP to work on erosion control in this area.

The Swedish-Chinese programme consists of four different, but closely interrelated sub-projects concerning soil testing techniques, biological soil improvements, agro forestry and energy forestry trials with multipurpose tree species. The main purpose of the energy forestry project is to reduce the level of soil erosion on hilly slopes, not suitable for agricultural crops or orchards and improve the economic value of these areas. To achieve this goal experiments have been established concerning evaluation of selected woody species, spacing effects on soil erosion and the effect of fertilization (sheep manure) on biomass production. The experimental sites are steep slopes (>25 ^{o}) and site preparations before planting are kept at a minimum level in order to minimize costs.

INTRODUCTION

The vast Loess Plateau in north central China is one of the worst eroded areas of the world. From an area of approximately 530 000 km^2 the erosion have been calculated to 1.6 billion tonnes of silt which runs into the Yellow River every year. The average erosion in the hilly and gully areas reaches over 100 tonnes/hectare and year. The erosion causes poor soil, ecological destruction and a constant threat of flooding of the river in the densely populated plain along its lower reaches. In some areas, like in Mizhi County, severe erosion of more than 200 tonnes per hectare have been recorded. This can be compared with the figures of what is considered to be acceptable erosion in USA: 5-10 tonnes/hectare and year.

Mizhi County in the Shaanxi province is located at lat 37 ^{o} and at altitude 850-1250 m above sea level. The climate is temperate, subarid and continental. Mean annual temperature is 8 ^{o}C with strong diurnal and annual variation (extreme temperatures are +35 and -25 ^{o}C). Mean annual precipitation is 450 mm falling mainly in July-October. Heavy storms are common during this period. The area consists of sandstone and metamorphic rocks, including coal, covered by a 50-150 m thick layer of an old loess plateau now heavily dissected and characterized by a rapidly growing gully formation.

The population in the county is about 40 000 households of which 90 % live in rural areas. The majority of the population live in cave dwellings dug out from the loess soil hills. They grow mainly maize, sorghum, millet, wheat and potatoes. The yields of grains are low, mostly below 1 000 kg/ha. Livestock such as cattle, horses, donkeys and mules are kept for draft power and manure. Goats and sheep are grazing on natural pastures, wasteland and on harvested agricultural fields. Pigs and chicken are also kept. Trees and bushes are not very common, covering only around 10 % of the area. Mineral coal which is easily available and cheap is used for fuel.

There is almost no natural vegetation remaining in the Mizhi area, although it falls within the decidous forest zone of northen China. Earlier attempts to control soil erosion by planting trees have resulted in low productive forests on the hilly slopes. Although species like Robinia pseudoaccacia and Pinus tabulaeformis, known for good growth in similar environment have been selected, the success of the planting efforts were limited in many places. Considering the variability in site-factors mixed plantations of trees, bushes and grass should be more suitable for diminishing the erosion and improving the economic value of steep slopes.

Since 1979 the Chinese government has established an Experimental Station for comprehensive erosion control at Mizhi, situated in the area with the most severe erosion. The station has got support from FAO/UNDP since 1980. In 1986 the station was upgraded to Shaanxi Research Institute for the Loess Plateau Control (SRILPC). The Institute is under the responsibility of Shaanxi Academy of Agricultural Science in Yangling. The FAO/UNDP projects have accomplished considerable achievments in the area concerning more rational land use and higher production in agriculture.

The Chinese-Swedish Soil Conservation Cooperation Project have been planned to cover important areas for the loess plateau control and activities of the Institute (SRILPC) and also to be suitable complements to the FAO/UNDP support and the ongoing WFP project.

MATERIALS AND METHODS

a. Experimental area

The soils of the area are quite uniform with relatively good water holding capacity. The texture is silty loam with silt to 60-80 % and sand 5-15 % and pH is about 8-8.5. The soil has a high proportion of $CaCO3$ which forms a surface crust and which is convenient for terrace building. The typical feature of the landscape is the terracing of the slopes . The intense cropping in the area has caused the development of various types of terraces, such as plain terracing, fish-scale terracing, contour-ditches etc and so called earth check-dams have been constructed. The check-dams reduces the sediment in watersheds and they are used for production of crops. As the technique and cost of constructing these dams are low they have been widely spaced in the area. Slopes steeper than 25 ^{o} should not be used for agriculture according to chinese regulations but should be covered with permanent vegetation.

b. Description of the Chinese-Swedish cooperation project.

Four different but closely interrelated sub-projects have started in 1987:

1. Development of simple soil testing techniques
2. Biological soil improvement experiments
3. Experiments on fruit and forage production for soil conservation (agro forestry)
4. Energy forestry trials with multi-purpose species

1. Development of simple soil testing techniques

In order to improve the farming systems and yields of crops it is necessary to be able to carry out proper soil analyses. This project aims at developing a soil laboratory and to train the staff to perform simple soil testing. The techniques required are of big interest not only for China but for many countries, including Sweden. Methods need to be developed as simple "boxes" for soil testing do exist in some countries, but they are often not adapted to internationally acknowledged systems for soil testing.

In Mizhi there is a rather well equipped laboratory through the FAO support with sophisticated instruments. However, the equipment was not specifically selected for soil analyses and some important parts are lacking. The need to train the personnel at the laboratory is great as some of the advanced equipment are standing idle due to lack of knowledge of how to run them.

Since the project started the equipment have been replenished and four chinese technichians have been trained in Sweden and in China. The laboratory is now carrying out all the soil analyses for the other three sub-projects and some ten different methods of simple soil testing techniques are being tested. When the methods have been worked out to run satisfactory larger quantities of analyses can be made for the farmers in the area.

2. Biological soil improvement

One of the main problems of the loess plateau is the low content of organic material. Crop residues, which is the natural supplier of humus, is taken away for fodder or fuel. This fact hampers the increase of the soil fertility of agriculture soil which, in turn, hampers the process to stop agriculture on steep slopes and plant grass, bushes and trees there.

This project aims at starting up research on the biology of soils at the Institute in Mizhi. The experimental work includes the effect of different crude material on soil organic matter content, estimating nitrogen fixation by some legymes, determining and examine different kinds of nitrogen and phosphorus fertilizers.

3. Fruit and forage production in an agro-forestry system

An important activity of the Institute and the WFP project is to plant fodder grass and fruit trees on steeper slopes (>25^{o}). Some kinds of fodder crops have been examined by the Institute and a variety of fruit trees are tested both on terraces and slopes in the demonstration orchard belonging to the Institute.

Sub-project 3 aims at examining the outcome of an agro-forestry system consisting of fodder crops and fruit trees. To plant grasses, legymes or a combination of the two together with fruittrees would mean a better protection of the soil between the trees and give a valuable combination of products. The project also includes testing of acceptance and digestability of various fodder of the animals.

4. Energy forestry with multi-purpose species

To be able to convince farmers to plant trees and bushes on slopes instead of agricultural crops, the plantations must give products which are appreciated. One such product is fuel wood.
Most households in Mizhi use coal for cooking and heating. The pollution problem is great in the area as the smoke is not all cleaned when it is let out in the air. Fuelwood would be a better bargain as it is renewable, gives less detrimental smoke and can be grown locally. The trees and bushes, selected for planting should give several products besides fuel, e.g. fodder, green manure, berries, construction material etc. They should preferable be nitrogen fixing with a large ability to coppice when cut.

The energy forest trials aims at reducing the soil erosion and improving the economical value of steep slopes not suitable for crops, by planting selected trees and bushes. Attempts will be made to develop methods for establishing woody vegetation at a minimum cost, on hilly slopes.

Experimental designs for energy forest trials in Mizhi

The most important decision when it comes to planting trees and bushes is to select the most suitable species. Important criteria for selection are for example that they should be well adapted to the local environmental conditions, such as drought, hot summers and cold winters, preferably they should be N-fixing species as fertilization is normally out of the question in this area, usefulness for the farmers must be high, they must be easily propagated and have a high rate of establishment success and finally they should coppice readily after harvest.

The knowledge about the biology and ecology of some of the selected species is limited and the project in Mizhi aims at investigating not only the production rate but also to study the coppicing ability and to determine the suitability of the selcted species for several purposes such as fuelwood (heat value measurements), forage and green manure (digestability studies). The effect of plantation design and management on soil erosion will also be evaluated.

Three different experiments have so far been established in Mizhi:

A. Testing and selection of species
B. The effect of spacing on soil erosion
C. Influence of fertilization on establishment and production of fast growing species

A. Testing and selection of species

Purpose: To study the establishment and production rate of selected woody species and their effect on soil erosion on hilly slopes. To investigate the influence of repeated coppicing on growth and to evaluate the species as sources for fuel wood and forage.

The following species are included: Robinia pseudoacacia
Ulmus pumila
Hippophae rhamnoides
Caragana intermedia
Tamarix chinensis
Amorpha fruticosa
Astragalus adsurgens

Site: Sun Jiagou, slope 30^{o}, south-east oriented.
Farmers used the site for cultivation with alf-alfa, potatoes, and beans. Abandoned because of low production.

The preparations before planting included soil analyses for N, P, K, pH and organic-C, Mg, Cu, Zn and soil texture. The experiment was planted with contour ditches and fish scale terraces. These are rather simple types of terraces with an increasing effect on the establishment rate to a low cost.

Planting in this area is best carried out during the autumn due to the soil moisture which is still present after the rainy season (July to September) and planting was done in November 1987.

Experimental design: plot size 150 m^2
4 replications
spacing 2x1.5 m (trees)
" 2x1 m (bushes)

Management: No weeding, irrigation or fertilization.

B. The effect of spacing on erosion

Purpose: To study the influence of spacing on soil erosion and to to estimate the optimal spacing for high, sustainable production.

Species: Ròbinia pseudoacacia

Site: Chen Jia po, 23.5^{o}, north-east oriented.
The site was sparsely covered with drought-resistant grasses and herbs like Artemisisa annua, Echinolopsilon divaricatum, Lactuca tatarica, Melilotus suaveolens etc.

Five soil samples were taken on each plot along a line stretching diagonally over the site. For each sampling plot the sampling depth was 0-20 cm and 21-50 cm. No site preparation was done before planting and one-year-old rooted stumps were planted in April 1988 (due to problems to find suitable experimental sites, autumn plantation was not possible in this case). In September, equipment for erosion measurements was installed.

Experimental design: plot size 200 m^2
4 replications
spacings: 1x1 m
1x1.7 m
2x3 m

Management: Weeding was carried out twice, no irrigation or fertilization.

C. Influence of fertilization on establishment and production

Purpose: To study the effect on establishment and growth rate of fertilization/night soil at planting.

Species: Robinia pseudoacacia
Populus opera
Salix lineastipularis

Site: Chen Jia po, 28.0 ^{o}, north-east and north-west oriented.
Previous vegetation like in experiment II.

Soil samples were described for experiment II. Before planting fish-scale terraces (0.5x0.5 m) were constructed. Planting was carried out in April (for the same reasons as in experiment II). In the planting hole for each Robinia and Populus plant 1.5 kg of sheep manure and 1.0 kg for Salix was mixed with the soil. In July the organic manure was complemented with 50 g of urea at each plant.

Experimental design: plot size 150 m^2
4 replications
spacing 2x1.5 m (Robinia, Populus)
" 2x1 m (Salix)

Management: Weeding was carried out twice (se experiment II).
No irrigation or further fertilization.

RESULTS AND DISCUSSION

Since the project just started the results so far are limited. In the annual report for 1987 it is concluded from the Chinese counterparts that the project got a good start and follows the plan of operation very well. Consultancies by Swedish experts in China and fellowships of Chinese scientists and technicians in Sweden have started up the activities in Mizhi. The experiments have been established and the experience from this work so far can be shortly concluded.

In sub-project 1 the laboratory for soil analyses have been built up. It is now a well functioning laboratory, with trained personnel who can handle most of the basic analyses. Besides the four fellowships to

Sweden another 6 members of the staff were trained at the Institute in Mizhi when the research-fellows returned to China.

Sub-project 2 started two of the four planned experiments during the first year of work. The results from nitrogen fixation experiments show that inoculation had a positive effect on yield of soybean and peanut. Different methods for determination of organic carbon in calcaerous soils showed that a treatment with 2 N H_2SO_4 + $FeSO_4$ was the best way to remove carbonate carbon in the soil prior to determination of organic carbon. The field experiments were partly destroyed by heavy hail-storms in the summer (1987) and will have to be repeated.

In the third sub-project it was concluded that the contents of organic matter was very low in the soil where the agro-forestry experiments were established. By comparing different cover crops, Lucerne gave the highest yields in the intercrop experiments. However, the water demanding Lucerne seemed to lower the moisture content of the soil- a disadvantage for the apple trees in the trial. Hard weather, storms and hail together with grazing sheep and insects caused a mortalilty of the apple trees of 35 %. The dead trees will be replaced and measures will be taken to protect the trees as much as possible.

The autumn planting of trees and bushes in sub-project 4 was disturbed by a heavy snow-fall in November -87 (has not happened in a hundred years!). However, plantation was completed some weeks later when the snow disappeared and before the ground froze. Two experiments were planted in early spring and as the spring and summer of 1988 was quite wet the survival rate and growth of the three experiments were high. Inventories of growth rate and performance will be carried out in the fall of 1988. The establishment of contour ditches and fish-scale terraces will be evaluated in terms of labour cost and benefit to the establishment of the plantations.

Samples from the species included in sub-project four were collected for heat value measurements and determination of acceptance and digestability as fodder. The analyses of heat value will be carried out in Sweden and the fodder aspects will be dealt with both in Sweden and at the institute in Mizhi.

Further data and detailed results for 1988 from all the different experiments will be published in the progress report of 1988, Swed Univ Agric Sci, International Rural Development Centre, Uppsala, Sweden.

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A NEW FARMING SYSTEM -- CROP/PAULOWNIA INTERCROPPING

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ABSTRACT

Crop/paulownia intercropping is adopted increasingly by farmers in the plains of North China, representing a new farming system. There are now 1.5 million hectares of farmland under intercropping. About 500 million paulownia trees in this region provide the local farmers with an annual timber growth of 5.7 million m3 with a value of 1.7 billion RMB yuan, 25,00,000 tons of dry leaves (7,500 tons of nitrogen) are produced yearly. This paper presents an analysis of the ecological and economic effects of crop/paulownia intercropping, puts forward the scientific basis for an arrangement of community structures oriented to maximum yields from both crop and tree, and finally it introduces the extension system that has made possible the rapid development of this technology in North China Plain.

INTRODUCTION

Crop/paulownia intercropping is a new farming system, which is widely practised and accepted by the farmers in North China Plain. This is the alluvial plain of the Huanghe (Yellow) and Huaihe River valleys located on N 30^0 - 40^0 and E 109^0 30′ 1220 . The climate is dry between October and the first part of June. The rainy season is from mid-June to mid-September due to the influences of the monsoon wind from East Asia. It is cold and dry in winter because of the wind from Siberia and the Mongolian Plateau. The extreme lowest temperature varies -10^0 to -20^0C. The mean annual rainfall is 500-900 mm, increasing gradually from the north-west to the south-east. Almost 80% of the rain falls during the wet season. The soil in this are is alluvial and much of it is quite poor. It is a sandy, saline, and alkaline soil. Before liberation, the people led a very poor life due to serious natural calamities, mainly sandstorms, droughts and floods. From May to June, a hot and dry wind often blows with wind speeds over 3 m/sec., temperature over 30^0 C and relative humidity less than 30%. This is quite harmful to agricultural crops, especially wheat, the main crop of the area and 20%-40% of the production is often lost as a result of the hot and dry wind. This area is the main agriculture region with a very large population (more than 300 million people). Both timber and firewood for farmers are quite scarce.

In the early 1960's, a strange phenomenon was found by the farmers in Lankao County, Henan Province i.e. trees of Paulownia elongata scattered in fields would not reduce the crop yield markedly and had an apparent effect in the resistance of sandstorm and soil erosion. The phenomenon also caught the attention of the local government and foresters.

Then in some villages in Lankao and adjacent counties small scale plantations were established. Since 1976 a systematic summary of the 20,000 hectares of crop/paulownia intercropping has been made. On the basis of the farmers' experience since 1983 systematic research has been conducted on the fixed experimental fields and in the same year the research got the support of the International Development Research Centre of Canada. At present there are 1.5 Mha of farmland under crop/paulownia intercropping forming a new farming system. This paper introduces the main research results obtained and ways to extend the results to the rural areas that have made possible the rapid development of the farming system in this region.

The objective of the research is to find the optimum artificial community structures by observing the ecological, biological and socio-economic effects brought about by different patterns of crop/paulownia intercropping. The research includes trials on spacings between rows and between trees with such densities as 5 x 6, 5 x 10, 5 x 20, 5 x 30, 6 x 30, 5 x 40, 5 x 50 m, the measurement of biomass and crop yield of the main crops (wheat, cotton, maize, sweet potato and tea), the changes of microclimate in the field, economic analysis of unit area and others. The experiments have been undertaken mostly on the plain on the old course of Huanghe River, Minquan County of Henan Province and Dangshan County of Anhui Province. Paulownia/tea intercropping has been studied in Tongling City which is a hilly area in the lower reaches of the of the Yangste River.

Paulownia, especially <u>P elongata</u> is a deep rooting species. In sandy and other soils, an average of 76% of the absorbing root system is at a depth of 40 - 100 cm, and only 12% of it is in the cultivated layer at a depth of 0 - 40 cm. In contrast, the root systems of the main food crops are distributed mainly in the cultivated layer. 80.1% of the roots of wheat, 94.6% of maize and 97.4% of millet are found in the top 40 cm. Therefore, competition for water and fertilizer between the trees and food crops is slight. On the contrary, the water in the deep layer and the fertilizers moved into the deeper layers may be absorbed by the roots of paulownia trees. In the dry season, paulownia can absorb underground water from the deeper layers and humidify the air by transpiration, which is beneficial for the growth of food crops.

The crowns of paulownia, especially of <u>P elongata</u>, are sparse and a large amount of light can pass through. The light penetration through the crown at the beginning of summer (in June) at the age of 7 - 8 years is 40 - 50%, and will be stable around 20 - 40% in the middle and later period of growth. Since the branching angle of paulownia is large, the leaves spread systematically and seldom overlap, so the food crops may obtain much light at any time. The light penetration through <u>P elongata</u> crowns is 20% higher than that of poplars (<u>Populus tomentosa</u>) and 38% higher than black locust (<u>Robinia pseudoacacia</u>).

The leaf renewal and defoliation periods of paulownia are later than other trees, about 20 days later than poplar, and the defoliation period is later than most other timber species. Late leaf renewal favours the growth of summer crops and late defoliation protects wheat seedlings from early frost damage.

Changes in Microclimate Factors under Intercropping

When the field is under crop/paulownia intercropping, the ecological environment will change along with the changes caused by temperature, humidity, wind velocity, evaporation and solar radiation. According to observations, when intercropping is practised the changes brought about in temperature humidity, wind velocity and evapotranspiration are generally favourable to the food crops. For example, comparisons made between an intercropped field and control plot show that intercropping can reduce the wind velocity on average by 21 - 52%, and reduce the evaporation of the ground (water surface) by 9.7% in the day time, 4.3% in the night time. The moisture content of the soil at 0 - 50 cm is higher than that of the control land. Intercropping also influences temperature. At the end of autumn, in winter and in early spring in the defoliation period, the wind velocity can be reduced by the wind resistance of the branches. As a result, the temperature is 0.2 - 1^{0} higher than the control land. In summer, in the intercropped land, the temperature is reduced by 0.2 - 1.2^{0}C during the daytime. All this helps to protect against natural disasters such as drought, wind, sandstorm, dry and hot wind, and early and late frost. In the light of hydrological balance, the changes are also favourable to the crops. The evapotranspiration of control land is higher than the intercropped land ie intercropping reduces the consumption of water in the field. However, solar radiation shows an apparent decline in the intercropped field as the trees age and density increases. The average solar radiation in the intercropped field with a density of 5 x 10 m (6 years old) is only 45.7% of the control and 80.6% of the control for an intercropped field of 5 x 30 m density (11 years old). As the distances to the trees are varied in the intercropped field, the horizontal distribution of solar radiation shows a great difference. This horizontal distribution of solar radiation is closely associated with the horizontal distribution of crop yield. Thus it is one of the priorities to get the best economic benefit through planting and silvicultural measures which aim at adjusting timely the solar radiation in the field.

Economic Effect of Intercropping

Effects on the yield of main crops 1) Effect on summer harvest crops: the main summer harvest crop in this region is wheat. The research done to date indicated that at densities of 5 x 20 to 5 x 40 with a rotation of 10 years, the yield could be 6 - 23% higher than the control. But a greater densities, when the tree is big and the solar radiation is not sufficient to meet the need for wheat growth, especially for the late growth, the yield of wheat would decrease correspondingly. 2) Effect on summer sown crops: the summer sown crops in this region are many, but the main ones are maize, cotton, soybean and sweet potato. Owing to the fact that the yearly precipitation concentrates on the growing season for those crops, the crops in the intercropped field have a stronger need for solar radiation than wheat does. according to the reports from Heze Prefecture of Shandong Province, in the intercropped field at eh densities of 6 x 25, 5 x 30, 5 x 40, 5 x 50 and 5 x 60, the tree age is 8 with dbh of 29.8 cm, height of 11.5 m, the yields of the summer sown crops are lower than that of the control, they are as follows: sweet potato -37.6%, peanut -32.2%, maize -25.9%, soybean -27.7%, cotton -14.5%. The crop yields show no difference when the intercropped trees are below five years old.

It should be noted that under 3 years old paulownia at eh density of 5 x 6 m, the yield of cotton is normal but when the trees are four years old, the yield of cotton is merely 13.8% of the normal yield. Consequently cotton cannot be grown in the intercropped field at the density of 5 x 6m. With a density of 5 x 10 m, the yield of cotton is less than 20%, whereas at 5 x 20 m, the yield of cotton reaches more than 80% or normal.

The effect on crop yield by the intercropping is intimately related to the yields of farmland management and soil improvement. In the 1950s and 1960s when sandstorms were not effectively controlled in the region of the old course of the Yellow River, the damage caused by the sandstorms was rather serious. The local farmers know that on such land the crops would yield nothing without the protection of trees. The crop/paulownia intercropping has an apparent effect in increasing the crop yield. Now that the level of farmland management has been greatly raised and widespread crop/paulownia intercropping means that there is now no field that can be used as a control.

According to studies of crop yields, given that the crop yield for the whole year should not be lower than that of the non-intercropped field, for production of more timber, fuelwood and fodder, the density of the trees should be 5 x 20 m before the trees are 6 or 7 years old; after that age the tree rows should be cut alternatively, making the density 5 x 40m. When the newly planted trees reach 4 or 5 years old, the remaining older trees are 10 or 11 years old these are then harvested. This is considered to be the optimum pattern of intercropping to guarantee the agricultural production as the main objective.

Economic Effects Generated by Paulownia Trees

During intercropping, the intensive management of the agricultural crops inevitably creates better growing conditions for paulownia than in pure paulownia forest. Under intercropped conditions, 10 year old paulownia trees reach a mean diameter of about 35 - 40 cm and the volume is 0.4 - 0.5 m3, with the better ones up to 1.5 m3. If 60 trees are planted per hectare, 25 - 30 m3 of timber will be produced in 10 years. This volume will be worth 8750 - 10500 Yuan RMB and the income from timber is 900 Yuan per hectare. This is of great significance for increasing the income and improving the living standards of the people. The paulownia timber alone generates 15 - 25% of the economic income by unit area. At present about 500 million paulownia trees are growing in the North China Plain (most are young ones). It is estimated that they can provide the local farmer with over 5 million m3 timber, which will alleviate the critical shortage of timber in the region.

The whole paulownia tree is valuable. Besides the timber it produces, the branches, leaves, and flowers can be used. One paulownia tree about 10 years old can produce 350 - 400 kg of branches for fuel. As a result the crop stalks may be returned to the field as manure. The leaves and flowers are rich in nutrients and are suitable for feeding pigs, sheep and rabbits. The leaves are rich in nitrogen (3.09% dry weight). The content of coarse protein in paulownia seedlings is 26%. A single paulownia tree, 8 - 10 years old, normally produces 28 kg of dry leaves. If every paulownia tree produces 5 kg of leaves, 500 million trees would yield 2500 million kg of dry leaves, which produces 650 million kg of coarse protein and is equivalent to 75000 tons of nitrogen. The trees also offer a large amount of fodder and organic fertilizer for animal husbandry and agriculture. Crop/paulownia intercropping can combine closely agriculture, animal husbandry and forestry so that a new farming system is formed in which the three components stimulate one another.

Extension of Intercropping in China

The crop/paulownia intercropping has been developed on the basis of farmers' experience. But such quick and large scale extension, with consistent improvement in practice, has been only possible by the close cooperation between scientists, government officials and farmers.

In 1973 when there was about 20,000 ha of farmland under intercropping the people were rich ad the crop yields were high and stable wherever the crop/paulownia intercropping was well practised. In 1974 the National Paulownia Research Group coordination was established and in 1976 the first coordination meeting was held. Since 1979 the paulownia project has been listed as a key project in the Ministry of Forestry and in 1983 it was listed as a key research project by the State Science and Technology Commission as well as supported by IDRC. In order to promote the development of paulownia, the research personnel employ various means including: 1) writing articles and reports, popularizing to leaders at different levels and farmers through television, newspapers and journals, 2) several large training courses have been sponsored to train the local forestry technicians, who would then train local government officials and farmers,

3) three scientific films have been made and shown through China Central Television and cinemas in provinces, prefectures, counties and villages, 4) demonstration bases are set up to show the silivicultural and utilization techniques as well as provide the government officials, technicians and farmers with good species. Now the eight bases of the Chinese Academy of Forestry has become the place for people to visit and study.

2 The Chinese Government has played a decisive role in the promotion of crop/paulownia intercropping on a large scale. Based on the masses' experience, a proposal was prepared in 1974 and submitted to the forestry ministers and the leaders of the State Council, which caught the attention of the leadership and the proposal was distributed to the provincial and county governments concerned. In 1977 the forestry minister conducted an on-the-spot meeting which was attended by 100 county directors from the North China Plain. Many prefectures and counties have taken intercropping as an integral part of the farmland infrastructure and put it in the overall programme. For the sake of forest development in the plain region, similar on-the-spot meetings have been held since 1977. Each meeting was attended by important local officials and some invited scientists. During the meeting appraisals were carried out among provinces, prefectures and committees.

3. Technical guidance is offered to farmers by local technicians, which is of vital importance to guarantee the intercropped trees in meeting the quality requirements. In every county there is a forest bureau and in every Xiang a forestry station. They are in charge of giving guidance to farmers in accordance with scientific research results and the experience summed up from the masses. Some of the local technicians take part in the research project directly, and some of the technicians are chosen and trained from the farmers.

BIOMASS PRODUCTION WITH FAST GROWING TREE SPECIES IN SHORT ROTATION PERIODS: PRESENT STATE AND PERCEPTIONS ON THE FUTURE IN THE FEDERAL REPUBLIC OF GERMANY

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1 INTRODUCTION

Investigations have been carried out since 1976 in the Federal Republic of Germany to establish to what extent the particular characteristics of rapid juvenile growth and resprouting capability of some tree species can be used under the climatic conditions of this country to achieve a high and sustained biomass production in an economically sensible way.

With the help of tested high yield clones we hope to obtain, in periods of 2 to roughly 12 years, yields that will serve a wide diversity of purposes. Fully mechanised work methods will be used and extensive regeneration techniques with coppices and suckers.

Initially this research work, begun on a modest scale, was intended primarily to provide knowledge on the possibilities of increasing the amount of industrial wood and energy available inland, while at the same time reducing the dependency on imports, especially of pulp, paper, cardboard and crude oil. Recently a distinct expansion of interest has been noticed as in addition there are expectations of an effective contribution to the reduction of surplus production in agriculture without endangering the farmers existence.

Investigations must cover all the important fields connected with the new form of land utilization site suitability and nutrition supply, breeding possibilities to increase and ensure production, cultivation, tending and harvesting measures, utilization of the raw material produced as well as managemental and legal aspects and matters of agro or forest politics.

As yet only a mainly production-related part of the necessary work has been tackled and carried out as far as the first preliminary results by comprehensive cooperative projects promoted by the Federal Government and by smaller research projects on specific questions. Other project areas that are not immediately concerned with production are urgently in need of scientific treatment, for without knowledge of the subject, as in the field of harvesting technique for example, no serious managemental analyses can be carried out. Experience gained in other countries must also be regarded at the moment as inadequate or only limitedly applicable to the conditions in this country. It should be taken into consideration therefore in the following exposition that due to the absence or imperfection of enquiry fundamentals definite statements are only possible to a limited extent.

2 AGRO-STRUCTURAL AND ECONOMIC ASPECTS

21 Area potential

Due primarily to uncertain prognoses on the development of partial areas of the agricultural market there are wide divergencies in the estimations of the areas in the Federal Republic of Germany and in the EEC which will no longer be used in the traditional way of foodstuff production up to the year 2000. According to crude estimations it appears probable that between 12 to 16 Mio hectares in the EEC and between 1 and more than 3 Mio hectares in the Federal Republic will be released from foodstuff production (DAMBROTH 1982; MUHS 1984; LEE 1986). HEIDRICH and SCHÄFER (1985) forecast for all EEC countries together (excluding Portugal and Spain), with 100 % future self sufficiency, a reduction in the cultivation of cereals of 0,3 Mio ha, of sugarbeet of 0,6 Mio ha, of wine on 0,5 Mio ha and of fodder for the production of milk and beef on 10,4 Mio ha. In a very recent investigation PLOCHMANN (1987) estimates for Bavaria alone a potential average surplus area of between 174.000 and 293.000 ha, related for the same period to those products which are a particular burden to the agricultural market.

There are differing opinions on the site conditions and yield potential of these as yet unlocated areas. Most valuations are based however on the assumption that the areas in question are primarily poorer arable and grazing land and in the mediterranean countries bushland, coppice forests and uncultivated land.

It is difficult to assess what proportion of these areas no longer needed for the production of foodstuffs could be used for fast growing tree species in short rotation periods until we know the climatic, exposition and soil conditions of the respective areas. A cautious assessment of the situation however suggests that up to the year 2000 1 to 5 Mio ha of the surplus area in the EEC, and 0,4 to 0,6 Mio ha of that in the Federal Republic would be suitable and available for the new form of cultivation (WILLER 1985; WEISMANN 1986; HUMMEL, oral communication 1987).

22 Site potential

Natural site factors are decisive for the choice of tree species for the production of forest biomass as they are in conventional silviculture. They have a decisive influence on yield performance and hence at the same time on the profitableness of the method. Investigations on site and nutrient factors form therefore an important part of interdisciplinary projects already being carried out (REHFUESS 1986). According to results already available from cultivation tests in this country and abroad all agriculturally used areas with a soil classification value of more than 30 and on which a tractor can be driven may be considered for this purpose. When planted with poplar or willow they should be able to produce phytomass yields of at least 10 t dry matter per year and hectare without expensive irrigation measures or intensive fertilization.

Economic site factors cannot as yet be satisfactorily assessed due to the paucity of investigations up till now. However it may be assumed that interest in the new form of land use exists especially in structurally poor areas. The energy supply of the farmers could be ensured cheaply by means of individual or common power plants on a cooperative basis which would do away to a large extent with their dependence on oil and gas especially.

Decentralised energy distribution in a rural district, as opposed to a relatively simple home supply, would be capable of functioning only if new conditions were created concerning energy policy. Medium to long-term contracts would need to be settled, and the infrastructure developed for trade and transport (transport distance between place of production and place of delivery not more than 10 to 15 km for regional markets and at the most 100 km when supplying district heating plants).

The development of a specific market for energy wood outside densely populated areas, would seem an additional, realisable possibility to those already existent of passing the raw material produced on short rotation plantations, in the form of chips, on to those industries using small wood (DIMITRI et al. 1981; BUCHHOLZER, ROFFAEL 1987; PATT et al. 1987). The chemical industry could also use part of the biomass created as soon as suitable processing methods can be applied on a large technical scale (PULS 1983; HILSINGER, oral. communication 1987).

As far as can be seen up till now no large scale usable site preferences for the new form of cultivation emerge from a comparison of the Federal Republic of Germany with other countries despite considerable differences as far as climate, economy and agricultural structure are concerned. Poplars and willows for example can use the favourable conditions of light and warmth in the Mediterranean countries to their full extent only on soil that has a good water supply or is artificially irrigated. Sites such as these will however in future still be reserved mainly for foodstuff production. On the other hand some supposed disadvantages in competition, from climatic conditions among other things, may be counterbalanced to a large extent by other influences such as the better infrastructure in the Federal Republic of Germany and some other countries.

23 Spectrum of tree species and cultivation methods

Many years experience in breeding and cultivating numerous tree species for the purpose of obtaining large and high-quality wood production according to conventional standards justify the assumption that poplars and willows are to be chiefly considered for this new form of land use under the moderate climatic conditions of this country. This assessment is showed in other countries also (BOHNENS 1987). LAVOIE and VALLEE (1981) reviewed suitable species for short rotation purposes in a moderate climate, covering 27 deciduous and coniferous geni with a total of 290 species or cultivars respectively: among these poplars and willows were ranked as the most promising.

Our investigations are therefore concentrated mainly on different sections and species of these two geni. In order to avoid large scale monoclonal plantations, due to their inherent ecological disadvantages, we plan to group together treatments with similar growth performance to form population mixtures and multiclonal varieties and to recommend them for cultivation in this form only.

Apart from the tree species already mentioned tests with alders and birches on moist to very moist soils and with black locusts on light soils lead us to expect complementary or alternative possibilities of land use. Some of these species, placed in pure stands or in mixtures with poplars and willows, could contribute to a reduction of the amount of fertilizer needed and to an improvement of the soil by means of their nitrogen-fixing ability.

In the Federal Republic of Germany field trials are being carried out at the present time on 24 tree species with 138 clones and 31 populations regarding their suitability for biomass production in short rotations: these tests are taking place at 17 different sites with a total area of more than 50 ha. The species include 13 poplar species of the sections Aigeiros, Leuce and Tacamahaca and 7 willow species. These figures cover also the many smaller tests that are being carried out with particular aims. The program is urgently in need of extension in order to arrive at definite statements on the basis of a wide range of different sites, and finally to work out practice-orientated recommendations for cultivation.

24 Suitability of agricultural enterprises

The structural and technical prerequisites for the introduction of this new form of land use may be judged as favourable in most agricultural enterprises. All measures required for the management of short rotation plantations can be carried out by the owner of the enterprise on his own as long as assistance is available for orientation and decision-making. For this purpose it is especially necessary to erect model enterprises, within state-owned agricultural enterprises for example, to train a sufficient number of technical advisors and to work out detailed recommendations for management.

The cultivation of fast growing tree species in short rotations fits in well with the existing agricultural work routine. After the plantations have been established the main activity takes place in the less work-intensive seasons: tending measures can be carried out mainly in early summer, harvesting and the preparation of the raw material in the winter months.

The already existing agricultural machines and tools can normally be used without problems for most of the mechanised work on short rotation plantations such as site preparation, inter-sowing of legumes, fertilization and transport of the harvested product. Inexpensive and suitable machines have already been developed for planting; in addition it would certainly be an advantage if technical harvesting methods could be oriented towards the conditions prevailing in agriculture. To this end felling and chopping units, sorting facilities and conveying devices would have to be designed in such a way as to achieve, by means of further attachments, an additional exploitation of the tractors and machine transporters already present.

25 Managemental aspects and promotive measures

The practical applicability of this new form of land utilization is determined to a large extent by its profitableness. Economic calculations and comparisons with conventional cultivation forms in agriculture do indeed necessitate the careful registration of data on costs and performance in all branches of production of fast growing tree species in short rotation, as well as that on harvest and the utilization of the raw material. Due to the reasons already explained no definite statements concerning achievable net profit can as yet be made on the basis of the few tests at the evaluatable stage.

In addition we lack objective standards for assessment. Quite apart from the difficulties of where subsidies should be granted in agriculture attempts to prove the competitive ability of ligno-celluloses must appear dubious as long as the net profit that is calculated in the normal way, and covers for example labour costs that are heavily increased by insurance payments, is compared with the gross returns from agricultural products which are cleared of all special expenses.

A cautious evaluation of model calculations so far published (i.a. PERTTU 1984; BUSCH, KREYSA 1985; KOPETZ 1986; SCHLIEPHAKE 1986) leads us to expect, under particular conditions, an economic superiority of biomass production in short rotation to traditional forms of agriculture. But one can perceive also that even slight changes in the expected yields, production costs or prices could alter the competition situation considerably.

If one accepts that the production of raw material containing ligno-cellulose should in future, on the basis of more precise business management analyses, be introduced into agriculture as an interesting alternative to foodstuff production, which would at the same time help towards stabilizing the financial situation of the farmers in the long run then several promoting measures by the state will first of all be needed. Small and medium-sized enterprises especially will be dependent during the establishment period on grants for buying plant material, for tending measures and necessary investments (tractor attachments, heating equipment etc.) as well as on support to bridge the income gap until the biomass produced can first be used. The law on communal undertakings, "Improvement of agro-structure and coastal protection", could be used as the legal basis for this promotion (WEISMANN 1987).

In addition legal regulations concerning the afforestation and clearance of woods must be applied as flexibly as possible, or standards must be worked out which enable the farmer to change back again from wood to foodstuff production without problems as long as a rotation period of 15 years has not been exceeded. Regulations already passed in Bavaria and Hesse provide, with the permission for afforestation, also permission to revert at a later date to the former situation without incurring the obligation of compensatory afforestation.

3 OVERALL ECONOMIC INTERESTS AND SOCIAL ASPECTS

31 Effects of size structure of the enterprises

The method of short-term production of ligno-cellulose can be used in different ways according to the size and capital situation of the farming enterprises. When existing technical and work structures can be used to a large extent it would seem especially promising as a help to safeguard the existence of those small and medium-sized enterprises that are particularly affected by the crisis-prone development in agriculture. With low investment they would be able to secure their own energy supply on a medium term on small production areas of 1 to 5 ha each, or to supply co-operatives with wood for energy or industry. Despite considerable differences in climate, soil and topography it should be possible to provide efficient plant material for most of the sites in question after carrying out a sufficient number of comparative trials with different clones.

The new form of land utilization also comes into consideration for larger agricultural enterprises. Prerequisites for management on areas of 10 to 100 ha are however an optimum degree of mechanisation, which requires relatively high investment, and a multiplicity of marketing possibilities in paper, pulp and wood based material industries and in regional heating power stations. It will not be possible to judge if and when the cultivation of fast growing tree species in short rotation can be realized on large-scale agricultural enterprises until we have sufficient knowledge on harvesting and preparation techniques and on the main fields of utilization. In the case of a large scale application of this new method as a complement or alternative to traditional crop cultivation, it would be conceivable and sensible to concentrate production in the vicinity of, for example, particle board or pulp industries or heating power stations. Concrete projects of this sort are already in existence in Sweden (HIEGE 1987). The marketing chances of larger production enterprises in regions of poor economic structure would have to be judged individually according to site and marketing field.

32 Effect on the employment situation

The use of relatively labour-intensive methods for the production of ligno-celluloses should lead to a stabilisation of the employment situation in small and medium sized enterprises, though as a rule no new jobs can be created in this way. Because of the generally better distribution of work in the course of a year - increased labour force requirements in summer and winter, reduction in autumn and to some extent in the spring - an effective contribution can be made towards eliminating seasonal unemployment.

On the other hand an entirely different situation exists in large enterprises. The large scale cultivation to be expected here necessitates methods requiring high capital but low labour expenditure which will probably lead to redundancy of workers.

HEIDRICH and SCHÄFER (1985) estimate the expense of managing short rotation areas at 38 to 80 man-hours per hectare and year depending on which method is used. On an area of 100.000 ha used for phytomass production, and at a cost of an average of 60 man-hours per hectare and year, this would correspond to 6 Mio working hours or the performance of 3410 labourers working 220 days a year and 8 hours a day.

Comparable investigations in other countries have produced similar results. According to CARRUTHERS and JONES (1983) 1350 to 3900 labourers are necessary to produce 1 Mio t of dry matter. PERTTU (1986) reckons on 2 labourers per 100 ha of short rotation area under Swedish conditions with a high degree of mechanisation.

33 Effects on the energy and wood market

Probably the most intensive investigations into the production of biomass in short rotation were carried out in Sweden in recent years (SIREN et al. 1984; PERTTU 1986). The Swedish government hopes that it will help to provide a de-centralised and reliable energy supply for the country. According to calculations published it is considered a realistic possibility that up to the year 1995 20 % of crude oil imports could be replaced by the yield from "energy forests" of willows on a formerly agriculturally used area of roughly 500.000 ha.

If the potential available area in the Federal Republic of Germany is of a similar size an average yield of 12 t dry matter per hectare would mean an annual total of 6 Mio t. This amount of raw material is almost as big as the total amount of waste estate timber from industry. In effectivity it corresponds to 2,7 billion liter heating oil or 27 billion kWh electric energy (in comparison: The crude oil imports of our country in 1984 were 67 Mio t or 78 billion l according to the statistical year book of 1985).

One may assume that the estimated amount of raw material will not be entirely marketed within a year, but initially in small and then gradually increasing quotas until the maximum annual production can be sold in about 15 years' time. This should have a more positive than negative effect on the forestry and wood-management of this country, quite apart from the present difficulties caused by the state of the market and catastrophes. However, optimistic prognoses seem justified only if it is possible without delay or at least in the time stated

- to build up a special market for energy wood

- to develop new, environmentally favourable processing methods for obtaining celluloses and semi-celluloses (ASAM-, NSSC-, Acetosolv- and Organosolv-technique; BUCHHOLZER, ROFFAEL 1987; PATT et al. 1987) so that they can be put into practice and thereby contribute to a distinct reduction of our high cellulose imports (at present almost 80 % of the entire amount needed). In this connection we give special importance to recent findings on the suitability of short-fibred chips with bark.

- to utilize part of the material created as raw material for the chemical industry. On the basis of knowledge already gained on different processing methods, up to 30 % of the total amount of crude wood in the Federal Republic of Germany could be used in this way as soon as practicable possibilities for use have been found.

Only by means of intensive research will there be a chance of assuring a wide range of industrial uses for biomass created in short rotation periods, beyond those of particle board and of finding additional marketing possibilities. This would also avoid an infringement upon the traditional marketing fields of forestry.

4 BREEDING AND ECOLOGICAL ASPECTS

41 Results of comparison trials

Those test results from at home and abroad which have so far been published were obtained exclusively with plant material which is normally used for conventional cultivation methods with long rotation periods. Authors from different European countries and from overseas all report on distinct clone-dependent differences in performance with average values of ca. 15 t dry matter per hectare and year from the most vigorous clones of the most tested tree geni poplar and willow (ZSUFFA 1982; NEENAN 1983; STOTT et al. 1983; HERPKA, MARKOVIC 1984; PANETSOS, SCALTSOGIANNES 1985; PERTTU 1986). Under climatic conditions roughly comparable to ours other species did not as a rule achieve the yield hoped for of 12 odt/ha/year (AFOCEL 1982).

Investigations up to now in our own country have led to similar results (WEISGERBER 1984, 1986). The oldest trial, established in 1976 in the vicinity of Hann. Münden on former agricultural land (mean soil value 38) comprises 58 black and balsam poplar clones and is managed in a two year rotation. After 3 rotations 32 clones yielded an average of 12 t dry matter (28,8 cubic metres without bark) per hectare and year. 6 clones produced an average yield of more than 18 odt (43,2 cubic metres without bark).

A clear differentiation can be observed regarding the qualitative characteristics of the clones similar to the results relating to growth performance. Those treatments especially which tend towards multi-sprouting and a high proportion of bark after being cut back are judged critically as far as the utilization capability of their wood is concerned.

In the trial plots established during the last years our interest is therefore mainly concentrated on site-adapted, healthy, vigorous clones with relatively few sprouts and branches and thus a lower proportion of bark. Our institute provides a large range of basic material covering numerous populations as well as more than 1100 clones, mainly of poplar and willow, which will enable the necessary selection measures.

42 Breeding aims and methods

Over and above the investigations already mentioned we plan, by means of directed breeding measures, to preserve a large diversity of those clones with a higher growth potential which are better adapted to the special demands of short management periods. The following breeding goals must here be considered (BOHNENS 1987):

- reliable growing behaviour after planting, site tolerance;
- a high net rate of photosynthesis;
- low water and nutrient consumption in relation to the biomass produced;
- optimum growth progress during the juvenile phase established as rotation period;
- high use of nutrients for secondary growth;
- narrow, compact crowns with relatively few branches, steeply sloping branches to make the best possible use of light in a close stand;
- low phototropical sensibility, tolerance of competition;
- resistance to biotic and abiotic damaging influences;
- good regenerative ability, maintained through several rotation periods, by coppices or suckers;
- easy and inexpensive propagation of plant material;
- favourable wood characteristics according to the particular test aim.

To achieve these aims the classical methods of selection, crossing and mutation breeding must be considered. In so far as they are applicable we may also make use of modern technological methods which have already been introduced into plant breeding on a large scale, or will be requiring increasing attention in the future. Possibilities range from vegetative large-scale propagation of high yield clones by tissue culture to somatic hybridization of plant species whose combination by sexual means was unsuccessful until now.

If it is already possible to achieve a dry matter production of more than 20 t per hectare and year with the plant material at present available and on sites of medium quality then one can expect to produce an average yield of ca. 30 odt/ha/year with newly bred clones, whereby there is a calculated genetical gain of 25 to 30 % for the characteristic growth performance. One must however take into consideration that the realisation of this kind of breeding program is expensive both in time and money. No short term spectacular discoveries are to be expected. A period of at least 20 years is estimated necessary for evaluating the most important characteristics and for developing promising species ready for use in practical forestry.

43 Legal requirements concerning trade and breeding

The raising and sale of the plant material needed on short rotation plots require control and protection by legal regulations in the same way as in conventional agriculture and silviculture. Existing legal regulations only partially meet the demands of the situation.

The German Law on Forest Reproductive Material as it stands from 1979 may be used on the presupposition that the new cultivation form on agricultural sites represents "Forest" in the sense of the Federal Forest Law and of the provincial forest laws. As however the most important tree geni used for biomass production in short rotations such as willow, birch and black locust, are not subjects of the stipulations of the Law on Forest Reproductive Material there is at present no possibility of effectively controlling commercial trade with reproductive material of the respective species and clones.

The Plant Variety Protection Law in its new form of 1985 can also be applied only in a limited sense to the manners of cultivation considered necessary on short rotation plantations. The regulations on the term "homogenity", which are directed exclusively to crop cultivation, prove particularly one-sided as fas as the protection of multiclonal varieties of forest tree species is concerned. In order to safeguard production we consider it essential that clone mixtures of this kind, which have defined proportions of the respective clones they comprise, should be identical only in those characteristics that are important for growth rhythm and apart from that should exhibit heterogeneous structures.

The control and protective regulations contained in both the above mentioned laws represent therefore in my opinion a useful legal basis but are in need of supplementation and adaptation to the specific requirements of this new form of land use.

44 Ecological effects

Investigations are being carried out on ecological aspects of the cultivation of fast growing tree species in short rotation periods. The following positive effects, in comparison with former agricultural utilization, emerge or may be expected (DIMITRI et al. 1982; WEISGERBER 1986; REHFUESS, written communication 1987):

1. Soils hitherto intensively cultivated can regenerate because

   - root-intensive tree species are capable of breaking through horizons of compacted soil created by many years of mechanical cultivation, especially under unfavourable weather conditions;

   - the supply of organic substance from leaf litter leads to humus enrichment;

   - surplus supplies of nutrients caused by too heavy fertilization are drawn off, thereby reducing the nitrate load of the ground water;

   - soil fauna is activated and enriched thus enabling a closed nutrient chain to be formed.

2. The ground being covered throughout the year affords effective protection against evaporation and erosion.

3. Expenditure on tending measures and the use of mineral fertilizers and herbicides can be reduced by underplanting or intermediate culture of plant species that fix nitrogen from the air.

4. Production phases of several years allow undisturbed development, during the respective rotation, of a more or less diverse accompanying flora depending on the particular site conditions.

5. Diverse feeding and resting places, sheltered from the weathers and other intrusions, are created for animals as well as possibilities for nesting, breeding and laying.

6. An improvement of microclimate is to be expected for neighbouring agricultural crops situated in areas sheltered from wind.

Adverse ecological effects are conceivable especially if large machines are employed on extensive cultivation areas. When special harvesting and transport systems are developed attention must be given to seeing that they are suited for careful treatment of the soil and the stands. Moreover soil compaction can be avoided in small enterprises to a large extent if harvesting is done only in frost periods.

The ecological advantages expected from the new, as against the traditional agricultural cultivation form should contribute to an enrichment of the landscape, especially in regions with relatively few forests. Short rotation plantations may also serve as optically effective dividing elements. On the other hand adverse effects cannot be excluded in forest regions with a high recreational value. Even here the cultivation of fast growing tree species could be justified if they are incorporated unobtrusively into the scenery by means of site-suited border trees and subdivision into partial areas.

5 CONCLUSIONS

Knowledge and experience hitherto on the short term production and utilization of raw material with a ligno-cellulose content on agricultural sites, in a manner comparable to agricultural production methods, encourages us to intensify investigations already in progress and to begin those scheduled as soon as possible. In my opinion there are good chances, especially for small and medium sized agricultural enterprises, of using this new method to advantage as a production alternative, with the aim of enlarging the present range of agricultural products and of combatting the overwhelming overproduction existing in some areas.

A comprehensive study initiated by the EEC in spring 1986 with the title "Forest Biomass Plantations in the EC" and which our institute played an important part in compiling, comes to similar conclusions. This study, in two volumes, covers the present state of knowledge and prospects deduced from it for the EEC as a whole, and for each member state separately, and is expected to be published at the end of 1987.

Much effort will still be needed however for the further development of this new form of land use before it can be put into practice. The exposition above has shown that there is still a great need for further research in all fields connected with the practical use of this method.

As the existence of many agricultural enterprises is endangered there is urgent necessity for a fundamental decision in favour of or against introducing the cultivation alternative described above, taking all important economic facts into consideration. On the basis of investigation results so far obtained we recommend the execution and promotion of pilot projects which will enable concrete statements to be made not only on the yield to be expected from a particular site, but also in suitable harvesting methods and on realistic marketing possibilities and uses for the raw material, taking modern methods of processing into consideration. At the same time changes must be brought about, by means of political decisions and legislative measures, in the present general conditions which hinder or preclude the practical use of this new form of ground utilization, especially in the fields of agro-structure, forest law and energy management.

S U M M A R Y

The cultivation of fast growing tree species in short rotation periods of 2 to about 12 years is intended to help combat agricultural over-production in an economically sensible way without endangering the existence of the enterprises. Furthermore the measures planned should lead to an increase in the amount of wood available for industry and energy in this country, and a simultaneous reduction in import dependency, especially of crude oil, but also of cellulose, paper and cardboard.

This paper attempts to show the possibilities and limits for this new form of land use, taking into consideration agro-structural, economic, and social as well as breeding and ecological aspects. The present state of knowledge in this country and abroad is based on relatively few research projects, often on very specialised questions, that are insufficient for a total assessment of this method. However the first available preliminary results, especially those related to production, give encouragement for intensifying investigations.

In view of the urgency of finding suitable solutions for the problems in agriculture we recommend accelerating the further development of the cultivation form described up to practical application by means of financial promotion of pilot projects. As there is considerable need for research in all fields connected with the application of the method all disciplines could cooperate to the best of their ability, thus guarenteeing a rational use of the funds needed.

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WILLOW BIOMASS AND ITS UTILIZATION

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ABSTRACT

China abounds in willow resource and there are more than 50 species and varieties suitable to the biomass production. The biomasses of 9 kinds of arboreous and 6 kinds of shrubby willow were studied, as a result the selected hybrids produced more biomasses. Fuel forest, withy forest and pole forest are the main management forms of man-made willow forests.

The vista of the production and utilization of willow biomass is vast because of willow's large number of species, rich resource, high-speed growth in young stage, high biomass products, easy cuttage, strong ability to sprout, wide distribution, adaptation sensitive reactions to environments, full utilization of whole plant and application as many different materials, and willows are very important in the development of wet depression and low land between dunes especially.

1. Willow Suitable for Biomass Production

The genus Salix has about 526 species, most of which distribute around the north hemisphere. There are 257 species in China, being 48.9% of the total number in the world, more than 50 of which are used for biomass production and belong to different sections as follows:

1. Sec. Salix: 12
2. Sect. Helix Dum: 12
3. Sect. Wilsonianae Hao: 12
4. Sect. Vimen Dum: 15
5. Sect. Amygdalinae W. koch: 3
6. Sect. Caesiae A Kern: 3
7. Sect. Cheilophilae Hao: 3
8. Sect. Flavidae Y.L. Cheng et Skv: 1

36 of them are used widely, 10 being arbor, 6 small arbor and 20 shrubby (Table 1).

II. Willow Biomass and Its Variation

Willows grow quickly during their young stage, therefore high quantity of biomass can be obtained in a felling cycle of 1-3 years. Jiangsu Forestry Research Inst. has studied the biomasses of 9 kinds of arboreous nad 6 kinds of shrubby willows.

1. Biomasses of arboreous willows in young stage:

The tests were carried out in the nursery of Jiang-sin-zhou, Nanjing, in 1981 and 1982. The cutting density was 40x50 cm and biomass survey was carried out in November of 1981.

In 1981, the first year of cuttage, biomasses of 9 kinds of arboreous willow's aerial parts were 15.10 t/ha and in 1982, the second year after cuttage, 7.8 t/ha (Table 2). Selected hybrids showed higher biomasses, for instance, the biomasses of (S. babylonica x S. alba) x S. matsudana were 20.89 t/ha in 1981 and 11.48 t/ha in 1982 but the biomasses of its parents, S. babylonica x S. alba and S. matsudana were 9.26 t/ha and 5.9 t/ha respectively. The biomass of S. alba from Sinxian was only 4.57 t/ha, however the biomass of the S. matsudana x alba (J390) was 16.82 t/ha. There were some variances between clones, and variances were different each year. In 1981, the variances between clones in the biomasses of trunks, branches and aerial part were significant and the heritabilities and the coefficients of hereditary variances were both high. However in 1982, the variance of leaf biomass between clones were obvious. As a result, the heritability and coefficient of hereditary variance were up to 59.16% and 54.72% respectively, meanwhile the variance of trunk biomass was not significant and the heritability and coefficient of hereditary variance were low. The ratio of environmental variance to the total variance was higher. These show that environment affects willow biomass significantly, as a result, more suitable the environment, more higher the biomass products.

To the whole aerial parts of 9 arboreous willows, the biomass distribution percentage is: leaves, 20.51%; branches, 22.19% and trunks 57.29%. Clone J333 has higher leaf biomass comprising 34.78% of the whole aerial part biomass and clone J194, J172 and J543 have higher trunk biomasses comprising 60.15-62.80% of the total part biomass.

2. Biomass of shrubby willow

The test was carried out in Dong-san-quiao, Nanjing, and all of the tested hybrids of shrubby willows were selected and breeded by Jiangsu forestry

Table 1. Willows Suitable for Biomass Production and Their Distribution

Species	Distribution (in China)	Position
Arbor:		
S. matsudana Kodz.	Northen, Yangzi and Huai river valleies, northeast, northwest	Plain, wet depression
S. babylonica L.	the Yangzi river & Yellow river valley	ditto
S. alba L.	northwest and Tibet	plain and bank area
S. wilsonii Seemen	middle and low reaches of Yangzi river	plain and wet depression
S. cavaleriei Lel.	southwest	hills, banks
S. tetrasperma Roxb	Guangdong, Yunlan, Tibet	ditto
S. maximowiczii Kom	northeast	ditto
S. capitata Y.L. Chou et Skv.	Northen China, northeast	ditto
S. koreensis Anderss	ditto	ditto
S. fragilis L.	northeast	ditto
Small Arbor:		
S. chaenomeloides	middle & low reaches of Yellow river	plain, wet depression
S. mesnyi Hance	Southen, southeast	ditto
S. rosthornii Seemen	central part, southwest and southeast	plain, wet depression, hilly land
S. dasyclados Wimm	northeast, Northen	plain, wet depression
S. pierotii Mig	northeast	ditto
S. songarica Anderss	Sinxian	plain, valley, bank
Shrub:		
S. suchowensis Cheng	middle & low reaches of the Yangzi & Huai river	plain, wet depression
S. linearistipularis	Northen, northwest	ditto
S. psammophila	northwest	wet sandy land
S. sungkianica	northeast	plain, bank
S. viminalis L.	northeast, Northen	ditto
S. siuzevii Seemen	northeast, Inner Mongolia	ditto
S. pentandra L.	northeast, northwest, Northen	hills, wet area
S. trianda L.	Northen, northeast	plain, bank
S. wallichiana	southwest, centralpart, Northen northwest	hills, bank
S. cheilophila	northwest, Northen, southwest	ditto
S. microstachya	northwest, northeast	wet sandy land
S. sinopurpurea	northwest, Northen, central part	hills, bank
S. turanica	Westen Sinxian	desert, bank
S. rosmarinitolia	northeast, northwest	wet sandy land
S. kochiana	northwest	ditto
S. integra	northeast	bank & wet place
S. gracilistyla	ditto	hills, bank
S. caspica	northwest	desert, bank
S. gracilior	northeast, Northen	wet sandy land
S. gordejevii	northwest	land between dunes

Table 2. Biomasses of 1-year-old Willows and Their Variations (ton/hectare)

Species	Clone	1981 Trunk	1981 Branch	1981 Leaf	1981 Aerial part	1982 Trunk	1982 Branch	1982 Leaf	1982 Aerial part	Root	Total
S. matsudana	P49					2.9	0.95	0.49	4.34	1.6	5.94
	J440	10.30	4.71	4.34	19.35						
S. babylonica	P2					2.85	2.93	2.23	8.01	2.02	10.03
S. alba	P77					1.78	1.24	0.29	3.32	1.25	4.57
S. babylonica x S. matsudana	J273	5.8	2.66	2.93	11.39	4.31	4.07	2.06	10.44	2.79	13.23
	J333	10.43	4.05	3.96	18.44						
S. matsudana x S. babylonica	J354	7.25	3.08	3.42	13.35						
(S. babylonica x S. alba) x S. matsudana	J712	12.62	4.62	3.74	20.98	5.41	1.92	1.41	8.73	2.74	11.47
	J543	12.53	5.30	2.97	20.80						
(S. matsudana x Chose-nia albutifolia) x S. matsudana	J194	7.53	1.75	2.72	12.00	3.16	1.47	1.25	5.88	1.27	7.15
	J224	8.80	3.55	2.75	15.10						
	J635	7.04	2.19	2.18	11.41						
Phenotypic variance	:	9.19	2.25	0.97	25.08	5.7	2.88	1.2	19.91	1.14	29.28
Genetic variance	:	3.72	0.88	0.29	10.05	0.42	1.17	0.71	7.59	0.12	9.71
Block variance	:	26.85	4.14	4.63	86.93	55.38	24.79	7.6	228.47	13.85	354.37
Error variance	:	5.47	1.37	0.68	15.03	5.28	1.71	0.49	12.32	1.02	19.57
Heritability (%)	:	40.47	39.11	29.90	40.07	7.37	40.63	59.16	38.12	10.52	33.16
Coefficient of hereditary variance (%)	:	20.81	26.18	16.27	17.37	16.92	44.88	54.72	35.35	17.06	31.76
Clone F	:	3.04*	3.22*	2.29	3.00*	1.24	3.06	5.37*	2.85	1.35	2.49
Block F	:	4.86	3.59	6.81	5.78	10.94	14.5	15.51	18.54	13.57	18.11

Research Inst. In 1983, the belt cutting was done in nursery with 40 cm in belt width, 3 lines in each belt and plant spacing being 10 cm. Space between belt was 60 cm. Branches were cut every winter for biomass. In July of 1986, the striped branches were reaped and their biomass was investigated. The result showed that the average fresh weight of aerial part was 23.07 t/ha (Table 3). Family 8-0 showed the highest biomass production with 32.92 t/ha average fresh weight, and family 7-0, the lowest biomass production of 11.45 t/ha average fresh weight. The biomass of branches and barks of family 6-0 was highest with 7.83 t/ha fresh weight. The differentiations between families in biomasses of leaves and of aerial part were obvious, but in the biomasses of branches, barks and sprouts, the differentiations were not obvious. The heritabilities of leaf biomass and aerial part biomass were 44.91% and 46.06% respectively. The heritabilities of the biomass of sprouts and barks were lower. The differentiation between the families of shrubby willow was presented mainly in the leaf product.

Leaf biomass consists of 33.33% of the whole fresh product of aerial part; branches and barks, 22.97%; sprouts, 43.65%. The dried weight of striped branches comprises 27.52% of the weight of fresh branches with bark.

III. The Utilization and Man-Made Forest of Willow Biomass

Biomass of willow is mainly used as fuel, fodder, withy and pole production presently. In Northern China, fuel forests of willow are planted widely and their twigs and leaves are used to feed livestocks. In most countrysides north of the Yangzi river, withy forests are spreadout for weaving various articles. And pole forests are common in China too.

1. Fuel forest of willow

About 430-510 million tons of plant are consumed as fuel in countryside of China, occuping 39% of the totally consumed energy, whereas only 6.3 million people use trees as fuel for more than six months each year. Willow trees have high quantity of biomass, strong ability to germinate and high heat efficiency. According to studying of S. viminalis, S. siuzevii, S. pierotii, S. fragilis and S. sungkianica f. brevistachys, their heat efficiencies are about 4521.2-4908 kc/kg. The product of dried branches of 8-year-old trees is up to 9.62 t/ha per year. The fuel forests of willow can lessen the shortage of energy in countrysides.

The willow fuel forests are made in bush and bunch, or arbor planting form in the sandy land and low-lying area of the northeast and northwest of China, with density of 1 x 1.5 or 1 x 1 m for bush and bunch planting form and 2 x 3, 1 x 3 or 1.5 x 2 m for tree planting form. In sandy land, S. caspica, S. psammophila, S. viminalis and S. sungkianica could be used and in depression, S. matsudana, S. pierotii, S. capitata, S. trianda, S. integra and S. gracilistyla could be used for planting fuel forests. 5-10 t/ha of dried firewood can be got every winter.

2. Withy forest

This is a man-made forest special for weaving materials and one of the higher benefit forms of man-made willow forests. Usually the fresh twigs are harvested 1-2 times a year and produce about 16 t/ha biomass.

Withy forests are made in bush and bunch in single or belt planting forms. Plant spacing is 10-60 cm and row spacing 60-100 cm for row planting form. For belt planting form, the width of belt is 40-80 cm and belt spacing is 60-100 cm. On each belt 3-4 rows with 10-70 cm planting spacing are planted. S. trianda, S. lineariistipularis, S. psammophila, S. microstachya, S. integra and

Table 3. Biomasses of Shrubby Willows (ton/hectare)

Species	Family	Fresh weight fresh branch	Fresh weight leaf	Fresh weight bark	aerial part	Dry weight of stiped branch
S. suchowensis x	4-0	14.42	7.31	3.91	21.73	4.42
S. integra	8-0	20.27	12.63	6.43	32.89	5.83
S. integra x	6-0	18.19	8.54	7.83	26.70	4.35
S. suchowensis	9-0	16.97	6.84	5.72	23.81	4.72
S. integra x						
(S. viminalis x S.	7-0	7.8	3.65	3.25	11.45	1.92
psammophila)	11-0	13.56	6.25	4.61	19.81	3.76
S. suchowensis x						
S. gracilior	13-0	19.18	10.24	6.28	29.42	5.41
S. suchowensis x						
(S. babylonica x						
leucopithecia)	16-0	15.07	6.13	5.36	21.2	4.08
S. suchowensis x						
S. matsudana	10-0	12.92	7.67	4.34	20.59	3.61
phenotypic variance:		27.53	10.51	3.49	60.08	2.48
genetic variance:		8.09	4.72	1.32	27.67	0.68
environmental variance:		19.44	5.29	2.17	32.41	1.8
heritability (h^2%):		29.39	44.91	37.82	46.06	27.42
coefficient of hereditary variance (%):		18.51	28.25	21.67	22.80	19.38
F (0.05)=3.19 :		2.25	3.45*	2.83	3.56*	2.13

S. caspica in the northeast and northwest of China, and S. suchowensis, S. trianda, S. viminalis and S. sinopurpures in Northern China and the area along the Yangzi river and Huai river are usually used for planting withy forests. The time of reaping twigs is in July and change to be in winter after every three consecutive years' harvests. And reforestation is made after 10-15 years consecutive reap.

3. Willow pole forest

This plantation is mainly used for rafters, stool handles and posts. These forests are usually the regeneration forests under pollarding method. Seedlings of 2-3 years old or high trunk are used for plantation with density 2 x 2 or 2 x 3 m and are pollarded 3 years after planting. The height of pollarded trees is about 2m and 5-10 strong sprouts are left. Pole forests are felled every 3-5 years and reforested after 50 years.

In the northwest of China, the tender willow twigs and leaves of the pole forests are used as forage. An investigation shows a 12-year-old pole forest of S. matsudana can produce 12.62 t/ha of fresh twigs and leaves or 5.26 t/ha of dried twigs and leaves. A willow pole forest of ten thousand hectares equals a natural sandy grassland farm of four thousand hectares in fodder productivity. And the fuel and withy forests of willow can produce forage in the same way too.

Planting willow forests for paper pulp has also a good prospect.

IDEOTYPE TREES FOR MULTIPURPOSE AGROFORESTRY SYSTEMS

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A B S T R A C T

In many countries of the world forests are disappearing at an alarming rate. Large scale reforestation programs are being undertaken, for which planting stock of good genetic quality is needed. Such stock is often lacking, especially for planting of multipurpose trees in agroforestry systems. The FAO-IUFRO conferences on research planning for developing countries held in Asia, Africa and South America invariably identified the need for genetic improvement of planting stock as a top priority.

Genetic improvement is needed for many characteristics, including productivity, suitability to sites and plantation systems, tree-qualities for use and pest resistance. However, in most cases we have not clearly

established the traits needed for a tree species in a particular environment, with regard to using prescribed approaches of cultivation and having specific objectives of management. The answer to this rather complex question is model trees, "ideotypes", and this should be the first step towards bioengineering improved tree species.

There is considerable information published on genetics and breeding of some important multipurpose tree species. Also, stock of a variety of tree species has already been selected and set aside in species trials, provenance trials, breeding collections and arboreta. Some of this information and stock could be directly used with the objective of breeding ideotype trees. A proposal is made for initiating such cooperative, international programs.

INTRODUCTION

Forests are the world's most valuable natural resources, not only for the users of the tremendous variety of products they provide, but also because forests protect the environment and exercise beneficial influence on the climate. Due to the population growth and the indiscriminate use of wood for human needs, forests are disappearing at an alarming rate. Reforestation programs are being undertaken to reverse the tide of forest destruction.

Planting stock of good quality is needed for these reforestation programs. Only some of the species from the original virgin forests can be used in reforestation, and many times new, pioneering species, which can be established and grown in plantations, are needed. At times these will be new and hybrid varieties of introduced species, such as Populus and Eucalyptus. Also, species which can be used as multipurpose trees and grown in agroforestry systems are needed for these reforestation programs.

Planting stock of trees with proper genetic quality for agroforestry systems is often lacking. In most cases, the planting stock is of haphazard collections of wild types or land races, rather than the product of intentional breeding. The FAO - IUFRO conferences on research planning for developing countries held in Asia, Africa and South America in the period from 1984 to 1987 invariably identified the need for planting stock of proper genetic quality as a top priority.

THE IDEOTYPE TREE CONCEPT

The ideotype tree is, in a broad sense, a biological model which is expected to perform in a predictable manner within a defined environment. More specifically, an ideotype tree is a plant model designed to yield an improved quality and quantity of useful products than a wild plant or a conventional cultivar (Dickmann, 1985).

The formulation of an ideotype tree is a useful step in tree improvement because it provides a clear goal for breeding. The ideotype provides a guide for the selection of potential breeding stock and for the manipulation of newly generated material. Developing ideotype trees provides an opportunity to devise and examine combinations of characters which may never occur otherwise (Donald, 1968).

Another justification for formulating ideotype trees is that they can be used as a basis for a better understanding of the physiology of tree-crops. The initial design is in essence a framework to build upon and to arrive eventually at a synthesis that leads to a greater understanding of the whole plant. Such syntheses are rare for trees. Wood-yield is a polygenic character, and only by breaking the yield down to its components, and systematically dealing with these, one-by-one, can major breakthroughs be made in tree improvement (Ford, 1976).

There are, thus, three main points concerning the concept of ideotype trees. Firstly, the ideotype is a model toward which the tree breeder should strive. Ideotype breeding differs from traditional breeding in that goals are specified for each trait. Secondly, this model is artificial and superior, designing a combination of genetically controlled physiological and morphological characters resulting in maximizing the quality and quantity of yield. Thirdly, studies of ideotype trees lead to better understanding of the processes in trees, the trees as whole plants, and the trees as parts of stands.

THE IDEOTYPE TREE TRAITS

Ideotype breeding usually entails a three-step approach (Rasmusson, 1987). First, decisions must be made about traits that are to be part of the ideotype breeding effort, and a phenotypic goal for each trait should be specified; second, genetic diversity must be sufficient to justify a breeding effort; and third, the breeder must be willing to conduct several cycles of breeding and test the trait in question in different genetic backgrounds and possibly in different environments.

An ideotype is designed for a defined environment. Different environments and cultural practices may require different models. There is no universal ideotype that fits all sites and purposes.

Desirable components of ideotype trees have been suggested by several authors, without stating specific phenotypic goals (Dickmann, 1975, 1985; Siren et al., 1979; Fege, 1981; Siren, 1985). A list of components which are of almost universal importance was proposed by Koski and Vihera-Aarnio (1986). These are as follows:

1. High rate of net photosynthesis,
2. Efficient light interception,
3. Full utilization of the growing season,
4. High harvest index,
5. Efficient use of water and nutrients,
6. Rapid juvenile growth,
7. Tolerance to competition,
8. Tolerance to abiotic stress,
9. Freedom from pests and diseases,
10. Suitable biomass properties, and
11. Ease of reproduction and plantation establishment.

Zsuffa and Papadopol (1984) proposed the following ideotype tree components for biomass plantations of poplars and willows:

1. Fast juvenile growth,
2. High and constant sprouting ability,
3. Immunity towards foliar diseases,
4. Resistance to stem diseases,
5. High capacity for healing of cuts and low stump decay rate,
6. Responsiveness to increased cultural inputs,

7. Non-preference from insect pests,
8. Narrow crown with relatively few ascending branches,
9. Ability to use fully the growing season,
10. Dark foliage with high specific leaf weight, and
11. Tolerance to post planting herbicides.

Ideotype trees for agroforestry will require all of the components listed by Koski and Vihera-Aarnio (1986), and several of the components from the second list, such as the form of the tree and the responsiveness to cultural inputs. The ideotype components need further specification and will vary according to factors such as species, site conditions and cultural systems.

The traits selected for improvement must be under genetic control. Enthusiasm of plant breeders is great when they select for a trait that they believe enhances yield and is controlled by a single gene. Unfortunately, some traits that fit such description (such as in barley, Rasmusson, 1987) have associated negative effects, likely the results of pleiotropy. An implicit assumption of the ideotype approach is that yield enhancing traits can be manipulated genetically and ultimately assembled in a single genotype (Donald, 1968). However there is often an interrelationship between such traits. Grafius (1978) suggested that the ability to manipulate traits independently is inversely proportional to ontogenetic proximity. Also trait interrelationship may include intraplant competition for a plant's growth resources resulting in compensation among plant parts, which may hinder breeding progress.

METHODOLOGY OF IDEOTYPE BREEDING

A variety of tree species of importance to agroforestry have been studied indicating the genetic variability available, the genetic control and genetic-environment interactions for different traits. Stock of many important species has already been used and described as cultivars, and also studied and set aside in breeding collections, arboreta, and species and provenance trials. There is a wealth of this information and collections, and some of it could be put to use in producing desired ideotype trees. Unfortunately this wealth has remained mainly unused because of the lack of properly designed ideotype breeding programs. Such ambitious and agressive breeding programs are a must if agroforestry is to be taken seriously.

The definition of the ideotypes and the inventory and establishment of breeding stock must be the first steps in such a program. Selection and breeding will then, in a relatively short time, provide cultivars and clones which will be far more productive and safer than those used earlier.

Following is an outline of steps in ideotype breeding:

a. The agroforestry systems are characterized and ideotype trees (species, traits) for each system are specified.

b. Existing stock in collections and trials is catalogued and characterized, especially as related to ideotype tree traits.

c. The ideotype tree traits are analysed, particularly with regard to the variation in expression and genetic control.

d. The most feasible, important and available traits for breeding are selected.

e. Breeding combined with genetic engineering work is undertaken and genotypes with ideotype traits are developed.

f. Multiplication (whenever possible by cloning) and testing of ideotype trees is undertaken.

g. The ideotype trees are included in development and demonstration programs.

The breeding of ideotypes must be a cooperative effort. Some steps, such as the characterization of plantation systems and definition of traits, multiplication, testing and demonstration of stock, must involve silviculturists and tree-growers. In other steps, researchers of different disciplines, such as geneticists, physiologists, pathologists, etc., must work together. Only well defined team work can bring results in this effort.

The model for tree breeding described by Gullberg and Kang (1985) can be applied for breeding of ideotypes, as well (Fig. 1). According to this model, a physically separate, long term breeding population is the substrate of actual genetic improvement. Breeding is carried out in alternate cycles of selection and recombination, and short term projects put into practice the results obtained in each cycle. Supportive research is a catalyst in all activities. For practical application, superior genotypes must be propagated in sufficient quantities and at a reasonable cost. Tools of biotechnology, such as tissue culture propagation, can be useful if difficulties occur.

When we think of the role of biotechnology in breeding ideotype trees, the following points should be kept in mind.

a. The progress in biotechnology has been very rapid. Recently, biotechnology has been successfully applied to many tree species.

b. Its main role is within tree breeding and supportive research. When used as a tool within carefully planned research projects, biotechnology can bring substantial benefits.

c. It is a tool for gene isolation, cloning and transfer.

d. It can assist in overcoming incompatibility barriers and shortening generation cycles.

e. It facilitates recombinations and mutations.

e. It can facilitate the propagation and maintenance of valuable genes and genotypes.

P R O P O S A L

Reforestation must intensify on a global scale to satisfy the needs of human societies and improve the environment. This effort will require large international investments. Properly engineered, good quality planting stock is an important requirement for the success of reforestation and the security of the investment.

Planting stock of proper genetic quality is many times lacking and there is, therefore, a definite need for programs in ideotype tree formulation and breeding. These programs should be international with regard to funding, scientific cooperation and exchange of plant material.

These programs should start where the needs are the largest and the possibilities for success are the best. China, with some of its areas badly needing tree-cover, as well as parts of Africa with serious problems of desertification, could be the places to start with such programs. There is strong interest, and national and international support for reforestation, in both of the above regions.

Ideotype breeding should start with species which are important for reforestation programs, have already been used in planting and breeding studies, and offer the diversity and plasticity needed for successful breeding. Deciduous trees in general offer a broader diversity than coniferous species.

Poplars and willows are among the deciduous species which have been most widely used and studied. They can be grown in a variety of environments, except perhaps in the tropics. These genera contain a large number of variable species which can be recombined, genetically manipulated and used as models. Many hybrid varieties and natural mutations have been planted on several continents. Large collections of specimens for study and breeding exist. I propose, therefore, that poplars and willows be chosen as the initial genera for ideotype breeding.

Eucalypts offer another example of wide diversity, use, and potential for recombination and genetic manipulation. They are clearly species of tropics and subtropics, and I propose that eucalypts be chosen in a first program of ideotype breeding for these regions.

IUFRO and FAO should play a major role in initiating and carrying out these programs. I propose that this Project Group and Ad-hoc Committee address their agencies with such a request.

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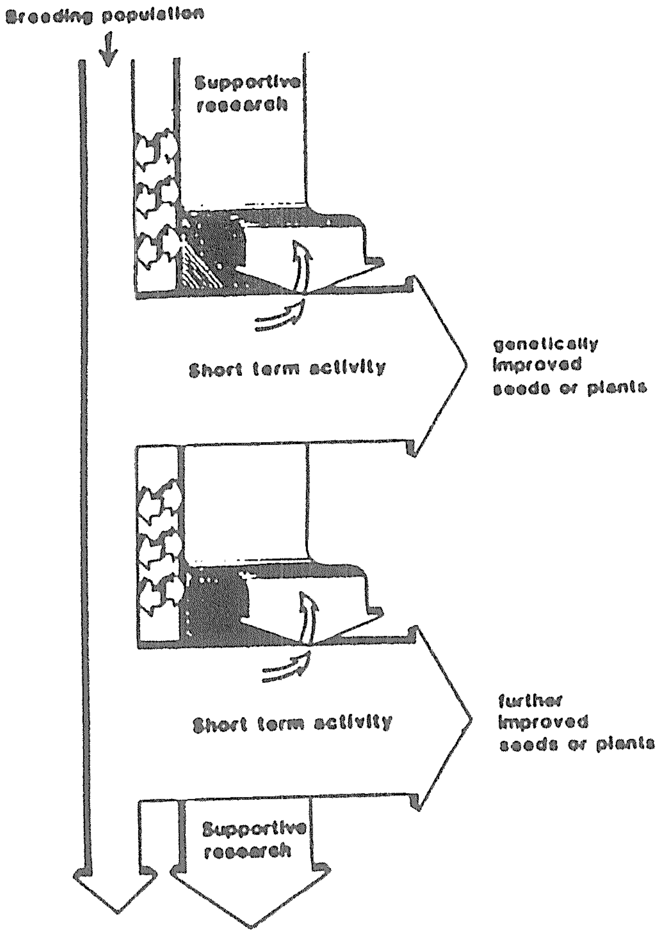

Fig. 1. A model for tree breeding (from Gullberg and Kang, 1985).

PROMISING NITROGEN FIXING TREE SPECIES FOR FUELWOOD IN SOUTHERN CHINA

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ABSTRACT

Among the 100 N-fixing tree species in Southern China, only some are fast growing and have high adaptability to poor site conditions. According to experiments and planting experience, species of *Acacia* and *Casuarina* can grow well in the dry and poor site conditions and have high productivities to about 2 - 3 cm in dbh annual increment, 2 - 3 m in height annual increment. and 30 tonnes of dry matter accumulation, these almost 2 - 3 times higher than *Leucaena*, *Albizia*, *Sesbania* and *Calliandra*. Compared to *Casuarina* species which are limited to coastal areas, *Acacia* species have wider adaptability and more potential species to be planted in energy forestry and agroforestry systems. Since *Acacia* were introduced to Southern China in the 1960s there have been 50,000 - 60,000 ha of plantations established. Among the introduced *Acacia* species, those widely planted are *A auriculiformis* and *A mangium*. Those species are mainly used in fuelwood plantations, mixed planting forests and protection forests. As multipurpose species, *Acacia* species can serve for fuelwood, small timber for farm tools and construction materials, green manure, and the flower is a source of honey.

INTRODUCTION

The area of Southern China (latitude below 23.5^0) is about 400,000 km^2. The annual mean temperature is 20^0C with the maximum 38^0 and minimum 5^0C; the rainfall averages around 1,500 mm annually, mainly distributed in the rain season (March to July in mainland and June to October in Hainan Island). From May to September is the typhoon season. The overuse of land brings about serious soil erosion and degradation of ecological conditions. At the same time the forest was depleted which not only causes shortage of timber but also shortages of firewood, forage and green manure. It is very important in these areas to select fast growing multipurpose nitrogen-fixing trees to provide firewood, small timber, forage, green manure and improve the ecological environment.

There are about 100 N-fixing trees native to Southern China but only a few of them can be used in production and most of them are not suitable for growing on infertile sites. Since the 1960s, some fast growing N-fixing tree species have been introduced into Southern China and species elimination trials were established in various site conditions. The experimental results show that the promising species are *Acacia*, and

Casuarina that performed much better than the introduced species of Leucaena, Calliandra, Albizia, Gliricidia, Sesbania and Prosopis which are not suitable for growing in poor conditions. Casuarina species are limited to coastal areas. Acacia species have high adaptability and are fast growing, high yielding and multipurpose.

An Acacia species introduced early is A auriculiformis which was introduced to Southern China Botany Garden in 1961 and the experimental plantations were established in Guangdong Forestry Institute and Zhaoqing Forest Experiment Station in 1964. Because of its good performance, it was widely used in reforestation programmes since the 1970s. At the same time, introduction of other Acacia species was started and over 40 Acacia species including A mangium, A cincinata, A aulacocarpa, A crassicarpa, A oraria etc were introduced to Southern China. The successfully introduced species are A mangium, A cincinata and A cunihamia.

With the introduced N-fixing species about 50,000 - 60,000 ha of fast growing plantations were established in Hainan Island, Leizhou Peninsula, and Pear River Valley in Southern China serving for fuelwood, small timber for farm tools and construction materials, green manure and protective functions.

GROWTH PERFORMANCE OF ACACIA SPECIES

The three Acacia species (A auriculiformis, A mangium and A cincinata) have high adaptability and performed as fast growing high yielding species in Southern China. A auriculiformis and A mangium have close growth rates but perform differently on different sites. A cincinata has good cold resistance and grows well in areas around the Tropic of Capricorn.

Compared to Eucalyptus species , Acacia species have higher ability to improve the soil. A large amount of litter can be found under Acacia plantations and the nutritional content of Acacia litter is higher than that of Eucalyptus species.

The yield of mixed plantings of Acacia and Eucalyptus is usually 5 - 10% higher than pure plantations of Eucalyptus.

Uses of Acacia species

Acacia species are widely planted in Southern China and take an important role in the reforestation in the area. Acacia species as they are fast growing and fix nitrogen are planted as short rotation multipurpose plantation which serve for firewood, small timber for farm tools and construction material, and protection. The leaves are mainly used for green manure to improve the soil and the flowers are a source of honey.

CONCLUSION

It is only about ten years since *Acacia* species were introduced to Southern China but their performance is good and to be considered as fast-growing, N fixing species for the area. Among the introduced *Acacia* species, the species with the best potential for development are *A auriculiformis*, *A mangium* and *A cincinata* which can be used for fuelwood, timber, protection forest and multi-cropping systems.

STUDY OF SILVICULTURAL TECHNIQUES OF FAST-GROWING FUELWOOD CROPS IN TROPICAL CHINA

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ABSTRACT

This paper is a firs report on the silvicultural techniques of fast-growing fuelwood species for Acacia auriculiformis and Eucalyptus exserta poor conditions. Four spacing treatments of 1.0 x 1.0 m, 1.0 x 1.5 m, 1.5 x 1.5 m and 1.5 x 2.0 m were adopted. The growth increments of diameter, height and biomass were determined. The changes of soil nutrients were observed also. The felling and regeneration trials began 3 years after planting.

INTRODUCTION

Acacia auriculiformis and Eucalyptus exserta are two fast-growing species planted across South China. There are some reports on the biological and ecological characteristics, silvicultural techniques and utilization but there are only a few reports on the productive potential and cultivation techniques for fuelwood under poor conditions. Experiments were started in 1982 on Hainan Island of Guangdong.

SITE DESCRIPTION AND EXPERIMENTAL METHOD

1 Planting site description and experimental method

The experimental site is located in the southwest hill platform of Qionghai county of Hainan Island. The altitude is 120 m and the terrain slopes gently. The soil is yellow laterite from sandy shale, damaged by over-exploitation and eroding seriously. The humus content of the soil is 0.27% and P 0.019%, N 0.026% with pH 4.9 which shows the soils low nutrient status.

The area belongs to the shallow basin climate of tropical monsoon climate. The mean annual temperature is 24.0^{0}C and minimum 5 C; mean annual rainfall is 2070.3 mm with the number of rainy days 168 per year.

The original vegetation was evergreen rainforest however, due to over exploitation by agricultural it has degenerated into a herbaceous community. The main plant species are: Dicranopteris dichotoma, Rhodomyrtus tomantosa and Machaerina myriantha. There had been a failure in planting Hevea brasiliensis at the site before the experiment, a planting of E exserta had also failed.

2 Experimental design

Four spacing treatments of 1.0 x 1.0 m, 1.0 x 1.5 m, 1.5 x 1.5 m and 1.5 x 2.0 m with 3 replications were used for each species. The felling and regeneration trials began 3 years after planting, including the measurements of biomass yield and felling methods for A auriculiformis.

3 Experimental Steps

The land was ploughed by tractor to 20 cm depth and then holes (25x25x30cm) were dug and the containerized seedlings planted. 50 g P fertilizer per hole was applied as a base fertilizer before planting and 40 g P + 25 g N fertilizer per tree was applied as top dressing in the second year.

RESULTS

1 Height and Diameter Growth

The growth disparities of height and diameter between the 4 spacing treatments are not great, but the disparities increased as the time passed. At the first year A auriculiformis diameter growth rate was almost equal to E exserta's and E exserta was higher than A auriculiformis. The diameter and height of A auriculiformis reached to E exserta's at the second year and surpassed it in the third year(Table 1)

Table 1 Height and diameter growth.

Spacing	A auriculiformis		E exserta	
	diam	ht	diam	ht
1.0x1.0	3.89	5.90	3.25	5.60
1.0x1.5	4.68	6.45	2.82	4.17
1.5x1.5	4.94	6.35	3.75	4.92
1.5x2.0	4.46	5.41	4.92	5.32

2 Volume

The volume accumulation in various spacing treatments is shown in Table 2.

Table 2 Volume at 3 years (m3/ha)

Spacing	A auriculiformis	E exserta
1.0x1.0	53.17	34.28
1.0x1.5	51.59	15.86
1.5x1.5	50.44	19.89
1.5x2.0	27.13	22.25

3 Biomass

The biomass accumulation in various spacing treatments is shown in Table 3

Table 3 Biomass Yield at 3 Years

Spacing	A auriculiformis fw	dw	E exserta fw	dw*
1.0x1.0	140.96	54.78	55.76	26.91
1.0x1.5	106.25	45.39	36.80	16.54
1.5x1.5	86.17	35.01	26.05	12.49
1.5x2.0	68.39	25.41	34.10	14.27

* fw = fresh weight; dw = dry weight

4. Changes in Soil Nutrients
It was found that A auriculiformis , a N-fixing tree species, has more ability to improve the soil. At the same time, it consumes more nutrients other than N because of its fast growth.

5. Silvicultural Techniques
it is important to improve the management measures to establish the fuelwood plantation under poor conditions. The all-over ploughing method should be used and base fertilizer (P and K) and top dressing (P and N) should be applied.

6. Felling and Regeneration
It is best to fell E exserta at 10-15 cm above the ground; the average height of shoots reach 60-80 cm after 3 months. The main factor affecting the ability of A auriculiformis to sprout is height of cut.

7. Economic Benefit
The total investment is RMB Yuan 555/hectare over three years for establishment of a fuelwood plantation. Calculated according to the lowest price of fuelwood of 30 yuan per wet tonne, a net profit of about 300 - 900 yaun is achievable.

AGROFORESTRY RESOURCES AND THE POTENTIAL FOR DEVELOPMENT IN SOUTHERN CHINA

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Southern China abounds in agroforestry resources, including both multipurpose plant germplasm and cultural practices. For reforestation programmes, many tropical and sub-tropical plant species were introduced with the native plant species to enrich the plant germplasm. The traditional agroforestry system, village-forest-garden, is modified with the use of introduced species and newly developed techniques. Large-scale agroforestry systems such as the shelter belts, intercrop and mixed planting forests are being developed. The paper describes the agroforestry resources and introduces some agroforestry systems, village-forestry-garden, shelter belts, wind breaks, intercrops, and mixed planting forests, in Southern China. An agroforestry plant species list is also included in the paper.

KEY WORDS: agroforestry, multipurpose plant germplasm, intercropping, village-forest-garden, protective forest, mixed planting, species list, Southern China

I. INTRODUCTION

The four provinces of Southern China, i.e. Guandong, Guangxi, Yunnan and Fujian, with a total area of 950,000 Km^2 and human population of 160 million and located in the tropical and sub-tropical zones, used to be covered by forests but the forests were depleted and converted to agricultural fields to meet the rapid increase in human population. The land use systems have been changed to satisfy the fundamental requirements of the high population density. However, these often result in degradation of ecological conditions, serious soil erosion giving diminishing yields. The initial response from the government was the strategy to set up large-scale reforestation programmes. For the reforestation programmes, many multipurpose plant species have been introduced into Southern China, to enrich the plant germplasm of the areas and provide greater chance of successful. The traditional village-forest-garden is being modified with the use of newly introduced plant germplasm and more sufficient landuse systems.

The current agricultural landuse systems in Southern China have their special characteristics such as high diversity of cultivated species and multistoreyed structure which display many agroforestry concepts. The elaborate traditional village-forest-garden survived throughout centuries as the result of long-term adaptation of cultivated plants and cultural techniques to local ecological conditions. It provides the sustenance requirements of the farmers and is also of economic importance. Research is focussing on the large-scale integrated agriculture and forestry to enhance the ecological stability of the agricultural systems, e.g. the use of windbreaks and shelter belts. More research efforts are also being made to improve the traditional forest planting patterns to look for some ecologically stable, economically acceptable forest techniques such as intercropping and mixed planting techniques.

Two major sections will make up the body of this paper. The first section will deal with the outline of the agroforestry plant germplasm resources and the second section with details of the agroforestry systems in Southern China, mainly the village-forest-garden, protective forests, intercropping and mixed planting techniques.

II. MULTIPURPOSE PLANT GERMPLASM

The multipurpose plant germplasm resources for agroforestry in China's tropical and sub-tropical areas are enriched by the abundant native gene resources and introduced foreign gene resources. The germplasm resources in Southern China have a distinguishing feature - most of the agricultural cultivars are from the native gene pools, but the most important forest tree species are introduced exotic species. An agroforestry species list is included in the Appendix.

1. Local gene resources for agroforestry

With the change in landuse forest land was converted to agriculture by cut and burn which caused serious soil erosion and forest tree species disappeared because they could not survive under the disturbed ecological conditions. But the agricultural gene resources were preserved and were improved. A lot of agricultural cultivars were produced over centuries of cultivation and recent breeding programmes. The main agricultural crops are annual crops, perennial crops and tree species which can provide fruit, food, and oil.

Annual Crops: Most of the annual crops are food cultivars. The main food crops in Southern China are rice. Other annual crops are beans, vegetable species, sugar cane, hemp species, tropical annual medicine species which are planted as cash crops and are economically important for the local people.

Perennial Plants and Tree Species: The major perennial species and tree species from the native gene resources are species for fruit, oil, and fibre. Cash species include banana, litchi, longan, pineapple, mango, jack fruit, arek, and sisal hemp.

2. Introduced exotic species

Most of the local forest tree species are not suitable to grow in the infertile soil so pioneer species are needed for large-scale reforestation programmes. Exotic species such as Eucalypts, Acacias, and Casuarinas have been successfully introduced to China's tropical an sub-tropical areas.

III. AGROFORESTRY SYSTEMS IN SOUTHERN CHINA

It is not easy to give a clear definition and classification for agroforestry systems. The agroforestry systems in Southern China, according to their components and structures, and functions, can be divided into several groups:

i) Village-forest-Garden;
ii) Protective Forest System;
iii) Intercropping System;
iv) Multipurpose Mixed Planting Forest.

1. Village-Forest-Garden

This traditional land use system, like the village-forest-garden in Indonesia (G Michon, 1983), has survived throughout centuries. The local farmers made this kind system for both their sustained food production and improvement of their environment. In the long-term development, the species component, spatial structure became more and more satisfactory to the local conditions. This kind land use system, like the natural forests, are different each other in components and structures which are affected by the local conditions. But they have a common character - the sustained crops and cash plants are planted amidst the houses and the surrounding area to provide the fundamental needs for their life and cash income for industrial products.

In this kind of landuse system, the plants are planted in a disorderly fashion but to any individuals they are in the right position in the artificial ecosystems where they can use the sunshine and other natural resources at high efficiencies. They are good examples of imitation of natural ecosystems and the only difference is the human pressure added and made them more productive. Figure i is a layout of the typical village-forest-garden in Southern China. The structure and function of each part are described as follows:

Home Garden : This part is amidst the house. It may include level ground for drying food, a pen for locking up the animals, and hundreds of disorderly planted species. This part provides some products such as fruits, firewood, small timber for construction and small farm tools, also have the function to improve the environment of the settlement.

Vegetable Garden : It is usually close to the house and fenced. Various vegetable species, such as tomato and cabbage are planted. This part provides the vegetable requirements of the farmers.

Fields : These are the main production part of the village-forest-garden. Two crops of rice are planted in the irrigated field every year and during the fallow between two crops, sweet potato is planted for forage or other legume species planted for green manure. In the dry field, mainly cash crops such as sugar cane and fruit species are planted for both a protective function and for by-products such as fruit.

Forest Plots : This is a part usually full of the new forest techniques. Besides rubber trees, introduced Eucalypts, Acacias and other fast-growing species appear in this part and new cultural techniques of intercropping and mixed planting are adopted. This part provides the fundamental firewood needs for everyday life and a cash income is generated by selling the products from the forest plots.

2. Protective Forest Systems

The protective forest systems, compared to the village-forest-garden, are the newly formed systems which have the function to protect the agricultural environment. The shelter belts to protect farmland in the plain areas and wind breaks in the coastal areas, are the major systems belong to the protective forests.

Shelter Belts to Protect Farmlands : A very good example is the shelter belt system in the Pear River Delta of Guangdong Province. There are about 4,000 ha of the farmland in that area which has been protected by forest belts. The main species adapted are *Casarina equisetifolia*, *Acacia auriculiformis*, *Taxodium distichum* and *T. ascendens*. With these fast-growing species, a belt is formed in the second year and performs its function in the third year'. According to the observations of the research network in that area, the microclimate conditions inside the network of shelterbelts (1-2^{o}C warmer and smaller wind speed and evaporation) are suitable for the growth of crops and the protective function becomes more obvious with bad weather. The economic benefit from the shelter belt forests, which only occupy about 5% of land is obvious, especially the benefit from the indirect ecological functions which is about 4 times that of the benefit from the direct wood products.

Wind Breaks in the Coastal Areas: A 3,000 km green great wall established mainly with *Casarina equisetifolia* appeared along the southern coast of China covering an area of more than 1 million hectares. This is a very good example of successful utilization of foreign plant gene resources. The structure of the windbreaks varies (0.5 - 30 km in width) according to the different local conditions. The major function of the windbreak systems are to control the drifting sand and resist strong winds. At the same time, they provide about 4 tonnes of firewood (litter and twigs) per hectare annually.

3. Intercropping Systems

The intercrop in Southern China is also a newly developed agroforestry technique. Agricultural crops or other economic shrub species are planted under forest or rubber plantations. This kind of system has many advantages compared to monocultural systems. The obvious one is to use the land and other natural resources more efficiently. At the same time, the farmers can get a cash income in the early stages from the intercropping crops, and do not need to wait 8 to 10 years to get their money back from the tree products. The systems are also good to enhance the growth of the trees because the more intensive cultural techniques such as weeding, fertilization are used in the intercropping lands. The following are some examples of the intercropping patterns which are used widely in Southern China.

Intercrop of Pineapple under Eucalyptus Plantations: Under one-year old Eucalypt plantations with a 3 x 1 m spacing, the pineapple plants are planted at 0.5 x 0.5 m. The initial harvest of pineapple can be obtained two years after planting. According to the investigation in the Baishiling State-run Forest Farm, the average yield of pineapple in the first four years is up to 2981 kg/ha/yr., this gives an average income of 1231 Yuan RMB/ha/yr (about $333/ha/yr). Excluding the costs for planting, tending, fertilizer and harvesting, a mean benefit of 581 Yuan RMB/ha/yr ($157/ha/yr) can be obtained.

Intercrop of Rattans under Forests: Rattans are the important cash palm species in Southern China. The rattan canes collected in natural stands are becoming limited. Artificial rattan plantations were started in Southern China to provide the requirements for the large-scale rattan cane industry. Rattans are usually planted under forests because they need shelter and support. In recent years research has concerned cultural techniques of commercial rattan species in Southern China.

Intercrops under Rubber Plantations: These intercropping patterns popular in Southern China recently. Several intercropping patterns are described below:

Rubber-tea pattern: Under the young rubber plantations with spacing of 8-10 x 2 m, tea trees are planted at a spacing of 0.25-0.30 x 1.0-1.5 m. In this way, there is about 40-50% of land covered by tea trees. This intercropping pattern also can be established in old rubber plantations which have been damaged and but are still harvested.

Rubber-coffee pattern: In the rubber plantations which are being harvested (the suitable spacings are 4 x 5 or 5 x 5 m) and for the plantations which are not being harvested - (with spacings of 3.5 x 6.0 or 2 x 8), coffee trees are planted at spacings of 1.5 x 1.5 m or 1 x 2m.

Rubber-pineapple pattern: This pattern of intercrop can be established in rubber plantations which are not being harvested . In rubber plantations with a spacing of about 2 x 7 m, the pineapples are planted at 0.35 x 0.50 x 0.80 m which occupies about 40% of the land.

The other intercropping patterns are rubber-sugar cane, rubber-banana, and rubber-tropical medicinal herb patterns.

4. Mixed planting forest

In Southern China, large-scale artificial plantations were established. The major species adopted in the reforestation programmes are mainly Eucalyptus. Those Eucalyptus plantations which are fast-growing and high-yielding can provide firewood, pulp, construction material and small timber for farm tools. But ecologically speaking, it is not enough to satisfy the goals of the reforestation completely. With the mixed planting techniques, combining Acacias with the Eucalypts, the mixed forests have more advantages compared to the monocultures of Eucalypts. Acacia species have higher abilities to improve the soil. The mixed planting patterns are various (one row Eucalyptus by one row Acacias or one row Acacias every two row of Eucalyptus with spacing from 1.0 x 1.0 to 1.5/2.0 x 4.0 m) according to the site conditions and management goals. The species widely used in the mixed planting forests are E. exserta, E. leizhou No. 1, E. ABL No. 12, A. auriculiformis and A. mangium.

IV. RESEARCH NEEDS

The abundant agroforestry resources, including both germplasm and cultural practices, give a foundation for further agroforestry development in these areas. Recent research concerns in agroforestry is another motive force for the development of agroforestry in Southern China. But more intensive research on agroforestry is needed to speed up land-use development. Research on agroforestry should give priority to plant exploration and breeding. To carry out the exploration for economically important new plants, perennials, trees and new methods to utilise the currently used agroforestry species is a foundation work for agroforestry development. At the same time, we should pay attention to the improvement and breeding of plants currently in use and the newly found multipurpose plants. In Southern China, the urgent need is for systematic breeding programmes for the successfully introduced Eucalyptus, Acacias, and Casuarinas which take important roles in the reforestation and agroforestry development. The techniques for establishment of productive landuse systems are also a major field in agroforestry research. This work should start with research on the current systems, their components, structures, ecological relationship between components, utilisation of nutrients and other natural resources, to understand the way the agroforestry system works and, at the base of that, we can development the systems and establish more productive ones.

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APPENDIX

LIST OF AGROFORESTRY PLANT SPECIES IN SOUTHERN CHINA

The following lists some plant species that are used in agroforestry systems in Southern China, but it is not a complete collection. The species, according to their uses, are divided into groups:

AS - Agricultural Species/planted for subsistence food production.
CS - Cash Species/planted for cash income, i.e. the economic plants such as the species for industrial raw materials, tropical medicine species etc.
FS - Fruit Species.
MS - Multipurpose Species/species have the characters of fast growing, high yield, high adaptability and can serve for fuelwood, small timber, forage, green manure and ecologically protective functions.
TS - Timber Species/planted for good quality timber production.

Acacia auriculiformis (MS)
Acacia cincinata (MS)
Acacia cunninghamii (MS)
Acacia mangium (MS)
Acacia mearnsii (MS)
Acacia melanoxylon (MS)
Acacia nilotica (MS)
Acacia teniana (MS)
Agave sisalana (CS)
Ananas comosus (FS)
Anona squamosa (FS/CS)
Areca catechu (CS)
Artocarpus heterophyllus (FS/TP)
Bambusa breviflora (MS)
Bambusa eutuldoides (MS)
Bombax malabaricum (CS)
Brassica chinensis (CS)
Calamus simplicifolius (CS)
Calamus tetradactylus (CS)
Camellia oleifera (CS)
Camellia sinensis (CS)
Casuarina equisetifolia (MS)
Casuarina glauca (MS)
Cassia siamea (MS)
Cassia spectabilis (MS)
Castania mollissima (CS)
Chaenomeles sinensis (CS)
Chukrasia tabularia (TS)
Cinnamomum comphora (TS)
Citrllus vulgaris (FS)
Ricinus communis (CS)
Saccharum officinarum (CS)

Smilax bracteata (CS)
Swietenia macrophylla (TS)
Syzygiom jambos (FS)
Taxodium ascendens (MS)
Taxodium distichum (MS)
Tectona grandis (TS)
Theobroma cocoa (CS)
Trachycarpus fortunei (CS)
Vernicia fordii (CS)

ENVIRONMENTAL PRECONDITIONING EFFECTS AND FOREST TREE BREEDING: A REVIEW OF RECENT RESEARCH

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Environmental preconditioning has several meanings in plant biology. In this paper 1 will first briefly discuss the various manifestations of preconditioning. Then I will review the results of work recently conducted within the context of forest genetics research.

Phvsiological Conditioning

Rowe (I964) first focused attention on the problem of environmental preconditioning in forestry. In particular he reviewed work with seed which indicated that conditions of maturation (light, temperature, nutrition) and handling can influence germination and subsequent seedling development. The influence of stratification and storage are now generally recognized and taken into account in development of stock production systems. Such effects are distinct from maternal influences which may be manifested in such things as seed size. Baskin and Baskin (1973) gathered from the seed literature further evidence for environmental preconditioning of germination. They especially noted the confounding of genetic and preconditioning effects in studies of geographical variation in germination. They suggested, as did others (e.g. Nelson et al I970), that common garden tests should be the source of seed for such geneological studies. While this approach may be suitable for strictly self-pollinated species, it presents problems for most other species since seed from a common garden of provenances will be the product of crosses among them (and perhaps with local populations) unless there are phenological barriers. Rowe (1964) also reviewed the substantial evidence for the effect of environmental preconditioning on phenological and flowering response of individual plants. For example, environmental conditions in "year one" may influence performance of plants in "year two". We now routinely use our knowledge of this relationship in, for example, producing planting stock with a high capacity for establishment and growth. Generally, no conditioning in the genetic sense is involved in this relationship.

Genetic Conditioning

From the standpoint of tree breeding the most potentially important sort of environmental preconditioning results in effects which are passed on to succeeding generations, either sexual or asexual. One of the earliest published records of this effect is that of Hofmann (1927) who treated bean *(Phaseolus vulgaris)* plants with chloral hydrate and observed that resulting growth abnormalities were passed on to as many as six generations. The abnormalities were not transmitted by pollen. Grun (1976) has reviewed evidence for such environmental preconditioning in the context of cytoplasmic inheritance, particularly the concept of plasmon factors, which are as yet poorly understood but appear to be inherited maternally. The major line of evidence comes from reciprocal crosses which produce unlike progeny. Cytoplasmic male sterility, which has been extensively investigated, can be accounted for by such a system of plasmon factors interacting with plasmon-sensitive genes. Hill (1967) has also suggested an interaction of extrachromosomal agencies and genes to account for inherited differences in flowering time and height of inbred Nicotiana rustica which were induced by various nutritional conditions. Differences induced in an initial parent population by combinations of N, P and K were transmitted for three generations. This sort of environmentally induced heritable variability has also been reported for Linum (Durrant 1962) and Pisum (Highkin 1958). On the other hand, there are many reports of failure to induce environmental preconditioning in agronomic plants (e.g. Austin and Longden 1965).

Progeny Tests

Evaluation of the above type of environmental preconditioning (or "C" effects) via progeny tests of forest trees has not been frequently done. In most tests "C" effects have been confounded with maternal effects, which are recognized as having a significant influence on progeny performance. For example, in a diallel experiment with Pinus strobus Kriebel et al (1972) noted that 78 percent of variation in progeny height at age 4 was due to maternal effects. Greathouse (1966) and Bramlett et al (1983) have shown through diallel experiments that germination characteristics of Psuedotsuga menziesii and Pinus virginiana respectively, are under some maternal control. Perry (1976) reviewed studies in Pinus taeda and P. elliottii which show that 45 to 80 percent of variation in progeny height at 4 to 8 years can be accounted for by maternal influences which are manifested in such factors as seed weight, seed coat thickness and stratification requirement. In addition to these observations of maternal effects, there are several reports of tests in which seed coming from several ramets of a parent clone were kept separate by ramet, thus allowing evaluation of ramet-within-family effects. If seed are then used in a progeny test one can assess "C" effects associated with conditioning of ramets due to their location or other factors. These effects, of course, are confounded with maternal effects associated with individual ramets and with different pollen parentage. Using this type of design Shear and Perry (1982) found significant ramet effects in dry weight of 35-day-old Pinus taeda progeny. Farmer and Cunningham (1980) observed that up to 17 percent of variance in first year shoot characteristics of Quercus alba could be accounted for by ramets within parent clones. However, the effect of ramets was statistically non-significant for most of the characters. We (Stoehr and Farmer in preparation) have recently found that ramet-within-parent variance in growth of Picea mariana rapidly decreases during the first season. In other work (Farmer 1981, Verheggen and Farmer 1983, Stoehr and Farmer 1986) significant ramet within-parent variation in flowering of Quercus alba and in seed characteristics of Picea mariana have been noted which might result in environmental preconditioning effects in progeny.

Clonal tests

Some vegetatively propagated species have exhibited clear retention of environmentally induced variation in successive vegetative generations. A well-known example of this phenomenon is found in commercial potato (*Solanum* sp) varieties (Went 1959). Ortets grown under cool temperatures give rise to "seed tubers" which have greater yield potential than "seed tubers" grown under warm conditions. These effects may last for at least two vegetative generations. Libby (1962) quantitatively evaluated this type of environmental preconditioning using *Mimulus guttatus* clones, ramets of which were grown under several environments before being vegetatively propagated. Rooted cuttings from these conditioned parent (or primary) ramets were then grown in a single environment, and growth and days to flowering evaluated via the analysis of variance. Environment of primary ramets accounted for 6.8 to 8.2 percent of total variance in 4-week height and days to flowering, respectively. He also noted that age of primary ramets influenced these characteristics.

Libby first suggested the evaluation of these cloning or "C" effects by two stage cloning. In this experimental approach several "primary" ramets from each clone in a sample population are grown under different environments for a conditioning period. Then a number of "secondary" ramets are taken from each of these primary ramets for evaluation in a uniform environment using the following type of design:

Source of Variation		Degrees of Freedom	Expected Mean Square
(2)	Conditioning Environments (e)	1	Vr + Vp + rpVce + crp0
(16)	Clones (c)	15	Vr + rVp + rpeVc
	Clones X Environment	15	Vr + rVp + rpVce
(2)	Primary ramets within environments (p)	32	Vr + rVp
(2)	Secondary ramets (r)	64	Vr
	Total	127	

In this design, variance associated with environments and primary ramets within environments is an estimate of environmental preconditioning effects. The design with various modifications has been used extensively in research with vegetatively propagated trees. It is important to note at this juncture that in vegetative propagation, intra-clonal or "C" effects may arise from either (I) environmental conditioning of ortets or primary ramets or (2) the influence of physiological aging and/or typophysis. In fact, the two influences may be frequently confounded. Burdon and Shelbourne (1974) have reviewed the complications of using clones to obtain genetic information.

Most of the studies to date with trees have evaluated "C" effects in rooting stem cuttings. In the first of these Wilcox and Farmer (1968) obtained secondary ramets from primary ramets of Populus deltoides which had grown for one year in a replicated clonal test. Primary ramets (i.e. preconditioning) accounted for 1 I, 12 and 7 percent of the variance in number of roots per cutting, early shoot weight, and foliation date, respectively. They noted that if secondary cloning had not been employed the variance attributable to primary ramets ("C" effects) would have been associated with clonal variance, and broad-sense heritability would have been over-estimated. Thus, quantitative estimates of "C" effects have application in heritability determination. In a thorough study of western hemlock (Tsuga heterophylla) rooting Foster et al (1984) found that 2 to 6 percent of total variation in several rooting characteristics was associated with primary ramets. In this experiment, primary ramets were grown in separate pots under relatively uniform conditions in a greenhouse. A portion of the material used in the experiment was subsequently used to evaluate "C" effects in both rooting and early height growth (Foster et al 1985). Since desirable rooting characteristics were positively correlated with height growth, eight percent of the variance in growth was accounted for by primary ramets within clones ("C" effects). In contrast to the above reports, research with Populus balsamifera cuttings collected from September to April has shown no effect of primary ramets on rooting, though "C" effects were occasionally noted in shoot growth and foliation time variance (Farmer et al 1988). Primary ramets used in this study were plants located in different replications of field and nursery tests. In a two year rooting study of 37 juvenile Larix laricina clones we have to date observed no "C" effects related to primary ramets grown in separate pots.

Growth and "C" effects have been formally examined in two studies of Populus balsamifera. In the first Farmer et al (1986) subjected primary ramets to moisture stress and control treatments, then compared the first-year growth of secondary ramets taken from them. While rooting percent and root growth were slightly decreased by applying moisture stress to parent ramets, shoot growth was not. Surprisingly, however, the main finding was that primary ramets within the conditioning treatments accounted for substantial variance in growth. Recently, we completed a three-year evaluation of the effect of environmental conditioning upon variance in growth and phenology in which primary ramets were grown in different locations within a nursery before recloning (Farmer et al 1988). By the end of the second year in a field test primary ramets within clones accounted for less than I percent variance in height. Thus estimates of heritability were not substantially altered by environmental conditioning. Cannell et al (1988) have reported a longer study with Picea sitchensis and Pinus contorta in which primary ramets of clones were grown for five years on upland and lowland sites in Scotland, then repropagated and grown for five years on a common lowland site. Five year height of secondary ramets was not influenced by conditioning of primary ramets.

Conclusions

To date, the relatively small amount of research on environmental preconditioning in forest tree species has revealed no effect approaching the magnitude of that reported for some agronomic species. In fact, there are no reports of "C" effects extending beyond the first sexual or vegetative generation. Maternal effects taking the form of variation in factors such as seed size and quality appear to have more influence than environmental conditioning. Effects of the magnitude noted to date in "C" effects studies can be easily accounted for by physiological considerations rather than extrachromosomal inheritance. This conclusion does not reduce the importance of considering "C" effects, whatever their basis, in evaluating genetic variance in such characters as rooting in species where they have been well demonstrated. And experimental material should be always grown under conditions which reduce variation in physiological quality. However, it does suggest that, until experimental evidence indicates otherwise, special efforts are unnecessary to avoid or account for environmental conditioning of a genetic nature in long term clonal or progeny testing of trees.

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RESEARCH RESULTS ON POPLAR WOOD PRODUCTION IN INTENSIVE SHORT ROTATION CULTURE AND EXPLOITATION OF THESE PLANTATIONS

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1. Introduction

Shortage of wood in general especially in two last decades has led to the excessive exploitation of forest funds. Intensive cultivation of fast growing forest species in short rotations can solve this problem, especially in those regions where there are large areas suitable for poplar and willow growing, as well as for the production of other fast growing species.

In temperate climatic zone there are suitable ecological conditions for poplar growing. Forest plantations and field experiments can be established in the riparian and inundation zones of rivers, on uncultivated and abandoned lands, as well as on degraded forest terrains.

Poplars have special advantages when they are compared to other forest species, as follows: fast growth, adaptibility to different environment conditions, possibility of cultivation in different systems which enable the production of large quantities of wood in short periods of time which can be used for different forms of processing in timber industry, as well as in pulp-and-paper industry and as a source of energy.

Introduction of this intensive wood production in short rotation depends on the results of research projects which should solve the problems regarding the choice of the most productive clone resistant to diseases, insect pests, climatic extremes, as well as the choice of the best soil type, different planting material and planting techniques. Choice of the best spacing system is very important for the effective exploitation of the natural phenomenon of wood volume increment, what should determine duration of production cycle.

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Choice of monoclonal or polyclonal poplar plantations can exert a considerable influence on the results of production, and at the same time, it can decrease a risk of decaying of certain clones. It is of great ecconomic importance if poplar production in plantations can be renewed from sprouts in the coppice system.

In this paper the results presented were obtained in investigations which started 15 years ago and are carried out hitherto focused on the above mentioned problems, as well as on exploitation of these plantations and utilization in the process of processing pulp, semichemical pulp, paper, and for fuel.

2. Results of investigations carried out hitherto

Investigations of poplar wood production in short rotation were organized in such a way that for each problem field experiments were established and the obtained results were calculated and analyzed. The investigations were focused on the following problems:

(1) The choice of poplar clones;
(2) The choice of planting material and planting techniques;
(3) The choice of spacing and felling cycle;
(4) The choice of the system of cultivation in monoclonal or polyclonal plantations;
(5) Renewal of plantations with sprouts from stump;

At the same time, effectiveness of different exploitation processes was also examined:

(6) Choice of the process of exploitation of short rotation plantations;

Produced wood was also examined regarding different aspects of exploitation in processing industry:

(7) Investigations of wood used for processing of pulp and semichemical pulp, and

(8) Possibility of exploitation of wood obtained from short rotation plantations for fuel (in furnaces).

The majority of the established poplar plantations are approaching at the age which can provide the maximum wood production, and some conclusions can be derived from the obtained results. Further investigations will answer how long should the optimum cycle of certain cultivation system last, but on the basis of the above results the most appropriate cultivation system can be chosen.

2.1. Choice of clones and cultivars

In the process of poplar breeding initial material of domestic and foreign origin was collected. Production of hybrid material obtained at Poplar Research Institute was examined, as well as foreign selections imported from other institutes. In a series of preliminary tests some investigations of variability and heritability were carried out, as well as of possible gain which can be achieved by selection for all properties important for breeding: surviving in rooting-beds and plantations, production of wood volume with all parameters of growth and increment,production of drywood substance, resistance to leaf and bark diseases, ability of renewal from sprouts on stumps (Herpka, 1987). Strategy of poplar breeding is presented in a scheme which describes: sources of material, field experiments, and all necessary examinations with testign of new selections used for the production of wood in plantations.

Chosen clones which won quick recognization by fast juvenile growth, growth vigour in their stool-beds, and healthy stumps, as well as by characteristics of basic wood density were included in a series of investigations in a form of clonal tests and comparative plantations, with the aim of testing their productive ability in a system with dense spacing.

2.1.1. In a clonal test with 32 poplar clones and spacing 3 x 3 m (1,111 trees per ha), in a deep alluvium of the Danube river, at the end of the sixth growing season, total wood volume production (with bark and branches) was examined. The highest production was achieved by selected hybrid clones (SEL/1970) of the species Populus deltoides, and (SEL/1976). Lower production was achieved by registered clones in production of the species P. deltoides (REG/1980) and Euramerican hybrid clones (EURAM), while the lowest production was obtained by hybrid clones with P. trichocarpa (TRICH.), and P. maximowiczii (MAXIM.) respectively:

Clones	No.	Tree Dimensions		Volume per Hectare	
		diameters from-to cm	heights from-to m	total m^3/ha	average $m^3/ha/year$
SEL/1970	3	16.0-16.4	14.3-16.6	127-158	21.2-26.4
SEL/1976	11	13.7-15.6	13.7-15.9	81-139	13.4-23.2
REG/1980	5	13.6-15.9	13.3-16.2	69-140	11.6-23.2
EURAM.	4	10.8-14.8	11.8-14.7	47-104	7.8-17.4
TRICH.	3	12.3-14.1	13.9-14.8	75-107	12.4-17.8
MAXIM.	5	12.0-14.2	12.3-14.0	63-90	10.5-15.0

Wood volume per hectare was calculated on the basis of survival of trees in plantations (in three blocks 60 trees from each clone were planted). The greatest production was achieved by two clones from group SEL/1970 (clones 9-31 and S 6-1) selected at Poplar Research Institute in 1970, as well as by one clone from group SEL/1976-70-76-9, and one clone from group REG/1980-55/65 which were also selected at Poplar Research Institute in novi Sad. It is expected that the average increment will increase with each year of plantation age, and the optimum felling cycle will probably be from 9th to 12th year of plantation development.

2.1.2. In comparative field experiment with 18 poplar clones and spacing 2.82 x 2.82 m (1257 trees per hectare) in a deep alluvium of the Drava river, at the end of the fifth growing season total wood volume production was examined (with bark and branches). The highest production was achieved by hybrid clones of P. deltoides selected in 1970 (SEL/1970), and little less production values were achieved by group of registered P. deltoides clones (REG/1980), and group of selected clones used for testing in production forms of field experiments (TEST.), while the production of Euramerican hybrid clones (EURAM.) had much lower values:

Clones	No.	Tree Dimensions		Volume per Hectare	
		diameters from-to cm	Heights from-to m	total m^3/ha	average $m^3/ha/year$
SEL/1970	4	12.8-14.7	14.1-15.6	94-140	18.8-28.0
REG/1980	5	13.0-13.8	14.7-15.1	104-117	20.8-23.4
TEST.	6	13.5-14.3	14.5-14.8	103-109	20.6-22.0
EURAM.	3	9.9-13.1	11.5-14.7	45-105	9.0-20.9

Wood volume per hectare was calculated on the basis of survived trees in plantation (in three blocks total of 105 trees from each clone was planted). The highest production was achieved by two clones from group SEL/1970 (clones S 1-8 and S 6-36) above 25 m^3 of the average annual increment per hectare.

2.1.3. In factorial field experiment with 8 poplar clones and spacing 2.82 x 2.82 m (with 1257 trees per hectare) on alluvium of the Danube protected from floods at the end of the nineth growing season wood volume production was examined (with bark and branches). The highest production was achieved by selected registered clones of P. deltoides (REG/1980), while group of hybrid Euramerican clones (EURAM.) had much lower production values:

Group	Clones	Tree dimensions		Volume per Hectare		
		diameters from-to cm	heights from-to m	total m^3/ha	average m^3/ha/ year	current incr. m^3/ha/year
REG/ 1980	618	18.0-20.4	19.2-21.9	257	28.5	50.2
	55/65	17.4-19.8	19.2-20.8	264	29.3	49.2
	457	18.2-19.0	19.5-20.3	252	28.0	42.5
	450	17.8-18.2	19.7-20.1	224	24.9	27.1
EUR-AM.	I-45/51	15.6-16.9	18.8-19.5	175	19.4	26.8
	3 (Ostia)	15.7-16.7	17.3-18.3	166	18.4	25.4
	I-214	13.7-14.7	16.6-18.8	129	14.3	23.2
	543	11.8-13.4	14.3-16.8	49	5.4	7.8

Wood volume per ha was calculated on the basis of sectioning of average trees and a number of survived trees in a field experiment. The greatest production was achieved by registered clone of P. deltoides, cl. 55/65, while the clones from the group of Euramerican hybrid clones had much lower production values (Marković and Herpka, 1986).

From these three examples where poplar clones were examined in a system of short rotation with dense spacing it can be seen that the highest production values were achieved by the clones selected in 1970 and 1976, immediately followed by all other registered clones of the same species, while Euramerican hybrid clones had much lower increment. In relation to that, it should be pointed out that Euramerican hybrid clones are very susceptible to leaf diseases (Marssonina brunnea, Melampsora sp.), as well as to diseases of bark (Dothichiza populea - bark canker in poplars), while, on the other had, selected and registered clones of P. deltoides are almost resistant to these diseases.

For all examined clones, and those which were felled at the end of the ninth growing season, current increment at the ninth year was greater than the average one. This points to the fact that rotation in these plantations should be longer.

Taking into account that applied cultivation techniques were performed without fertilization and irrigation, it can be concluded that maximum average increment of 30 m^3 per hectare can be considered as satisfactory, although this increment can be increased with some additional interventions.

2.2. Choice of planting material and planting techniques

Choice of planting material and planting techniques depends on various factors and should be in harmony with them (exp. soil properties, aim of wood volume production, etc.). If soil profile is homogeneous and enables ascendant moisture fluctuation above ground water, planting can be performed in a surface layer of soil. If layers of sand prevent rising of moisture above the level of ground water, plantations should be established with deep planting technique to the level of ground water. In that case, one should choose planting material appropriate for this type of planting technique.

In a series of field experiments investigations were carried out on two localities with different planting material and planting techniques. Chosen registered clones of P. deltoides were included in these tests. Only few field experiments were established with several selected Euramerican poplar hybrid clones.

2.2.1. From the Table below (2.2.1.) it can be seen that different planting material was included in the research:

- cuttings of different length (Reg.no. 1, 2),
- roots of rooted cuttings (Reg.no. 3),
- rooted cuttings (Reg.no. 4, 5, 8, 9),
- one-year-old plants with two-year-old roots (Reg.no. 6),
- two-year-old plants with three-year-old roots (Reg.no. 7),
- one-year-old sprouts from stool-beds (Reg.no. 10),
- two-year-old sprouts from nursery (Reg.no. 11).

Planting depth varied from 25-100 cm for homogeneous soils, and 2.7-3 m for soil profiles with sand layers.

INFLUENCE OF PLANTING MATERIAL AND PLANTING TECHNIQUES ON SURVIVAL OF TREES IN PLANTATIONS

Table 2.2.1

Reg. no.	Planting material (age)	Planting depth cm	Survival in % for Clones: P.deltoides from-to	P.deltoides average	x Euramericana from-to	x Euramericana average
1	2	3	4	5	6	7
1.	Cuttings 25 cm	25	87-90	88.0	-	-
2.	Cuttings 30 cm	30	87-93	90.0	-	-
3.	Roots of rooted cuttings	30	92-100	96.4	-	-
4.	Rooted cuttings cut immediately *)	70	87-100	97.4	-	-

1	2	3	4	5	6	7
5.	Rooted cuttings cut later**)	70	84-94	88.4	-	-
6.	One-year-old plants with two-year-old roots	80	84-100	91.5	-	-
7.	Two-year-old plants with three-year-old root	90-100	78-99	92.1	-	-
8.	Rooted cuttings cut immediately*)	270-300	92-95	93.5	52-88	83.0
9.	Rooted cuttings cut later**)	270-300	72-84	73.2	31-91	71.0
10.	One-year-old sprouts from stool-beds	270-300	81-94	90.6	32-90	68.7
11.	Two-year-old sprouts from nursery	270-300	87-98	94.0	50-87	83.0

*) Cutting of the overground part of rooted cutting was done at the ground level immediately after planting.

**) Cutting of the overground part of rooted cutting was done at the ground level later when it was observed that there were problems with breaking into leaves.

It was observed that on alluvial terrains with homogeneous soil profiles, where normal planting was applied, survival of trees was the best (97.4%) in treatment (4) established with rooted cuttings at a depth of 70 cm, so that the overground part was immediately cut at a terrain level. At the same time, very good results were achieved in field experiments established with (3) roots of rooted cuttings (96.5%), and one-year-old plants (6) (91.5%), as well as two-year-old plants (7), (92.1). Lower values were obtained by planting of (1) short and longer cuttings (2) (88.0, 90.0%), as well as by planting of rooted cuttings (5) which were cut later when it was observed that there were some problems in breaking into leaves, (88.4%).

When deep planting was applied on alluvial sandy terrains to the level of ground water (up to 3 m), the best percentage of survival (94.0%) was achieved by planting of two-year-old sets (11) cut in a nursery, as well as by deep planting of rooted cuttings (8) with reduced root, where the overground part was cut immediately after planting (93.5%). At the same time, satisfactory results (90.6%) were achieved by planting of one-year-old sets (10) cut in a stool-bed. Considerably lower results were obtained by planting of rooted-cuttings (9) which were cut later, when it was observed that there were problems regarding breaking out in leaves, (73.2%).

The above results were obtained with the clones of Populus deltoides. Euramerican hybrid clones, which were examined in the process of deep planting did not achieve so good results as those obtained by P.deltoides. Two-year-old sets (11) and rooted cuttings planted by deep planting which were cut immediately after planting (8) achieved the same results (survival was 83.0%). Considerably lower percentage was obtained by rooted cuttings (9) which were cut later (71.0%), and one-year-old sets from stool beds (68.7%).

2.3. Choice of spacing and rotation

In a series of field experiments wood volume production per hectare was examined in relation to different spacing and different number of survived trees. The greatest number of planted trees per hectare was 16.000, and the lowest was only 800. Investigations were carried out in plantations which approached to the optimum of rotations, while in some plantations felling was performed at the end of felling cycle, and plantation was renewed from stumps.

2.3.1. Total wood volume is presented for the examined poplar clones of the Aigeiros section, and for chosen clones of Populus deltoides (DELT) regarding their properties of growth and increment, and resistance to diseases, as well as for some clones of Euramerican hybrid poplars (EURAM.):

TOTAL WOOD VOLUME PRODUCED PER HECTARE IN FIELD EXPERIMENTS WITH DIFFERENT SPACING OF TREES

Table 2.3.1

Reg. no. of test	Survived trees/ha	Examined clones	Plantation age	Wood Volume per ha m^3 total from-to	Wood Volume per ha m^3 average from-to
1.	7666	DELT.	2	27.4-31.1	13.7-15.6
	10338	DELT.	2	29.9-37.1	14.9-18.5
	15156	DELT.	2	33.1-42.0	16.5-21.0
2.	6945-13890	EURAM.	3	140.0-156.0	46.6-52.0
3.	2868 - 4116	DELT.	4	86.2-90.5	21.5-26.1
	2850 - 4108	DELT.	6	121.2-125.8	20.2-21.0
4.	2500	EURAM.	4	90.0-183.0	22.5-45.7
	2500	EURAM.	6*)	132.0-323.0	22.0-53.8
5.	1131	DELT.	9	232.0-311.0	25.8-34.5
6.	1100-1778	DELT.	9	168.0-253.0	19.8-28.4
7.	1275	DELT.	5	126.0-140.0	25.1-28.0
8.	3105	DELT.	6	138.8	27.7
	1545	DELT.	6	125.9	25.2
	775	DELT.	6	95.4	19.1

*) Wood volume of thinning after the fourth year of plantation age is included in total wood volume production.

From the results presented in the above Table it can be seen that in field experiments under Reg.Nos. 2 and 4 the highest wood volume production was achieved. These results refer to the Euramerican hybid clone I-214, which was cultivated in these field experiments before spreading of the leaf disease Marssonina brunnea, and when this clone was resistant to all diseases spread until then. It achieved the greatest increment then, because of its exuberent juvenile growth and growth vigour after thinnings performed at the early stage of development. In new plantations established later, (see Chapter 2.1) this clone had very low wood volume production.

Taking into account the needs for wood assortments (especially of pulp-and-paper factories), it can be concluded on the basis of our investigations that for 10 year rotation with the cultivation of 1000 to 1500 trees per ha the optimum spacing varied from 2.5 x 2.5 to 3 x 3 m. In denser spacings, wood of small dimensions is obtained with great percentage of bark, not suitable for the obtaining of good pulp, and on the other hand, the investigations carried out hitherto did not prove that in denser spacing and in shorter rotations a considerable higher wood volume values can be achieved.

In plantations established on favourable alluvial terrains with intensive treatment of cultivation and adequate planting techniques applied on the most productive clones of P. deltoides, average increment of 25-35 m^3 per hectare annually can be achieved. In these plantations no irrigation or fertilization was applied.

It is suggested that the effects of irrigation and addition of fertilizers should be examined later in the course of these investigations in order to determine their influence on the increase of total wood production.

2.4. Choice of the System of Cultivation in Monoclonal and Polyclonal Plantations

Large monoclonal plantations of forest species are exposed to danger of sudden appearance and spreading of diseases, so the investment in such plantations can be very risky. After spreading of the leaf disease Marssonina brunnea, and disease of the bark Dothichiza populea on the most productive Euramerican hybrid clone I-214 up to then, it was concluded that it was necessary to start investigations more intensively on poplar breeding, and after selection to include a number of selected clones into established plantations. It is still a debatable question whether to plant selected clones on large areas in the system of monoclonal or polyclonal plantations.

2.4.1 Preliminary investigations were carried out in a field experiment where spacing 2.5x2.5 m was applied (1,600 trees per hectare). One-year-old sets from stool-beds of five registered clones were planted on loamy-sandy alluvial soil at a depth 2.7 to 3 m (deep planting). Apart from plots planted with one clone, there was a plot established with a mixture of selected clones in randomized block system.

At the end of the sixth growing season, dimensions of trees were measured, and survival of trees was determined, as well as wood volume production (with bark and branches) per hectare, Table 2.4.1. Mean values of tree dimensions and wood volume production for (A) all experimental plots have shown that for individual clones in monoclonal plots (1-5) these values varied considerably (97.3-147.3 m^3/ha), while volume production values in plot with mixture of clones (6) was equal to the average (C) of monoclonal plots (129.8 m^3/ha).

COMPARISON OF MONOCLONAL VERSUS POLYCLONAL TREATMENTS OF POPLAR CULTIVATION IN THE FIELD EXPERIMENT (MO-PO/81) AFTER SIXTH GROWING SEASON

Table 2.4.1

Treatments (clone)	Diameter cm	Height of trees m	Survival in %	Volume per ha m^3	Average increment m^3/ha/y	Index %
A. Mean values for experimental plots						
1 450	13.4	14.8	98	147.3	24.5	113.5
2 457	13.5	14.9	94	144.6	24.1	111.4
3 55/65	13.1	14.5	99	139.3	23.2	107.3
4 618	13.1	14.8	83.6	120.7	20.1	92.9
5 725	12.9	15.2	68	97.3	16.2	74.9
6 mixture	13.2	14.8	88.2	129.8	21.6	100.0
B. Mean values for each single clone in treatment (6)						
450	12.8	14.7	88	120.0	20.0	92.4
457	13.6	14.6	86.6	132.9	22.1	102.4
55/65	13.5	15.5	90.8	146.0	24.3	112.4
618	13.2	14.9	90.0	132.1	22.0	101.8
725	12.9	14.3	85.6	118.2	19.7	91.1
C. Average of monoclonal plots 1-5						
1-5	13.2	14.8	88.5	129.8	21.6	100.0

Analysis of the growth and increment of each individual clone (B) in a treatment with mixture of all clones (6) have shown considerably lower varying in production values (118.2-146.0 m^3/ha) than in monoclonal plantations.

On the basis of the results obtained in field experiments it can be concluded that it is less risky to cultivate poplars in polyclonal plantations, because if some of the clones are badly damaged or lost (diseases, insect pests, etc.), their loss will be compensated by better increment of other clones.

2.5. Renewal of Plantations with Sprouts from Stumps

The problem of plantation renewal with sprouts from stumps is a complex one, because it depends on various factors, as follows: time of felling, plantation age, reduction of sprouts on stumps, number of sprouts left on stumps, etc. Genetic ability of renewal from sprouts on stump depends on the resistance of clone to different diseases, insect pests, as well as on the very stump, whether it is healthy or not in its cross-section.

In selection objects, especially in stool-beds with gene pool of juvenile clonal material, it was observed that after renewed felling some of the clones gradually disappeared, while others retained their growth vigour for long periods of time.

In a series of field experiments, investigations were carried out examining the possibility of plantation renewal from stumps by felling:

(1) after two-year-cultivation in plantation,
(2) after four-year-cultivation in plantation,
(3) after seven-year-cultivation, and
(4) after nine-year-cultivation in plantation.

2.5.1. In a field experiment established with roots of rooted cuttings in three spacings: (a) 1.2 x 1 m (8,333 trees per ha), (b) 1.2 x 0.7 m (11,111 trees per ha), (c) 1.2 x 0.5 m (16,666 trees per ha), on loamy--sandy alluvial soil, poplar trees were cultivated with one sprout on stump (without fertilization and irrigation) in four rotations. Each rotation lasted two years. Four registered clones of Populus deltoides were examined in that research, and mean values were calculated for survival and total wood volume production with bark and branches:

SURVIVAL OF TREES AND TOTAL WOOD VOLUME PRODUCED
IN FOUR BIENNIAL ROTATIONS IN THREE DIFFERENT DENSE SPACINGS

Table 2.5.1

Initialy planted trees/ha	I Rotation survival %	I Rotation produc. m^3/ha	II Rotation survival %	II Rotation produc. m^3/ha	III Rotation surviv. %	III Rotation produc. m^3/ha	IV Rotation surviv. %	IV Rotation produc. m^3/ha
8,333	92.0	28.8	81.6	54.0	71.3	62.5	47.6	33.0
11,111	93.0	32.2	79.1	55.5	64.6	62.5	37.3	31.7
16,666	90.9	39.3	74.8	60.5	58.6	68.3	25.9	27.3

From the above data it is obvious that number of trees decreased in each next rotation, so that at the end of felling cycle of 8 years (4x2 years) only 25.9 to 47.6% trees survived. For this reason, at the end of felling cycle, the initial number of trees decreased to the approximate equal number of survived trees (a) 3,963, (b) 4,194 and (c) 4,302 trees per hectare. The greatest wood volume production was achieved in the second and third rotation (60.5, 68.3 m^3/ha), while the lowest values were obtained in the fourth (27.3 to 33.0 m^3/ha) and in the first rotation, respectively (28.8 to 39.3 m^3/ha). So, during eight years of cultivation in two-year rotations 178.2 to 195.3 m^3 of wood with bark and branches was produced per hectare, or annually 22.3 to 24.4 m^3 per hectare (Herpka and Marković, 1984, 1985; Marković and Herpka, 1986).

2.5.2. In a field experiment established with cuttings of 25 cm of two registered clones of P.deltoides in two spacings (a) 2x1 m (5,000 trees per ha) and (b) 2x1.5 m (3,333 trees per ha) on loamy-sandy alluvial (without fertilization and irrigation) felling was done at the end of the fourth growing period (Table 2.3.1, reg.no. of test 3). At the beginning of the first growing period after felling of trees, all unnecessary sprouts from stump were cut, and on each stump only one sporut with the best growth vigour characteristics was left.

DEVELOPMENT OF THE SPROUTS FROM STUMPS IN TWO GROWING PERIODS
AND COPPICE IN TWO DIFFERENT SPACINGS

Table 2.5.2

Spacing	First year of coppice: height of sprouts m	First year of coppice: survival of stumps planted %	Second year of coppice: height of sprouts m	Second year of coppice: survival of stumps planted %
2 x 1 m	1.81	82.6	5.9	80.3
2 x 1.5 m	1.72	84.8	5.7	84.0

In the course of the first year of cultivation (second rotation in a coppice system), all cut stumps were sprouting, while the number of survived trees in plantation slightly decreased in the second year of cultivation. Both examined clones have shown similar ability of growing of sprouts and survival of stumps. Height increment of the second year of cultivation was especially high and it was approximately 4 m.

2.5.3 A plantation established with one-year-old sets from stool-beds by deep planting up to 3 m (the overground part was immediately after planting cut at the ground level, spacing 1.5 x 1.5 m), with 405 clones from 12 half-sib families of P.deltoides, was cut after 7 years of cultivation (Herpka, 1982; Herpka and Marković, 1985). The field experiment was renewed from sprouts on stump in the second rotation.

At the end of the first rotation only 87.1% of planted trees survived in the plantation, and at the end of the first growing period in the second rotation and coppice system 90.8% of the survived trees were sprouting. Sprouts from stumps were not reduced in the course of the first coppice vegetation so at the end of that period it was possible to determine relations between number and total length of sprouts per stump, as well as their correlation characteristics according to the height and diameter of tree from which sprouts were developed.

FREQUENCY OF NUMBER AND TOTAL LENGHT OF SPROUTS ON STUMPS AFTER FIRST GROWING PERIOD IN COPPICE OBTAINED BY FELLING OF SEVEN-YEAR-OLD DENSE EXPERIMENTAL PLANTATION

Table 2.5.3

Number of sprouts per stump-clones		Total lenght of sprouts per stump-clone - m	
From-to	Frequence %	From-to	Frequence %
1-3	18.3	0.1-5	22.2
4-6	16.5	5.1-10	15.1
7-9	20.0	10.1-15	23.4
10-12	16.3	15.1-20	17.0
13-15	14.3	20.1-25	13.6
16-18	9.6	25.1-30	6.2
19-21	2.7	30.1-35	2.0
22-24	1.7	35.1-40	0.3
25-27	0.6	40.1-45	-
28-30	-	45.1-50	0.2
Average for families	5.9-11.7	7.7-17.9	

Distribution per stump and clone, respectively, as well as variability of mean values per families called for new investigations focused on the choice and selection of genotypes with desirable characteristics of the growth vigour and ability of renewal from stumps.

Study of the relation between (A) diameter and (B) height of tree of certain clones determined before felling in plantation, in comparison to the number (1) and total length of sprouts (2) on stump in a coppice system has shown that there is a highly significant positive correlation between these values:

(A):(1) $y = 2.6897 + 0.5816x$, $r = 0.93$
(A):(2) $y = 4.4864 + 0.4549x$, $r = 0.74$
(B):(1) $y = 3.8638 + 0.3132x$, $r = 0.85$
(B):(2) $y = 5.4273 + 0.2809x$, $r = 0.79$.

2.5.4 In renewed plantation with sprouts from stumps of the field experiment cut at the ninth growing season, in the first year of coppice growing all the sprouts from stumps were left to the spring of next year when reduction was done by felling of all unnecessary sprouts, so that only two sprouts (the best developed ones) were left on stump. The field experiment was established with a spacing 2.82 x 2.82 m (1,257 trees per ha),(Table 2.1.3). At the end of the first growing season, a number of stumps with sprouts was determined, all sprouts on stump were counted, and the average heights of sprouts were calculated. Measurements were repeated at the end of the second year in a coppice system. In Table 2.5.4 results on survival of trees are given, as well as dimensions and number of sprouts of clones of P.deltoides.

SURVIVING OF TREES AFTER NINE-YEAR CULTIVATION AND SPROUTING OF STUMPS WITH DEVELOPMENT CHARACTERISTICS OF COPPICE

Table 2.5.4

Clone	Percentage of surviving			Sprouts in coppice			
	at the end of first rotation	in coppice		1st year		2nd year	
		end 1st year	end 2nd year	no. per. stump	height m	no per. stump	height m
618	85.8	76.6	67.1	10.6	1.5	1.81	5.0
457	87.4	76.3	56.6	10.7	1.4	1.76	4.9
450	84.3	73.7	65.0	11.2	1.5	1.85	5.1
55/65	90.2	85.1	78.3	13.5	1.5	1.84	4.9

From the above Table it can be seen that in the course of cultivation and renewal of plantation in the coppice system, a number of living stumps is considerably decreased, so a number of trees in the field experiment at the beginning of cultivation was: 121.4%, 99.5%, 120.2% and 144.1%. Investigations focused on renewal of plantations from sprouts on stumps have shown that poplars can reproduce second generation of trees in the coppice system, and that growth vigour in the coppice system is almost equal to the increment in the first rotation after plantation establishment. At the end of the second year, height of trees was 4.9-5 m, so during the second growing season height increment varied from 3.5 to 4 m.

If in plantations with 1,200 to 1,500 trees in second rotation two sprouts are left on stumps, a number of trees in a coppice system will be approximate to the initial number of planted trees.

Further investigations should examine the influence of the time of felling and stump age on the growth vigour of poplars, as well as to determine the production in a coppice system in order to evaluate the optimum duration of felling cycles.

2.6. Choice of Exploitation Techniques in Short Rotation Plantations

A great number of trees of small dimensions per unit area at felling time is one of the main characteristics of these plantations which effects both felling technology and assortment production. If in these plantations standard methods of work are applied (Exp. power saw), costs will be higher and effects of work lower. At the same time, if power saw is used in the production of standard wood assortments, a great deal of tree (diameter below 7 cm) is regarded as residue. These circumstances and favourable conditions for mechanized work (flat terrains, uniformity and symmetrical distribution of trees) were taken into consideration when these investigations were planned.

2.6.1. In a number of field experiments a few typical manual technological variants were parallelly realized (with power saw), as well as two mechanized technological variants (felling of trees and production of long pulpwood with harvester, and chipping of whole trees at a temporary landing or in plantation (Djoković, 1984; Djoković and Nikolić, 1986; Djoković and Zeremski, 1987; Djoković, 1987; Djoković, Zeremski i Komlenac, 1987). Standard pulpwood (1m and 2m) was produced by power saw, as well as so-called "long pulpwood" (4-6m). Branches and tops with a diameter below 7 cm were collected in the process of production of standard pulpwood, transported to the temporary landing, and chipped there. In Table 2.6.1 partial effective times are presented per phases for all compared technological variants. Effective times presented in the Table refer to the plantation with average value $D_{1.30}$ = 15 cm and transport distance to the road (500m).

EFFECTIVE TIMES (min/m^3) OF COMPARED TECHNOLOGICAL VARIANTS

Table 2.6.1

Technological variant	Work			
	Manual	Transport equipment	Chipper	Harvester
1m, power saw	46,5	12,5	1,1	-
2m, power saw	35.0	11,0	1.1	-
long pulpwood, p.saw	27,3	9,1	1.1	-
long pulpwood, harvester	12,1	9,1	1.1	4.0
full tree chipping	8,0	6,7	3.9	[illegible]

The greatest percentage of manual work was in the production of standard pulpwood (1m), and the lowest was in full tree chipping. On the other hand, when costs were analyzed, the cheapest way of production was chipping of whole trees by harvester.

When harvester is used, shere of manuel work in total applied work is decreased. Costs of production are lower than those of the production of standard pulpwood (1 and 2m).

For chipping of tops and branches with a diameter below 7 cm in a production of standard pulpwood (manual and mechanized), only additional chipping is necessary (1.1 min/m^3) in order to obtain approximately 20% assortments more from the same plantation.

From the above data it can be concluded that by application of mechanized methods (chipper and harvester) costs can be considerably reduced, exploitation of wood can be better (without residue), and the whole process can be improved, more efficient and humane.

2.7. Utilization of Wood from Short Rotation Plantations for the Production of Pulp and Semichemical Pulp

Investigations of structural, physical and chemical properties of wood of some poplar clones of P.deltoides (117/2, 131/6, 131/9 and 182/2) aged 8 years were carried out, as well as examininations regarding their influence on characteristics of unbleached sulphate pulp and semichemical pulp (Kopitović, Klašnja, 1985). Specimens of standard pulpwood whole trees, and branchwood with and without bark were taken for cooking under laboratory conditions.

The results of the cellulose obtained have shown considerable differences in increment of specimens obtained from standard pulpwood and whole trees (53.8% and 53.4% on the one hand and branchwood (only 44.4%) on the other share of bark in chips has negative influence on the level of delignification and on mechanical properties of pulp. Pulp obtained from branches has not so good mechanical characteristics as pulp obtained from whole trees but its quality is satisfactory for the production of paper.

Almost the same situation is with semichemical pulp (NSSC process), although the differences between semichemical pulp obtained from branches (72.4%), and whole tree (79.4%) are not so apparent. Mechanical characteristics of semichemical pulp obtained from branches have the lowest values, but they can be satisfactory in the production of corrugating board.

From the field experiment "Topolje" at Valpovo where plantation with two clones of P.deltoides (cl. 618 and cl. 457) was established in 1982, with two spacing systems (2x1 m and 2x1.5 m), wood specimens were taken from clones aged four years for the production of semichemical pulp in laboratory conditions. Chips was obtained from whole trees by chipper BRUKS 800 CT. The results regarding obtaining of semichemical pulp under laboratory conditions (Klašnja, Kopitović, Koralija, Ivković, 1987) have shown that spacing did not have a considerable influence on the yield of semichemical pulp, which varied for all specimens from 74.4-76.1%. Mechanical properties of semichemical pulp obtained in that way had lower values than those obtained from "standard" pulpwood. Problems which appeared because of great share of bark and lower values of mechanical properties of semichemical pulp can be solved by cooking of chips obtained from branchwood with chips obtained from standard wood assortments.

Branchwood from several clones of P.deltoides and P.euramericana from field experiments established by Poplar Research Institute in Novi Sad was used for obtaining of semichemical pulp in the process of NSSC under laboratory conditions (Klašnja,Kopitović, Koralija, 1987). Cooking was done with normal (10%) and lower content of Na_2SO_3 (8%) in relation to absolutely dry chips, with the aim of increasing the yield. On the basis of this research it was proved that mechanical properties of semichemical pulp had not much lower values as usual. So, it was concluded that branchwood from some poplar clones obtained in short rotation plantations can be used for the production of semichemical pulp, especially when it is cooked with chips obtained from pulpwood.

In this way, branchwood, as well as wood from whole trees, especially if it is obtained from younger and denser plantations, can be better used in fiber production and can lead to better exploitation of total wood volume.

2.8. Study of the possibility of utilization of wood from short-rotation plantations for obtaining of thermal energy by combustion in special constructed furnaces

Taking into account the fact that wood volume obtained from short-rotation plantations has lower dimension values, chipping appeared to be the best way of the first phase of processing in forests.

From the point of view of energetic valorization of this wood the following advantages were achieved:

- completely mechanized work in forest,
- simple transport and loading, and
- automatic process of combustion in combustion chambers.

In our research granulation of chips varied from 25 to 50 mm, although the best results are achieved with chips from 14-25 mm. Chips from these plantations is characterized by high moisture values, and high percentage of bark in total wood volume. At the same time, a high percentage of chips was obtained from thin branches which are not easily chipped by chippers, so a considerable amount of pieces longer than 50 mm is found.

On the basis of the fact that poplar chips has high voluminous values (150-180 kg/m^3) economic transport distances are considerably shortened. For this reason, our research was focused on construction of small combustion chambers and furnaces which can be used for heating of individual houses and small firms (power 40 to 250 kw).

At Poplar Research Institute a few prototypes of combustion chambers were examined in a period from 1982-1988 for obtaining of thermal energy by water heating.

In three main examined prototypes (power 40, 150 and 250 kw) almost the same combustion parameters were achieved, as follows:

- Combustion temperature .... from 800 to 1,100 C
- Content of CO_2 in gasses .... from 8 to 16%
- Content of CO in gasses .... below o.5%
- Content of ash ....up to o.5%
- Degree of efficiency .... from 65 to 78%

* moisture content in chips up to 35%.

The achieved results have shown that chips obtained from poplar wood in short rotation plantations is suitable for obtaining the thermal energy in burner units with construction adapted to the above characteristics and specific qualities.

Conclusion

Investigations carried out hitherto have confirmed that it is possible to choose poplar clones of high productive potentiality suitable for cultivation in intensive short rotation plantations.

For each system of cultivation under certain soil conditions it is necessary to select appropriate planting material and planting techniques.

Production of wood in short rotation plantations can be achieved in few different cultivation systems depending on production goal and desired assortments:

(a) In short rotation plantations with 8,000 trees per hectare and rotation 2-3 years, (renewal in the coppice system up to 4 times) approximately 25-30 m^3 of wood volume can be produced annually (with bark and branches). Number of survived trees at the end of rotation decreased for 50%.

(b) In 4-6 year rotations with 3,000-5,000 trees per ha, it is possible to produce annually from 28-32 m^3 per ha (with branches and bark), although a number of survived trees in the second rotation decreased for 25-30%.

(c) In rotations from 8-10 years with 1,200 to 1,600 trees per ha, average annual production per ha varied from 28-32 m^3. Number of trees in the second coppice system decreased for 30%.

When the possibility of plantation renewal in the coppice system is examined, it was determined that in dense plantations (a) and (b) it is necessary to leave only one sprout on stump (the best one), and in the planting system with decreased number of trees (c) two sprouts with favourable characteristics should be left.

The best exploitation of plantations is achieved by chipping of whole trees by chippers in plantation, while in the system of cultivation (c) wood for mechanical pulp can be also produced from thicker parts of tree.

Produced wood in all systems of cultivation can be processed in pulp and semichemical pulp of somewhat lower quality, but in a mixture (when it was added to the pulp of the highest quality) it was used for the production of paper of good quality.

All the above mentioned systems for the production of wood in short rotation plantations produce wood of satisfactory energetic quality what was proved in special constructed furnaces and combustion chambers.

Economic effects of this production have not been examined entirely, yet, although we think that they will be competitive with other sources of energy if exploitation and transport costs are decreased.

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ECONOMIC DEVELOPMENT

Summary of the Session on Economic Development
MULTIPURPOSE TREE PRODUCTION SYSTEMS
Joint Workshop of IUFRO P.1.09.00 and IPC/FAO Ad-hoc Committee on Biomass Production Systems in Salicaceae
Beijing, September 5-7, 1988

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This Multipurpose Tree Production Systems Workshop of IUFRO (International Union of Forestry Organizations) P.1.09.00 was organized around the themes of sustainability, biodiversity and economic development. Economic development and ecological and environmental management are the expected products of biologically engineered multipurpose tree production systems, which is just one example of the many popular production systems discussed in the paper on biological engineering. The immediate objectives of our biological engineering efforts are often sustainability and biodiversity (see Figure 1). Sustainability ensures economic and ecological benefits. Biodiversity ensures the preservation of the gene pool that may be required for the biology component of strategies to maintain and increase sustainability.

This session covered case studies and overviews of a wide range of countries ranging from industrialized to developing.

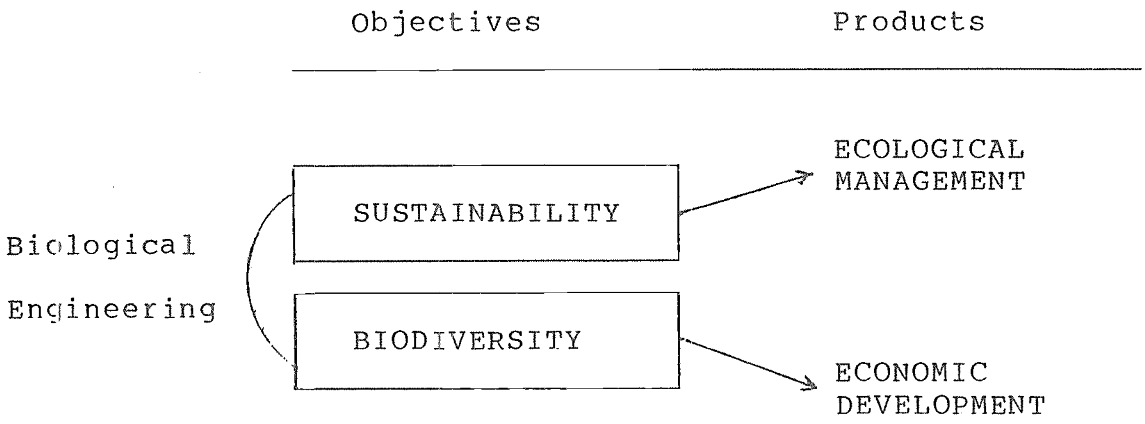

Figure 1 Objectives and Products of Biological Engineering in Examples Dealt with in this Paper

The papers include:

Lee, D. K. and K. H. Lee, Energy Potentials of Woody Biomass, and Waste Materials from Animals, Industries or Cities in South Korea.

Gerden, K. A. and B.B. Kaale, Socio-economics of Fuelwood Plantations.

Bradley, D. P. and D. C. Lothner, What Can Economics Say about Sustainability and Biodiversity.

Chao, T., C. Chen , Z. Yang and S. Tian, The Growth and Economic Effect of Purlin Plantation Management with Intercropping in North China Plains.

Lu. S., Research on Sustainable Agroforestry at the Nanjing Forestry Institute

The main points and considerations covered by this session are summarized below:

1. The case of an effective implementation plan to achieve higher than 60% forest cover in Korea after the war was presented.

2. The active role of biomass as a source of energy and materials in an industrialized country using Korea as an example was

presented.

3. In production system design, the needs of the land user as a starting point was discussed (the Tanzania experience).

4. In production system design, equity may have priority over efficiency.

5. Successful agroforestry systems in China were presented as examples of successfully-implemented biologically-engineered production systems (the North China Plains experience and the Jiangsu and South of Yangzi experience).

6. It was proposed that IUFRO initiate work on models for analysis of ecological, social and economic aspects of urban wood fuel supply (Swedish projects in Africa can be used as appropriate application cases, and the small holder versus large plantation issue will be analyzed).

7. It was proposed that sustainable systems in the general context are equitable, efficient, flexible, self-sufficient, integrated, and consistent with social institutions.

Forest Biomass for Energy: Research, Extension and the Smallholder

by

C Å Gerdén [1)]

1. Introduction and aim

At previous IUFRO workshops in Uppsala, Sweden and Ljublana,Yuogoslavia the increasing, se rious deforestation in the developing countries has been thoroughly highlighted. Calls have been made for immediate countermeasures resulting in a stable balance between deforestation and reforestation, instead of the present 10:1 ratio. No alternative, feasib- le energy source other than (forest) biomass appears to be within reach for the masses of the developing countries in the foreseeable future. "The safest remedy seems to be a biomass production at a scale never before experienced" (Sirén et al, 1987).

This paper concentrates on discussing certain socio-economic features of the ones that are going to produce a substantial part of the woody biomass needed - the small subsistence farm household. What do their social and economic conditions imply for future research and extension?

2. Some points of departure: The role of the forest departments and the smallholders

The national statistics on what it would mean to break even, between supply and demand of fuelwood, are staggering. For example, in Tanzania it has been estimated - in spite of encouraging afforestation efforts - that treeplanting needs to be increased more than 10-fold, in order to strike a balance between supply and demand (for a population that is growing by 3.3 % per annum). (Kaale Mwandosya, 1983). Such overall, average figures indicate the magnitude of the problem, but must be

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regional or zonalized to contribute to the basis for plans and priorities in national fuelwood programmes.

Both demand-side and supply-side woodrelated policy measures can be considered to reduce the problems pertaining to the "wood-gap". For many developing countries the conclusion has been that - even with a substantial reduction in demand through improved stoves, charcoal kilns etc - there is a great need for increased wood supplies (Raskin, 1986).

Due to the magnitude of the problem and the investments required to step up treeplanting substantially it goes - nearly without saying - that it is impossible for the government forest departments of the developing countries to plant, grow and conserve trees to satisfy the energy needs of their fast growing populations. The staff, funds, vehicles etc for such a gigantic task are simply not there - even with very generous donor inputs.

The role of the government forest department has thus been defined as mainly giving catalythic support to initiate mass participation in producing wood energy. The users - in most cases smallholders (defined as holdings under 20 acres) - in rural areas have to produce their wood energy using their own resources.*)

However, while promoting rural selfreliance in wood energy, the governments would plant, themselves, to satisfy the needs of (big and quickly growing) population centres (where naturally, the population does not have access to enough land to be self-reliant in woodfuel).

To supply urban areas with wood-fuels from government managed large-scale plantations, seems like a logical solution. Some reports indicate that, even in this case, the small holders may have a role to play due to problems of making the large-scale plantations economically viable. That point will be highlighted below.

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*) The approach and socio-economic aspects to be considered in extension work - above all the need to involve the rural villagers/house hold in the planning and execution of fuelwood projects - have been elaborated by Kaale at a previous IUFRO-workshop, and should not be repeated here (Kaale, 1985).

3. Large-scale and small-scale production of woodfuel for urban areas

Peri-urban plantations are expensive to establish. The costs are around US dollar 800 - 1200 per hectare, but may be as high as US dollar 7000 - 9000 for irrigated plantations in difficult areas in Sahel (Dubre, 1984). In order to cut transport costs, these plantations are sited close to urban-markets. With expanding cities, land values, wage rates and increasing possibilities of other profitable use of the land, the economic viability of the plantations decreases. If populations are displaced by the plantations, it has sometimes been possible to include them in the forestry labour force. However, in many cases they have been evicted to become part of the urban masses (ETC, 1987).

For urban centres with fairly large surrounding natural forests, the large-scale plantations "compete" with the more or less legal cutting from the unreserved natural vegetation ("public land" in Tanzania). The use of "open access tree-resources" is difficult to control. The forest 'miners' often get their raw material very cheap and the consumers do not pay the environmental costs of defforestation. To make the competion with the plantations more even, the government can raise charges (levies), establish charcoal check points with fees etc. However, with the enormous growing demand from the urban consumers, effective control of the woodfuel supply is most likely to be difficult and continue to undermine the economic viability of the periurban plantations - - - till the natural forest has been depleted.

In several cases, woodfuel plantation projects first clear natural ("waste") forest and then establish plantations at substantial costs (promising high returns). There are examples of plantations that, later, did not produce much more wood than the cleared natural forests. The cost of establishing an Eucalyptus plantation in Bandia, Senegal was US dollar 800/ha. It produced 1.5 m3 /ha/year. In the same area, an indigenous scrub forest, (Acacia Seyal), produces an average of 1 - 1.5 m3 per ha and year with no management and no establishment costs (Falconer, 1987). In such a case, the woodfuel plantation certainly begs the question: Does the end justify the means?

Looking for alternatives to traditional large- scale woodfuel plantations for supply to urban populations, the UNDP/World Bank compared the viability of the following options in a study for Tanzania: 1) A conventional peri-urban plantation run by Forest Department, 2) Small holder woodlots in a taungya system (in which food and tree crops are produced on forest land), 3) Management of the natural forest with enrichment planting.

In brief, the break even stumpage price (TAS/m^3) for peri-urban plantation, smallholder woodlots and forest management + enrichment planting turned out to be 315, 95 and 93 respectively. The much higher establishment costs (not least mechanisation with high foreign exchange component) for the peri-urban plantation, is the main reason that the small holder method cost became only one third of the cost of the plantation stumpage method. The average annual wood produced (15.2 m^3 /year) was the same for the plantation and the smallholder alternative, while the management + enrichment planting produced only 2 m^3 /year. (UNDP/World Bank, 1987).

The present stumpage charge for wood from natural forests is TAS 10/m^3. That means, that none of the above options can compete with wood (if paid at all) from the open- access, natural forest.

It should be noted that the above are pre- project calculations. The outcome of implemented projects may look quite different. However, the UNDP/World Bank study indicates that the plantations will have great difficulties in becoming economically viable for urban firewood and charcoal markets. The study suggests that they may play a role in producing higher-priced construction poles. Such a scheme,however, is not a solution to energy problems(although acknowledging that 25 - 30 % of a "pole-tree" can be used as wood fuel).

The above costings quoted have been made on the basis of a sustained production in the large- scale plantation. However, there are indications that the second rotation in some large- scale tree monocultures under tropical conditions encounter problems of survival - trees are dying, maybe because of impovishered soils (Gerdén, 1988). Such a development was forecasted in a study by Lundgren (1978). A mixed small-scale tree-culture may show a better long-term sustainability.

The above notes suggest that it would be worthwhile to try assess pilot-schemes on smallholders producing woodfuel for the urban markets. There are - of course - many socio- economic conditions and forest regulations that have to be considered as regards how attractive such an investment would be to smallholders. In the case of Tanzania, the fairly large remaining natural forests around e.g. the capital Dar es Salaam are still supplying so much "free" wood that the smallholders would probably think thrice before investing in wood for the market instead of e.g. growing food. The shortage and the commercialization of fuelwood have not yet developed so far as in the state of Gujarat in India, where the wellknown "tree-farmer" Patel decided to plant trees (mainly Eucalyptus) on 50 of his 60 acres farm and is making a bigger profit than if agricultural crops would have been planted (Patel, 1985; Pant, 1980).

Let us make a final note as to what extent the large-scale fuelwood plantation addresses the causes of deforestation. Generally speaking, the plantations are woodfuel factories for urban markets and attempt to decrease the pressure on natural forests in the urban hinterlands. The latter objective assumes that a major reason for deforestation is cutting of the existing forests for obtaining woodfuel. However, several studies indicate that the main drive behind deforestation is clearing for agricultural land for growing population, and that even the present supply of fuelwood/ charcoal to urban areas is based on such agricultural practices (Spears, 1986; Du Toit et al., 1984; Byer, 1987). In other words, if the urban dwellers would stop using woodfuel, the deforestation rate would hardly be changed.

A plausible action to slow down clearing would then be intensification of agriculture - to raise more food crops (and trees) on the existing agricultural land to feed the growing population. This puts agricultural, rather than forestry, interventions into focus solving woodfuel supply to urban areas. Strategic questions regarding trends for future agriculture productivity, settlement and land clearing patterns and when new land will "run out", as well as the urban woodfuel demand, should be answered in an integrated consideration of the role of large-scale woodfuel plantations.

3.1 An IUFRO-concern?

The issues concerning the establishment of economically viable solutions to the supply of woodfuel for urban masses are very complex, (to say the least). Information to answer critical questions is very limited. It seems that IUFRO could make a contribution in this field, through facilitating sharing of experiences and further research. Reference is made to the discussion of research and development needs regarding Forest Biomass energy production, in the IUFRO-report from Yugoslavia 1986 (Siren et al., 1987). Under the heading "Production economics" (page 15), a call is made for more accurate costing figures and more sensible economic analysis, regarding large-scale projects. "Accounting conventions and methods for analysis vary considerably from country to country (let alone between agriculture and forestry)". It could be a task for IUFRO to iniate the development of models/manuals for analysis of social, ecological and economic aspects regarding urban woodfuel supply - be it produced in large-scale plantation and/or by smallholders.

4. The smallholder as producer of woody biomass

The following is a brief list with comments on socio-economic aspects regarding the smallholder as a producer of woody biomass. The aim of this discussion is to give a background to some suggestions pertaining to future direction of IUFRO-research. One should be careful with generalisations on characteristics of rural households. No smallholder or group of smallholders is exactly alike. However, some general remarks may hopefully prove useful, within the context of the given aim.

4.1 Perception of the problem

The general view of the problem expressed in IUFRO-documents, is that in the long-run, deforestation will have a profound negative impact on the viability of the rural economy. The woody biomass should therefore be replenished. Take action!

This view is gradually shared more and more by rural households (Helmfrid, Persson, 1987; Energy Unit, 1988) but by no means by all (Gerdén, et al, 1988;). Besides the fact that water, agricultural production etc is regarded as the primary problem to deal with, in many cases the first action to solve fuelwood scarcity seems to be to substitute with agricul ture waste and cowdung - not to plant trees. For example, a household survey in semi-arid parts of Tanzania showed that 61 % use dung and 60 % residues (Nilsson, Kikula, 1983). Hosier (1984) reports the same from Kenya drylands. Another reaction is to alter the diets to include foods which need less cooking (Hoskins, 1979). When scarcity grows, people start to use less fuelwood to delay rather than hasten to a catastrophe (Foley, 1987; Hancock, 1987).

The steps taken above by a smallholder to adopt to the growing woodfuel scarcity will not lead to a sustainable solution. However, it does not involve any significant changes in traditions that never included sincere investment in treeplanting, improved cookstoves etc. Such innovations would also mean extra costs in very limited time and cash budgets.

4.2 Individual and communal planting

Smallholders in a village, planting communally, a village woodlot, has been one important component in e.g. the Tanzanian village forestry programme. Experience has shown that they, in many cases, have met limited success. Organisational ability of the village government (especially in villages with heterogeneous populations) to mobilize for joint self-help schemes and maintain the communal trees, loss of private land for communal use, lack of confidence in village leaders or uncertainity of who and how the village woodlot was going to benefit after harvesting, are constraints that have severely hampered their implementation(Skutsch,1983).

The survival rates in village woodlots are generally lower than for trees planted by the individual household (Nilsson, 1983). The above mentioned organisational and social complications for communally planted woodlots are simply not there, when the individual household is planting the trees. This - among other things - have made some programmes to shift emphasis to family woodlots in trying to enhance people's participation in the implementation (Thompson, 1979,1983). A World Bank project in Niger and a CARE-Uganda Project for Forestry ruled out communal village woodlots for the mentioned reasons (Tapp et al., 1986).

However, relying on the rural housholds to put the treegrowing act together, we have to consider their internal constraints, e.g. in the form of roles between man and woman, land and tree tenure.

4.3 Husband-wife and trees

In many African societies the females, that do most of the work in the agricultural fields, are also the traditional carriers of fuelwood to the homestead. Even in cases where there is plenty of woody biomass around the homestead, the women may have to go far to the common land/ natural forests to get fuelwood for cooking. Studies in Kenya and Tanzania have shown the male household head regards the trees as his property - although planted by the wife - and intends to sell it as a cashcrop (e.g. straight planks from Gre- villea Robusta), (Helmfrid, Persson, 1986; Chavangi, 1985). If the wife from the outset knows that she will not control the use of the produced biomass, it becomes, very likely, a strong disincentive to participate in planting trees.

Another, obvious constraint when a fuelwood project tries to enhance the participation of women, is that they simply do not have time to include this extra activity into their around-the-clock household, agricultural, etc., workload. To get water, feed, shelter and clothe the family, have higher priorities than domestic energy. When looking for alternatives to woodfuel - e.g. paraffin or other sources of energy requiring cash-outlays - the issue of trade-off between time and money is decided by the male household head (Hosier, 1985). The woman decides on fuelwood collection. If she wants to buy fuelwood or other source of energy, the man, who is in the control of the limited financial resources, will take the decision. Time sources (controlled by the women) are greater than monetary resources for the rural household.

4.4 Land and tree tenure

Above, we touched upon an example of women and the right to trees. Depending on local traditions and laws, the clearing of trees or the planting of trees will give the right to use ("own") a certain piece of land. Tree and land tenure many times do not coincide. People may have right to trees and tree products on land which they themselves do not own (Gluckman, 1965; Allan, 1970). The harvest of produce such as fruits, nuts can be seperate from ownership rights. For example, in Ghana, women have the right to use the kernels of palms owned by the men (Fortmann, 1983).

The holders of a right, and the users of a right, regarding trees vary from culture to culture. Any project that does not take careful consideration of these aspects, in project planning, may go very wrong, especially if the woody biomass is supposed to benefit a certain (poor) group in the society concerned by the project.

4.5 Distribution of benefits of woody biomass

Needless to say, woodfuels are subject to local power structures and traditions when it comes to the question of who will benefit from the woody biomass produced. Many studies on rural or urban development schemes have shown how the well-intended ambitions to primarily assist the poorer sections of the society, were aborted by local elites, customary laws, bureaucratic procedures, etc.(e.g. Ostberg, 1987; Cernea, 1981).

Although there are great social obstacles to development programmes, to effectively benefit the rational, risk-minimizing poor (landless) household, some studies indicate that there may be something more to be expected for the poor in tree-projects: Advantages like cheap establishment, quick-growing species, multipurpose and divisibility (a tree can be cut piece by piece, like converting the whole tree to small units of currency depending on current need of cash), and regenerative capacity (coppicing). Seen from the point of view of the poor themselves, the trees are like bank deposits with low initial deposits and high rates of appreciation (Chambers and Leach, 1987).

For smallfarm household in Kenya, in areas with high population density, it has been found that a relatively large part (in comparison to low density areas) - up to a quarter of the farm - is devoted to tree-growing. The basic reason seem to be that a high proportion of the members of the small household, earn cash income off the farm. Because of labour shortages, the smallfarm household then finds that a) tree management - although giving lower returns per hectare than cashcropping - gives higher returns per unit labour, b) tree management has lower initial costs than cash- cropping - thus the need of getting (non- available) credit facilities is less for trees (Arnold, Gregersen and Dewees, 1987).

5. Approaches to promote treegrowing among smallholders

The above list - which is by no means exhaustive - indicates important socio-economic aspects, when assessing the capacity of the smallholder to produce woody biomass. The extremely complex issues involved, varying from one geographical and cultural setting to the other, is usually approached in project formulation with one basic premise: The producers of the woody biomass in the smallholder farm must be involved, and actively participate, in the planning and execution of the woodfuel project.

"Participatory management" is the hallmark of many rural development projects. To involve the local residents is time-consuming, can be costly, but will in the long-run lead to more succesful project. For example, in Niger, the project started after two years of preparatory field work based on discussions with the residents (Taylor and Soumare, 1984). The project was aiming at managing 5000 ha of reserved forests involving the local residents. However, projects are normally started after much shorter time for discussions with the locals - if at all.

The need for devoting a substantial part of the project resources, to the preparatory phase, with local involvement has been highlighted, in an overview of evaluations of various projects in Africa. The more succesful projects spent around half of the project resources to prepare the locals (and thereby the project staff) for the project (Gerden, 1988).

Seeking (research) approaches that fulfill the basic criterias of increased **productivity, sustainability** and **adoptability** required by local socio-economic conditions, the International Council for Research in Agroforestry - ICRAF - has developed an Agroforestry Diagnosis and Design (D&D) methodology. In brief, it diagnoses land management problems and designs agroforestry solutions. D&D is an iterative process where the original diagnosis and implementation is refined, in the light of new information from on-farm research trials, on-station research and extension trials.

Most important is ICRAF's definition of the land use system: A distinctive combination of three interrelated factors: the **land resources** exploited by a particular **technology** to satisfy the production objectives of a particular type of **land user**. The human element carries (equal) weight in the diagnosis, in order to avoid a design that results in technically and environmentally feasible, but socially non-adoptable, agroforestry technologies (Raintree, 1987,a).

The ICRAF-manual for D&D states; "If at first you don't succeed, try and try again". Considering the many social constraints mentioned above, it will take considerable time, trial and error to get the research and development process in the right direction. Involvement of the local farmers in the research and development process, through on farm trials, is a step to guarantee that the result will be relevant, not only to the natural environment.

6. Research approaches visavi smallholders

The D&D approach to expose research needs has a **multidisciplinary diagnosis** of the land use system as a starting point. This approach fits, when looking for avenues of research and development to assist the smallholder in increasing woody biomass production. The technologies and interventions suggested, will likely be integrated with a broad range of activities essential to the smallholder - like grafting a woody biomass component on to non- woodfuel activities.

Although results reached in one area might be applicable to very similar areas, in general **local diversity must be recognized.** With reference to socio-economic conditions described in a previous chapter, problems and solutions are site-specific.

Recognizing that solutions are specific to a certain place, time and groups does not negate the fruitful **sharing of succesful experience** between researchers. With modifications, a certain intervention may work succesfully, also in another area.

Once again, **working through people** will often give the research and development process the best information of real opportunities and constraints.

7. Research needs felt in one Community Forestry Project in Tanzania

The D&D is a methodological tool to assist agroforestry researchers and extension workers to identify relevant research goals and arrive at sound agroforestry recommendations (Raintree, 1987,b). Per definition, it has a farm or a group of farms as a starting point. Recommendations arrived at through D&D, may form one component of national community forestry programmes. Other relevant concerns, in strategies for extension work, will be outlined below. The description of the below strategy and the above mentioned socio- economic conditions for smallholder woodfuel production will give background to suggestions on avenues for future research.

The author is involved in the implementation and evaluation of a Community Forestry Pilot project in certain semi-arid areas in Arusha, Singida and Dodoma regions in northern and central Tanzania. The population living in the areas are mainly agro-pastoralists and some (pure) pastorolist and hunter tribes. After an overall analysis of potentials and constraints (Swedforest, 1986) and subsequent discussions, a strategy for the pilot project was formulated as follows:

A. Decentralisation of nurseries

The aim is to encourage and assist villages, schools, non-governmental organizations, private and government institutions, households and individuals to produce their own seedlings.

B. Treegrowing without the use of nurseries

Trees can many times be more succesfully and economically grown by cuttings, truncheons, wildlings, stumps and direct sowing rather than planting a seedling raised in a nursery.

C. Integration with agriculture, livestock and soil conservation

It is part of the strategy to enhance integration of treegrowing with soil conservation measures, as well as to plant trees together with agricultural crops and for fodder production, on the same piece of land (agro-silvipastoral forestry).

D. Demand-orientated seedling production and distribution

This item, concerns how well the mix of different kinds of seedlings in the central nurseries correspond to the demand of the costumers, and that the seedlings are distributed, planted and tended in such a way that a reasonable survival rate is achieved. The use of indigenous species is promoted.

E. Conservation of existing natural forests

Under this point the project encourages villages with natural forest areas on, or close to,the village land to establish local laws (by-laws) with the aim to achieve sustainable yield. For example, the villagers may cut branches but not whole trees, not burn and restrict grazing. The project is also promoting the establishment of alternative sources of forest products for villages that are close to encroached watershed areas (Catchment Forest Reserves). Attempts have also been made to cooperate with local groups to establish and effectively guard "traditional forest reserves" for circumcission, traditional dances, rainmaking etc.

F. People's participation

Needless to say, the above points can not be succesfully implemented if the extensions foresters do not cooperate fully with the people that the project is supposed to serve. The promotion of rural treegrowing through seminars, demonstrations, in school classes, political meetings etc must be a main activity in the workplans of the extension foresters. The ultimate aim is to have as many households as possible, selfreliant in satisfying their own treerelated needs. We would like to see that the peasant is not only an agriculturalist or a live-stockkeeper but also a household forester.

7.1 Areas where research may promote the project

During the past three years, evaluations have shown that the above pilot project has scored some success for several of the items in the strategy - especially for decentralisation of nurseries. Our evaluations have also pointed out constraints where we feel that further research may lead to more success:

7.1.1 Seeds and the household nursery

Due to transport and other resource constraint the production of seedlings has to be done by many "amateurs". The project has met problems in delivering seeds that fit the small-scale, non-professional production process where improper soil mixes and watering hamper the tree growth. We teach people on how to collect seeds in their own environment for their nurseries, but for further improvment we need the hardy, improved seed, treated to withstand the non-professional production process.

7.1.2 Treegrowing, using cuttings and direct sowing

Cuttings (truncheons) are traditionally used, in many tribes in the project area, to fence in cattle and homesteads. To use cuttings on a larger scale to afforestate is hardly considered, currently. Within the project, efforts are being made to collect information from the elders in the villages on the use of cuttings, in order to assess their potentials for the project.

Besides being indigenous to the local environment, the cuttings have a distinct advantage in comparison to seedlings, as they should be planted during the dry season when the requirement on labour (for agriculture) is low. Thus, they seem fit to the smallholder (women) labour situation. By emphazing the use of cuttings, the project has achieved three planting seasons: one in October - a dry month when the cuttings should be planted to prepare themselves for the short rains in November - December. (If planted during the rains, the cutting will rot.) The second planting season is during the short rains in November - December, when preferably the more drought-resistent species, like Cas- sia Simaea, should be put into ground. The third one is during the long rains in February - April, when all kinds of seedling species may be planted.

Considering the above advantages of cuttings, and the fact that the know-how in the forest research community about cuttings in semi-arid areas is comparitively limited, it seems to present a field of future, possibly very fruitful, research (for the smallholders). Besides descriptive research and classification, there may be options for cloning and genetical manipulations(?).

Direct sowing is another method of growing trees without the use of nurseries. Research aimed at improving seeds, for this way of planting, would assist our project a great deal - especially if the seeds can germinate under dry conditions. A practical example, in this context, was the way of arranging minicatchments to retain moisture, and at the same time reduce the labour requirements in combination of direct sowing, that came out as a result of an agroforestry D&D experiment by ICRAF in Kenya (Raintree, 1987,b).

7.1.3. Livestock and trees

Integration of livestock, (fodder) trees and grazing is an area where the project has, so far, not made much progress. The issues at stake concern basic socio-economic patterns of livelihood for pastoralists and agro-pastora lists and is more complex than just to make propaganda for fodder trees. Starting from the present situation, longterm, realistic, step-by-step improvements to redress growing imbalances regarding over-grazing, etc., should be accompanied by research and sharing of experiences from other areas.

Rotational grazing schemes and the establishment of "grazing forests" have been discussed within the project, but no concept - except trying to extend appreciation of fodder trees in demonstrations, has been tried in the field. IUFRO is welcome to accept (the coordination of) a long-term core research project, aiming at feasible solutions to the woodfuel - livestock - fodder - overgrazing complex in arid and semi-arid lands.

This challenging task has already been tackled in various ways by the people concerned and their governments. One (not sustainable) way is to resort to increased use of agricultural waste and cowdung - another, that the Tanzanian government has used in two instances in a soil conservation project in the central Dodoma region, is to remove the cattle through the use of law, completely, from heavily eroded areas. The areas destocked have shown a remarkable capacity for revegetation (Östberg, 1985).

A study suggested a combination of improved cattle breed, fenced and zero-grazing for the reintroduction of cattle in the reclaimed areas. Crucial factors for a smallholder in such a context are the costs of investing in improved breed and the labour to cut and carry the feed (SUAS, 1987).

7.1.4 Conservation of existing forests

When our project is trying to promote a more sustainable use of existing savannah (miombo) woodlands, the pertinent questions arise: What does the local extension forester advise the villagers, regarding proper silvicultural management of the natural forest of the village? Some of these forests contain precious species of hardwood like blackwood (Dalbergia Melanoxylon) and Mninga (Pterocarpus) and Mvule (Chlorophera Excelsa) and can be regarded as a potential (foreign exchange earning) export crop, by the village. What is the advice, from the forest research community, on proper tending and propagation of these and other important species? Also, in this field, our project would welcome an initiative from IUFRO in further research to assist the smallholder/ village production of woody biomass.

Reference is here again made to the potentials of truncheons/cuttings. For example, Pterocarpus trees have been succesfully produced in the Philippenes using 2 m long branches, which were dipped in a solution of rooting hormone for 24 hours and then directly planted in the field. This system saves the years of delay, normally involved in waiting for a seedling to reach this size. (National Academy of Sciences, 1979.) - Truncheons are also reported to have been succesfully used for Pterocarpus in Kopalapala , Tabora region (Gerdén, 1988).

8. Summary

This paper has tried to describe socio-econo mic potentials and constraints regarding smallholders, who inevitably are going to produce and use a substantial part of the future woody biomass - hopefully in sustainable forms. The smallholders have an essential role to play in supply of woodfuel, to both urban and rural areas. Suggestions are made that IUFRO should take the initiative in (coordinating) research which focuses on the smallholder as a producer of the woody biomass - be it an agriculturalist, agro-pastoralist or pastoralist. In line with a smallholder oriented research in woody biomass for energy, the following suggestions on research tasks are made:

--- to develop models for analysis of social, economical and ecological aspects regarding urban woodfuel supply, from smallholders and large-scale plantations

--- to develop seeds appropriate to smallscale nurseries run by non-professionals, as well as seeds suitable for direct sowing under dry conditions

--- to investigate the potentials of cuttings traditionally used in semi-arid areas as means to increase the production of woody biomass

--- to conduct long-term research seeking sustainable and socially feasible solutions to woodfuel-livestock(over)grazing complex in arid and semi-arid lands

--- to do research on silvicultural management of savannah (miombo) woodland for sustainable increased yield of, for example, precious hardwood species.

The paper emphasised that research approaches focusing on smallholders, should be multi- disciplinary, recognise local diversity, share succesful experiences and be working through the people concerned.

Finally, in the (economic) analysis of woody biomass production programmes, it is not only the financial value of the fuelwood produced that should be counted. In the above forestry research tasks, it is the multi-product approach that is most important: Ecological values and social values (shorter distances to fuelwood) are many times more valuable, than the energy product itself. The value of a preserved common good - like a watershed, a habitat and a soil conserved - or trees on under-utilized waste-lands, and fodder trees, playing a role in the rehabilitation of evergrazed pasture lands, may make forestry schemes very sound investments in many developing countries.

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WHAT CAN ECONOMICS SAY ABOUT SUSTAINABILITY AND BIODIVERSITY?

Dennis P. Bradley and David C. Lothner [1/]

Abstract.--New perspectives on the physical realities of our earth-sun ecosystem may contradict widely accepted beliefs about the possibility for economic development. Because sustained economic growth, as currently defined, may be very unlikely, there is a need to redefine our development goals. As a result, questions of equity must receive more attention. Economics can help evaluate the equity and efficiency of various alternatives for achieving more sustainable societies.

Additional keywords: Entropy, equity, efficiency, opportunity costs, externalities.

On the surface, sustainability and its associated issue, biodiversity, seem to be decidedly noneconomic subjects, presumably dealing with physical or biological factors. But these concerns stem from a growing awareness of the environmental limitations to economic growth and raise profound economic and philosophical questions. As currently defined, sustained economic growth in our closed earth-sun ecosystem may simply not be possible, in the face of rapidly rising population growth and per capita consumption of material and energy.

Assuming that we can agree on a new definition for sustainability, economists can help evaluate the efficiency of alternatives by which it might be achieved, and on the equity of the impacts created by the various alternatives. In this paper we will highlight the characteristics of sustainable systems, describe shortcomings of ongoing research, and suggest some changes that will be necessary before we can develop relevant and rigorous evaluations of more sustainable, equitable, and efficient biomass production systems.

ECONOMIC GROWTH REDEFINED

Economics has been defined as the problem and process of allocating and using limited resources to satisfy potentially unlimited human wants. This definition implies a number of important ideas. First, there are limits on what is possible. Second, these limits imply the possibility of conflicts as well as the need to choose among alternatives. Third, because conflict is dangerous and to be avoided, there is a need to decide what is really desired. As it turns out, sustainability and biodiversity affect the nature of these economic solutions. But what are they and how are they related?

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Sustainability, as applied to human lifestyles, is the characteristic of meeting the needs of current generations without significantly reducing the opportunities of future generations. Of course, this definition raises many questions. More on these later. The goal of biodiversity is to maintain as many species as possible for as long as possible. Indeed, biodiversity may be a necessary condition for achieving a sustainable lifestyle. As we will likely find out, (and we hope, not too late), biodiversity is no luxury!

In addition to our definitions, we must also discuss ultimate ends and ultimate means, if only briefly. The reason we must go this far back is that our difficulty in defining sustainability, and in developing practical guidelines to action are due to what Georgescu-Roegen (1976) describes as "dangerous myths" about the possibilities of economic growth and development. Briefly, he and a few other economists have suggested that a blissful, technology-filled future without economic want is not just unlikely, it is impossible!

Regarding ultimate means--that is, the materials and processes for satisfying human needs--it is perhaps best to contrast two views of the economic world. In one traditional view, the economic process is modeled as a cyclical, unbounded flow of goods and services and productive factors in one direction, and the flow of money in the other--producers on one side, consumers on the other. While Ricardo and Malthus raised the issue of limits to growth early on, most mainstream economists think that our genius for technical solutions can eliminate the problem. If a resource becomes scarce, we can create an even better substitute; if new technology creates problems, we can turn them into opportunities. Under this view, if resources are only what we, ourselves define, then the fundamental economic questions become: (1) How many people do we want to inhabit the earth? (2) At what standard of living? and (3) How fast can we get from "today" to the desired future? Under such a vision, there would be little need for ethics, except in the short run, because the implied infinite supply of everything would eventually eliminate the reason for conflict or a need to choose.

But Georgescu-Roegen and others such as Daly (1977) take a dramatically different view. Instead of an unbounded horizon, they are convinced that the so-called Second Law of Thermodynamics severely restricts the way matter and energy flow in our closed earth-sun system, how they are cycled in a variety of geological and biological processes, and how they are either reradiated to space or somehow change the "equilibrium." In a radical contradiction to the cyclical, unbounded view outlined above, they see a linear, bounded flow of material and energy from an original state of low entropy (concentrated, high-quality energy and other resources) to a state of high entropy (dispersed, inaccessible, low-quality energy and other resources). While technology can improve the efficiency with which matter and energy can be used to meet needs, this conversion of "good" matter-energy into "unusable" matter-energy is irreversible. And while recycling can recover usable material from waste, it must consume even more energy to accomplish this. Most important, as we learn daily, any qualitative or quantitative changes in these flows of matter and energy must take place within the limits of the earth's delicate equilibrium.

Thus, in this linear, bounded view, all economic-ecological processes (with or without man) can be described as "turning good material into waste"! If true, only two questions are possible: (1) How many people? and (2) How wealthy? There is no third degree of freedom. That is, the third question, "How fast can we get there?" is incorrectly worded. Instead we can only passively ask, given our first two answers, "How long can the situation last?" The answer to this third question is imprecisely but categorically determined by the answers to the first two questions. As Georgescu-Roegen further points out, our current views about the practical absence of limits results in equating our real need to "develop and grow" with the erroneous goal of maximizing flows." On the contrary, he suggests that in order to even approach a sustainable future, we must seek to minimize flows, while meeting real, nontrivial needs.

If the linear, bounded model is correct, some pessimists raise the specter of a bleak future filled with deprivation and conflict as the few "haves" and the many "have-nots" vie for control of the earth's limited and necessarily dwindling resources. But this isn't the only possibility. Despite the universe's obvious physical limitations, there is this mysterious thing Georgescu-Roegen calls "...an immaterial flux, the enjoyment of life, whose relation with the entropic transformation of matter-energy is still wrapped in mystery." The sustenance and enjoyment of life doesn't have to mean "two cars in the garage." Indeed, while we undeniably need a minimum of food, clothing, and shelter, pessimists tragically miss the most important of human needs: our mental and spiritual well-being. These are the ultimate ends referred to earlier, not mere goods and services.

In a provocative book, "Finite and Infinite Games; a Vision of Life as Play and Possibility," James P. Carse (1986) classifies all human activity into two games; finite and infinite. Finite games are played to win, thereby stopping play. Infinite games are played to continue the play. The contrast is stark and illuminating. While contemplating the infinite may seem preposterous, especially at a conference about short-rotation forestry, it is important to realize that sustainability is the infinite game Carse is referring to. But playing an infinite game when finite games have been the rule for thousands of years requires some convincing indeed. While sustainability in any absolute sense is impossible, it seems clear that there is much more that can still be achieved.

It is true that the efficient use of resources today is a necessary condition for having any resources left tomorrow. Thus, there is a need for appropriate improved technology. But the fact is, any real concern for tomorrow, which implies equity, necessarily constrains resource use today--thus, the priority of equity over efficiency. That is, the quality and distribution of growth is more important than the quantity and rate of growth. Future generations count, even if they can't possibly count as much as today's. Achieving a sustainable lifestyle therefore requires a more equitable distribution of resources (however that may be defined or accomplished). But as we know all too well, this conflict between "ends" and "means," between efficiency and equity, will not be easily resolved.

EFFICIENCY, EQUITY, AND SUSTAINABILITY

Most people think economics is concerned only with profit and loss--that is, efficiency. Despite some truth in this perception, economics is not obsessed with efficiency to the detriment of culture, human welfare, and other living things. Indeed, welfare economics (or political economics), which considers equity, or the distribution of the benefits and costs, has always been more important than neoclassical or production economics, whose chief aim is efficiency. If it were otherwise, economists would actually be running the world, instead of only thinking they do. It is appropriate that as we meet in China, a country dedicated to achieving greater equity, we attempt to compare the often conflicting goals of equity and efficiency.

Regarding efficiency, production economics has developed complex tools to measure how productive factors should be combined to either meet a practical objective at some minimum cost, or in the absence of constraints (is this even possible?) to maximize some benefit. These productive factors are the biosphere (land, water, plants, animals, and atmosphere), labor, capital, technology, management, and government.

Regarding equity, welfare economics has also developed tools to measure the distribution of costs and benefits. This distribution or sharing can be between individuals, social strata, regions, and nations. But the issue of sustainability necessarily raises two more concerns: biodiversity, which is concerned with preserving an equitable balance among all life forms, and intergenerational sharing, which is concerned with preserving a balance between present and future generations. These balances are currently undefined.

If one accepts the case just made for a different reality of physical, economic, and cultural constraints to at least attempt to play an infinite game, then the way we apply economics must similarly change. While an extensive set of tools for examining efficiency and equity issues has been developed, how they relate to building a sustainable future is unclear. Following are a few suggested characteristics of sustainable systems--there must be others--which relate to some of our existing ideas about economics and culture.

1. <u>Sustainable systems are equitable.</u> Those who <u>get</u> should <u>pay</u>! That is, those who receive the benefits have an obligation to pay as many of the costs as possible. Such systems attempt to ensure that some other existing group or some future generation doesn't pay if they can't share the benefits; to see that all costs are considered including opportunity costs and externalities; and to see that the benefits are essential, as opposed to trivial. Defining what is trivial is sure to be controversial. Yet, the realization that any consumption today probably constrains future consumption in some fashion, demands that we give it serious thought.

Given the assumptions about limited resources or, probably more important, limited waste absorptive and assimilative capacity of the environment, opportunity costs are the tangible or intangible benefits forgone or irretrievably lost because of some action or inaction today. Opportunity costs are unavoidable, yet they must be considered in much greater detail. Burning a gallon of gasoline today means you can't burn it tomorrow. Do the benefits today outweigh a more important need for that gallon tomorrow?

Every action has a variety of consequences, some intended, others not. Externalities are the consequences, both positive and negative, that are unplanned and/or uncounted. Timber management frequently creates wildlife habitat as well as wood. Final harvests frequently cause soil erosion. The first may be a fortunate accident, but the latter may result in the eventual destruction of future forests or wildlife on that land. Externalities, like opportunity costs, are unavoidable but sustainability requires a more accurate accounting.

2. Sustainable systems are efficient. Such systems use plentiful resources as much as possible while carefully husbanding scarce resources. They use the latest appropriate technology, which contributes to the efficiency of resource consumption and the equity of impacts, not just the cost evading technology so frequently seen.

A major concern of efficiency is the comparison of alternatives whose costs and benefits vary in amount and timing. Given life's inherent risks, a dollar today is usually thought to be worth more than the promise of a dollar tomorrow. This is the basic rationale for using an interest rate to compare different streams of benefits and costs over different times. A nominal interest rate consists of (1) a component representing the real possible long-term productivity increase (generally thought to be about 3 to 4 percent), (2) a component reflecting the current inflation rate, and (3) a component reflecting the risks inherent in a specific investment.

Considering only the first component, real long-term growth, some economists have argued that any interest rate above zero percent will eliminate any consideration of the future. If benefits, regardless of their importance, are a long way off, discounting makes them appear trivial. Even worse in some minds, if a popular action today incurs serious costs far in the future, the immediate benefits appear immense, while discounting makes the costs appear irrelevant.

Thus, inappropriate discounting represents a severe obstacle to achieving a more sustainable future. The nature of sustaining investments is frequently the creation of subtle (therefore difficult to appreciate) benefit streams received over very long periods. Conversely, nonsustaining actions, which frequently are based on an exciting new technology, may offer huge immediate gains--but we often learn later, to our regret, that all the costs weren't considered. One approach is to accept the need to discount, but to apply it only to those situations which don't compromise an essential feature of sustainability, such as soil productivity or climate.

3. Sustainable systems are flexible. Such systems can still produce usable benefits in spite of widely varying input quantity and quality. As a result, such systems would be less vulnerable to the expected variation in weather and periodic infestations of insects and disease. Similarly, the products of flexible systems can be used for a variety of needs.

4. Sustainable systems are self-sufficient. A number of features are implied. First, whenever possible, such systems use locally available labor, soil, water, energy, etc. As a result, these systems are less vulnerable to import embargoes of critical factors. Similarly, products should be intended primarily for local consumption, not export, thus making the system investments less vulnerable to export embargoes or competition. These suggestions do not deny the need for trade and all its well-documented economic advantages. Yet, transport has a huge appetite for energy, with all its inherent opportunity

costs and externalities. This property of trade suggests some reconsideration for sustainability's sake.

5. Sustainable systems are integrated. National, regional, or local systems complement each other so that wastes and joint products from one process can be shared or redirected to other systems within the region with minimum disruptions. While increasing entropy is unavoidable, integrated systems can increase materials and energy efficiency.

CURRENT RESEARCH AND FUTURE DIRECTIONS

Equity has been explicitly and implicitly considered in a large number of short rotation intensive culture (SRIC) studies to date. Opportunity cost has been a major focus of these applications. Risk assessment, for example, recognizes that while we all seek to avoid waste and irreversible decisions, we cannot see the future clearly. Thus, we attempt to find strategies which minimize the effects of uncertainty about future needs, costs, and impacts. Hoganson et al. (1987), in an evaluation of SRIC's potential to reduce market uncertainty, considered SRIC's ability to produce wood in less time than conventional forests. Using conventional forest management, investments in land and regeneration must be made now to produce trees in 40 years. With SRIC, however, we could wait another 25 years before sinking these investments. At that time, we may find that our concerns were exaggerated or that some new technology has given us an even better opportunity. Similarly, postponing investments would eliminate the carrying costs for 25 year's worth of conventional forest inventory. Thus, SRIC would reduce the irreversible commitment of scarce resources--i.e., opportunity costs.

A related study by Hoganson and Lothner (1987) examined the use of SRIC in a forest-wide context. The problem was an existing forest with a large future potential but a currently imbalanced age-class distribution. This age imbalance would mean widely varying future outputs--an important equity issue. They showed that if SRIC material is a substitute for conventional trees, then SRIC would be a cost-efficient way to stabilize annual wood flows.

Several studies have examined the regional impacts of wood energy development based on SRIC. Lichty et al. (1987) used an input-output model to estimate the intersectoral changes resulting from the introduction of locally produced energy and the reduction of fossil fuel imports. As expected, the benefits to the region were increased employment, income, and cost savings. However, these benefits were obtained at the expense of the local fossil fuel importers as well as the fossil fuel producing regions. The analysis doesn't indicate whether society, in total, is any better off. A new approach has been suggested by Lichty and Bradley (1987) based on a social accounts matrix being developed by Alward (1986) to examine the tradeoffs between different groups within the region due to SRIC investments. In this proposed effort, SRIC would be used to replace some existing soil erosion prevention efforts and some farm crop price supports. Again, the impacts of these alternatives on different groups in the region--an important equity issue--would be addressed.

However, many equity issues have not been considered in SRIC studies to date. For example, the whole idea of SRIC is modeled after agronomic principles like those used to achieve the "green revolution." Agronomists take great pride in this example of what technology can accomplish. But there are several concerns about its sustainability and widespread applicability. These new systems, SRIC included, often require much water and energy, and extensive use of fertilizer, pesticides, and herbicides. There may be other problems. The long-term effects of these practices is precisely what sustainability is about.

The efficiency of SRIC has been its most highly studied feature. Many studies have examined the inputs and outputs of SRIC systems in an attempt to determine their economic potential as well as to identify various constraints on their eventual success (Colletti and Gan 1987, Parikka 1987, Ranney et al. 1987). However, related to our discussion about equity, the nature of the costs and benefits used in these efficiency analyses needs more detailed study. As we know, many inputs (e.g., air, water, soil) have been taken for granted at an assumed zero imputed cost. In addition, many suspected externalities have not been internalized.

A more serious problem for efficiency analyses is the evaluation of "values" not traded in a market. Returning briefly to the cyclical image of producers and consumers mentioned above, which we don't want to abandon completely, an efficient process is supposed to turn out commodities for people by using people (and other factors) efficiently. While using people doesn't necessarily imply exploitation, being useful and performing useful interesting work is a basic human need! But how should this value be considered in an efficiency analysis? Are systems which don't make people feel useful exploitive? Are they sustainable? Efficiency can only help decide how to do something, not what should be done, or why.

So far we have outlined a few characteristics of what sustainable systems should look like. But a number of tasks remain. First, scientists must learn far more about the natural and man-made processes that affect our lives. Many of these are the clearly important ones, such as climate, agriculture, and nuclear power; others haven't even been imagined but may play pivotal roles in our lives at some point. These processes (or production functions, as economists call them) must be better understood before economists can help analyze the costs, benefits, externalities, and all the other interactions.

Considering the great uncertainty about resource use and ecosystem interactions, complex modeling of some sort will be required. Despite serious problems with even the simplest models, such as the much-maligned Club of Rome report (Meadows et al. 1972), there seems to be no other method for systematically anticipating the future. A serious problem, has arisen from unreasonable public expectations for model accuracy and prediction brought on in part by exaggerated claims and expectations of some scientists. When hopes are dashed, the overreaction is often bitter, and makes progress even less likely. This scientific wishful thinking, while understandable, must be replaced with more patience. Ambiguity will simply not go away; we must learn to live with it.

Second, for centuries welfare economics has considered how costs and benefits should be distributed among and between human generations as well as between other living things. But these questions involve far more than economics as a science. The so-called value or normative questions referred to earlier are philosophical issues. One measure of a society's long-term potential for success would seem to be its accommodation to the underlying physical and natural reality. Of course, scientists are changing this reality daily. If part of our current difficulty lies in our incorrect perceptions of economic and physical reality, as suggested above, then facing this new reality is a necessary first step in developing new values.

Third, while the physical and value questions are formidable, sociological issues may be more difficult. What characteristics do sustainable societies exhibit? To the extent that our problems with addressing sustainability result from cultural blinders to reality, understanding these cultural factors is another important step.

One possibility is to develop an experimental approach to the engineering of new institutions. While we all recognize the need to develop new technology, and experiments to verify our designs, we have missed a similar opportunity with institutions. Considering the speed with which some of our apparently unsustainable production systems seem to be affecting our world for the worse, we may no longer have the luxury of waiting for our institutions to catch up. Thus, there is a sixth characteristic of sustainable systems which should be emphasized.

6. <u>Sustainable systems and society's institutions are consistent.</u> Achieving sustainability will probably require dramatic changes in our social and political institutions, and this is a great obstacle. New institutions will be required to (1) educate people about the need for new attitudes toward growth, (2) collectively determine the direction for change, (3) collectively develop the traditions and motivations to maintain these changes, and (4) construct the new social and technological machinery to achieve these goals.

SUMMARY

In a sense, taking Sustainability into account requires perspectives no different from those already employed in any economic analysis. However, due to the unavoidable and urgent reality of constraints on resource flows and environmental absorptive capacity, equity and its focus on opportunity costs and externalites must be given greater attention. Considering existing uncertainty about resource use and ecosystem interactions, complex modeling of some sort will be required. Despite serious problems with models, there are no apparent alternatives for anticipating the future. But even more crucial and difficult than the technical and economic problems are the sociological and philosophical issues that must be addressed. It remains to be seen whether these new institutions and traditions will require more from humans than they can give. Let's hope that sustainability, individual freedom, and achieving human potential are not contradictions. But this game, whether finite or infinite, is the only one in town.

Because China seems to be straddling an "agrarian past" and a "technological future," it is fitting that we meet in Beijing to discuss sustainability. Many Western economists have argued that efficient, technological, market-driven solutions are the key to economic growth and development. That these have their place cannot be denied; China's experiments will no doubt confirm what the West has amply demonstrated. But from the above discussion, it seems that a culture such as China's, grounded in the tradition of the land and its seasonal rhythms, and an enhanced sense of equity, has the more flexible, sustainable perspective for the long-term. Perhaps China's long history can reteach the required humility toward nature and a realistic appreciation of the limits to "growth" that modern technological society seems to be losing. We hope China never loses sight of this truth, and in the process keeps equity a true partner with efficiency in achieving a sustainable future.

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ENERGY POTENTIALS OF WOODY BIOMASS, AND WASTE MATERIALS FROM ANIMALS, INDUSTRIES OR CITIES IN SOUTH KOREA

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Abstract

Rapid industrialization in Korea calls a rapid increase in energy consumption oil being totally imported and being used as a major source for energy in Korea, is unstable for supply. Therefore, the development of alternative energy source is urgently needed.

Biomass defined as an organic matter produced through photosynthesis is effective and renewable resource of solar energy. It is one of the most promising resources. Biomass producers were divided into four sectors; forestry, agriculture, livestocks, and municipal and industrial wastes.

The aims of this research were 1) to investigate the present amount of biomass, utilizable biomass and biomass being used for energy in each sector, and 2) to analyze the trend of its change during the last five years.

The present amount of biomass, utilizable biomass and biomass being used in forestry sector were 9266.9 $\times 10^{11}$Kcal, 343.3 $\times 10^{11}$Kcal and 216.7 $\times 10^{11}$Kcal in caloric value, respectively. Those in agricultural sector were 408.8 $\times 10^{11}$Kcal, 107.3 $\times 10^{11}$Kcal and 98.9 $\times 10^{11}$Kcal, respectively. The present amount of biomass and utilizable biomass in livestocks sector were 116.0 $\times 10^{11}$Kcal and 43.7 $\times 10^{11}$Kcal. This biomass increases rapidly with increasing consumption of meat and milk product and large raising scale, and should be actively utilized not only because

of an alternative energy source but because of reduction in water pollution.

The present amount of biomass, utilizable biomass and biomass being used in municipal and industrial wastes sector were 2522.0 $\times 10^{11}$Kcal, 252.0 $\times 10^{11}$Kcal and 29.2 $\times 10^{11}$Kcal, respectively. The amount of municipal waste, sewage and excretions will increase with increasing living standard, population and urbanization.

Potential ethanol yield from fibrous biomass would be 38.6 $\times 10^{6}$Kl for the present amount of biomass, 2.3 $\times 10^{6}$Kl for utilizable biomass and 1.8 $\times 10^{6}$Kl for biomass being used.

Converting total present amount of biomass, total utilizable biomass and total biomass being used into oil equivalence(M/T), These showed 164.5%, 12.2% and 5.6%, respectively to the total oil consumption in 1986. Thus 6.6% being now unused, can be more utilized by an active plan in the future. In addition, because of limitation and unstable supply of oil in Korea, a promising way of producing biomass is a short-rotation intensive culture system with rapid growing woody species.

I. Introduction

Korea, one of Newly Industrializing Countries needs a great amount of energy source to accelerate rapid industrialization, and the major energy source is oil, which is totally imported. The total reserves of oil on the earth, however, are limited; it is a fossil fuel and its supply is unstable due to the Organization of Petroleum Exporting Countries' stratigic control on its production. Under this situation, thus the development of alternative energy source is urgently needed to ensure a continuous and stable supply of energy.

Biomass products are promising for energy in Korea because of the certainty in production renewability, safety from pollution in processing, and a great help to the development of other industries. The amount of organic matter being fixed per year on the earth is 1.6 $\times 10^{11}$M/T, of which two-third came from land plants. The annual food consumption by human in the world is about 3.7 $\times 10^{15}$Kcal, which is only 1.4% of the solar energy(2.6 × 10^{17}Kcal) used by plants.

Practically, biomass could be produced from the following four sectors in South Korea; forestry, agriculture, livestocks, and municipal and industrial wastes.

Recently, some studies on biomass production from each sector were reported in Korea. Lee et al(1980) suggested the possibility of some high biomass producing species as an alternative energy sourec. Lee(1984), Yim et al(1981), and Chang(1984) reported the status and prospect of biomass products and uses for energy, and the Korea Advanced Institute of Science and Technology (KAIST, 1981) proposed a synthetic strategy for the development of biomass and bioenergy. Forest biomass production were studied with high biomass producing woody species such as Pinus rigida, Robinia pseudoacacia, Pinus Koraiensis, and Populus. Lee(1984) presented the status of forest biomass resources and its developmental strategy. Korea Institute of Energy and Resourecs(KIER, 1982) also reported a utilization policy for agricultural and forestry by-products as an energy source. Althouth studies on the biomass production in forestry and agricultural sector have been active, those in sectors of livestocks, municipal waste and excretions, and organic materials from industries have been rare. The present status of the scrapped materials from livestocks and manufacturing industries, and the techniques for their utilization was only reported by KIER (1985). Until now, however, the simple method of surveying biomass resources has not been developed systematically, and most of the methods have been much time consuming and costly.

In this study, the data used to estimate the amount of biomass products from each sector could be collected readily from the associated statistical Yearbooks and published reports. The method of estimating biomass is the simply revised technique based on the existing methods.

The aims of this study were to investigate the present amount of biomass, utilizable biomass, and biomass being used for energy for each sector and to compare the trend of those amounts during the recent five-year period 1982-1986.

II. Mehtods for biomass estimation (in each sector)

A. Forestry sector

This sector could be divided into two subsectors such as forestry and forest products.

1.Forestry subsector

a. Present amount of biomass

Its estimation was based on data of stem volume with bark, branch volume, leaves, sapling, forest for fuel, weed on forest floor, calculated or presented in Forestry Statistics[3] or in other published reports.[4,8]

b. Utilizable biomass

It was divided into three parts according to its origin ; residues after cutting, fuelwood harvested, and debris from various silvicultural practices, which were also calculated on the base of the published literature and reports.

c. Biomass being used

Fuel products from forests presented in Forest Statistics[3] were considered as biomass being used. The fuel products were into four parts ; firewood, charcoal, leaves and branches and others.

2. Forest products subsector

a. Present amount of biomass

KIER(1982) selected the representative five types of wood processing industries which produce lumber, plywood, furniture, musical instrument, and pulps. KIER also classified wood waste from these industries into sawdust, slabs, planing refuse, side-splits from whole logs, residues from veneer and plywood, and others, and reported the ratios of those parts to total amount of logs processed. These ratios were adopted to calculate the present amount of biomass in forest products subsector.

b. Utilizable biomass and biomass being used.

According to the report published by KIER(1982), the wood wastes from wood processing industries are mostly utilizable for various purposes and 85.1% of them has been utilized as an energy source. Therefore, this porting was considered both utilizable biomass and biomass being used.

B. Agricultural sector

Estimation was based on the data from Statistical Yearbook of Agriculture, Forestry and Fisheries

1. Present amount of biomass

It generally consisted of by-products from rice, barley, potato, pulse, special crops, other crops, and fruit trees. Except for the amount from rice which was presented in the Yearbook, those of other by-products were estimated such that the total planting area for each crop presented in the Yearbook was multiplied by the amount of its by-products from unit planting area.

2. Utilizable biomass and biomass being used

These were divided into hull and others.

a. Hull

According to the report of KIER, 21.5% of hull was used as fuel and also considered both biomass being used and utilizable biomass.

b. Others

KIER[8] reported that agricultural by-products except for hull were utilized for manure(48.3%), feed(22.0%), fuel (24.5%), sale(2.2%), disuse(0.7%), and others(2.3%). Of them, utilizable biomass was 25.2% composed of fuel(24.5%) and disuse(0.7%), and biomass being used as an energy source was 24.5% for fuel.

C. Livestocks sector

Biomass from this sector consists of mostly domestic animal's excretions, which are concentrated organic matters, so that methane gas could be generated from the fermentation process. The estimated amount based on the data presented in Statistical Yearbook of Agriculture Forestry and Fisheries.

1. Present amount of biomass

Typical domestic animals in South Korea are Korean cows, milk cows, pigs, and chickens. The amount for each of the domestic animal's excretion, the proportion of organic matter in the excreted amount, and the amount of methane gas generated from unit organic matter weight, could be used to estimate the present amount of biomass. This amount was calculated from the multiplication of these three kinds of excretions by the total number of each domestic animal.

2.Utilizable biomass and biomass being used

According to the report of KIER[7], the minimum number of livestocks raising for the resonable utilization of their excretions, requires 20 for cows, 50 for pigs, and 1000 for chickens. The amount of excretions from domestic animals included in these raising scales was, considered as utilizable biomass. However, domeseic animal's excretions were hardly utilized as an energy source

D. Municipal and industrial waste sector

The biomass amount in this sector could be divided into municipal, waste, living sewage and excretions, and organic industrial waste materials.

1. Municipal waste

a. Present amount of biomass

According to the annual reports by Environment Administration, municipal waste could be classified into combustible, incombustible, and reusable things. Of them, amount of combustible waste was considered the present amount of biomass for energy source.

b. Utilizable biomass and biomass being used

The amount of utilizable biomass would be equivalent to the present amount of biomass. There are three methods such as reclamation, incineration and reuse for treatment of garbage. The waste to be incinerated as fuel, could be estimated as the biomass being used.

2. Living sewage and excretions

The amount of sewage and excretions which can be treated by existing or planned facilities, was regarded as the present amount or the utilizable biomass, because those could generate methane gas as an energy source. The amount which has been treated by existing facilities was considered the biomass being used.

3. Organic waste matrials from industries

These industries are those which produce alcohol, beer, pulp, glutamine, orange, etc. The portion recovered among the waste produced from these industries was regarded as the present amount or the utilizable biomass. Only alcohol producing industry, however, has the recovery facilities, so that the amount of treated waste was in these industry was considered the biomass being used.

E. Biomass conversion to heating value

In forestry and agricultural sectors, the amount per either volume or air dry weight unit, was converted to that per oven dry weight unit. To calculate total heating value(Kcal) for each part or crop, its total oven dry weight was multiplied with its own caloric value per a unit oven dry weight. In livestocks sector and municipal and industrial waste sector, the biomass presented with volume of methane gas was converted to heating value by the multiplication with the coloric value of unit volume of methane gas. Heating values were also coverted to oil equivalent quantities with caloric value per a unit oil weight.

III The present status and future prospect of biomass

A. Forestry sector

1. The present status

a. Present amount of biomass

Data from Forestry Statistics[3] used in estimating the present amount of biomass are shown in Table 1. Generally, mean growing stock steadly increased with increasing years. In 1986, it was about $30m^3$/ha, and total growing stock was calculated to be about 0.2 billion m^3.

Table 1. General information on forestry, fuel production and log consumption in Korea.

Year	Mean stock (m^3/ha)	Stocking (10^3m^3)				Forest Area (10^3 ha)			
		Total	Conifers	Broad-leaved	Mixed	Total	Conifers	Broad-leaved	Mixed
1986	29.57	192,931	89,583	50,923	52,424	6,524	3,270	1,182	1,831
1985	29.47	179,309	81,849	49,331	48,201	6,531	3,281	1,158	1,823
1984	26.29	171,946	78,254	47,616	46,076	6,540	3,280	1,161	1,832
1983	25.10	164,362	74,730	45,640	43,992	6,547	3,274	1,157	1,847
1982	24.07	157,756	71,535	44,066	42,155	6,554	3,260	1,158	1,860

Year	Area of practice (10^3 ha)	Log harvest (10^3m^3)	Fuel (M/T)					Log consumption (10^3 m^3)
			Total	Firewood	Char-coal	Branch & leaves	Others	
1986	4,728	1,105	2,816,419	280,285	1,650	1,927,742	606,742	7,014
1985	5,073	1,067	3,108,864	268,528	728	2,333,696	577,912	6,766
1984	5,083	1,029	3,989,732	259,134	1,595	2,392,091	1,336,962	6,891
1983	4,862	1,137	4,403,768	260,597	1,133	2,524,765	1,617,273	7,625
1982	4,986	1,205	4,342,770	172,025	4,466	2,411,767	1,754,512	6,772

On the other hand, forest land area gradually decreased due to its conversion into housing construction, or pasture establishment. Timber production and log consumption have been irregulary changed. Fuel production from forests decreased rapidly. The present amount of biomass in forestry subsector estimated from these statistics is shown in Table 2. In 1986, the total amount was estimated to be 192.26 × 10^6 M/T in oven dry weight(9115.8 × 10" Kcal in heating value). Stems without bark occupied 47.9% of the total amount, and branches, saplings and barks did 17.2%, 10.7% and 7.5%, respectively. Sapling stocking was not annually measured and not expected to change during the five years. Thus statistics presented in Forest Inventory Report(1981) was used for its biomass estimation without revision. Biomass of weed did not increase because most of it were annual herbs. However, most of the forest biomass parts continuously increased with increasing years. The present biomass in forestry subsector was absolutely greater than that in forest products subsector (Table 5).

Table 2. Present biomass for each part in forestry subsector.

	Year	Stems	Branches	Barks	Leaves	Saplings	Fuel forest	Weed	Total
Oven dry weight (10^6M/T)	1986	92.14 (47.92)*	33.02 (17.17)	14.47 (7.53)	6.24 (3.25)	20.57 (10.70)	12.78 (6.65)	13.05 (6.79)	192.26 (100)
	1985	86.12 (47.24)	30.90 (16.95)	13.56 (7.44)	6.22 (3.41)	20.57 (11.28)	11.87 (6.51)	13.06 (7.16)	182.29 (100)
	1984	82.62 (46.81)	29.65 (16.80)	13.01 (7.37)	6.23 (3.53)	20.57 (11.65)	11.36 (6.44)	13.08 (7.41)	176.51 (100)
	1983	79.00 (46.32)	28.35 (16.62)	12.45 (7.30)	6.23 (3.65)	20.57 (12.06)	10.85 (6.44)	13.09 (7.68)	170.54 (100)
	1982	75.89 (45.90)	27.24 (16.48)	11.96 (7.23)	6.18 (3.74)	20.57 (12.44)	10.40 (6.29)	13.11 (7.93)	165.34 (100)
Caloric value (10"Kcal)	1986	4,477.0 (48.90)	1,601.0 (17.49)	701.4 (7.66)	305.0 (3.33)	1,0226 (11.17)	553.8 (6.50)	495.0 (5.41)	9,155.8 (100)
	1985	4,181.6 (48.22)	1,497.3 (17.27)	656.4 (7.55)	303.8 (3.50)	1,0226 (11.79)	514.4 (5.93)	495.6 (5.72)	8,671.8 (100)
	1984	4,011.3 (47.79)	1,436.7 (17.12)	629.9 (7.50)	304.3 (3.63)	1,022.6 (11.28)	492.3 (5.87)	496.2 (5.91)	8,393.4 (100)
	1983	3,835.5 (47.32)	1,373.8 (16.95)	602.4 (7.43)	304.5 (3.76)	1,022.6 (12.62)	470.0 (5.80)	496.8 (6.13)	8,105.6 (100)
	1982	3,683.9 (46.90)	1,319.7 (16.80)	578.7 (7.37)	302.0 (3.84)	1,022.6 (13.02)	450.8 (5.74)	497.3 (6.33)	7,855.0 (100)

* Numbers in parenthesis indicate percentage to total biomass.

b. Utilizable biomass and biomass being used

Of the present amount, the utilizable biomass was estimated to be 7.85 x 10^6M/T in oven dry weight(343.3 x 10"Kcal in heating value) which is about 4.03% (3.70% in heating value) of total present amount. For utilizable biomass by its origin(Table 3), forest products subsector consisted of 27% and forestry subsector did of 73% ; 44% in by-products from reforestation and tending practice, 27% in fuelwood harvest and 2% in residues after cutting The biomass being used in forestry and forest products subsectors(Table 4) was estimated to be 4.93 x 10^6M/T in oven dry weight(216.7 x 10" Kcal in heating value), which occupied about 2.53% in oven dry weight(2.34% in heating value) of the present amount, and 62.80% in oven dry weight(63.12% in heating value) of the utilizable biomass. According to its origin, biomass being used in forestry subsector decreased rapidly with increacing years, but did not change in forest products subsector. Therefore, the

Table 3. Utilizable biomass for each part in forestry sector.

	Year	Residues after cuttings	Fuelwood harvest	By-products from reforestation & tending practice	Waste from wood processing	Total
Oven dry weight (10^6 M/T)	1986	0.15(1.89)*	2.16(27.56)	3.43(43.69)	2.11(26.87)	7.85(100)
	1985	0.14(1.74)	2.16(26.98)	3.68(45.90)	2.03(25.38)	8.01(100)
	1984	0.14(1.88)	2.16(26.83)	3.69(45.74)	2.07(25.70)	8.06(100)
	1983	0.15(1.88)	2.16(26.58)	3.52(43.33)	2.29(28.18)	8.14(100)
	1982	0.16(2.14)	1.74(23.04)	3.62(47.86)	2.04(26.96)	7.53(100)
Caloric value (10"Kcal)	1986	6.4(1.88)	93.7(27.30)	148.6(43.28)	94.6(27.55)	343.3(100)
	1985	6.0(1.88)	93.7(26.75)	159.4(45.50)	91.2(26.04)	350.3(100)
	1984	6.0(1.70)	93.7(26.59)	159.7(45.34)	92.9(26.37)	352.3(100)
	1983	6.6(1.86)	93.7(26.33)	152.8(42.93)	102.8(28.89)	355.9(100)
	1982	7.0(2.12)	75.4(22.82)	156.7(47.42)	91.3(27.63)	330.4(100)

* Numbers in parenthesis indicate percentage to total biomass.

Table 4. Biomass being used for each subsector in forestry sector.

	Year	Forestry subsector	Forest products subsector	Total
Oven dry weight (10^6 M/T)	1986	2.82(57.19)*	2.11(42.81)	4.93
	1985	3.18(61.00)	2.03(39.00)	5.22
	1984	3.99(65.83)	2.07(34.17)	6.06
	1983	4.04(65.77)	2.29(34.23)	6.70
	1982	4.34(68.08)	2.04(31.92)	6.38
Caloric Value (10"Kcal)	1986	122.1(56.35)	94.6(43.65)	216.6
	1985	137.9(60.18)	91.2(39.82)	229.1
	1984	172.9(65.05)	92.9(34.95)	265.8
	1983	190.9(64.99)	102.8(35.01)	293.7
	1982	188.2(67.34)	91.3(32.66)	279.5

* Numbers in parenthesis indicate percentage to total biomass.

component ratio for biomass being used in forestry and forest products subsectors changed from 68:32 in 1982 to 57:43 in 1986. The reason for decrease in biomass being used from forestry subsector was ascribed to less fuel collection from forests at rural areas and easy purchase of such other fuel sources as molded coal, gas, or oil.

2. The future prospect

During the last five years(1982-1986), the present amount of biomass increased steadily, the utilizable biomass showed no variation, but the biomass being used decreased steadily(Table 5). This change was due primarily to that of biomass in forestry subsector. The reason for decrease of biomass being used in forestry subsector was originated from wage increase. Thus this trend will continue to show for coming years. In forest products subsector, the biomass being used will not increase greatly because of little domestic use of end-products.

Table 5. Present biomass, utilizable biomass and biomass being used in forestry subsector and forest products subsector.

	Year	Forestry subsector		Forest products subsector		Total	
		Weight (10^6 M/T)	Calory (10" Kcal)	Weight (10^6 M/T)	Calory (10" Kcal)	Weight (10^6 M/T)	Calory (10" Kcal)
Present biomass	1986	192.26(98.72)*	9,155.8(98.80)	2.49(1.28)	111.1(1.20)	194.75(100)	9,266.9(100)
	1985	182.28(98.71)	8,671.8(98.78)	2.39(1.23)	107.2(1.22)	184.66(100)	8,779.0(100)
	1984	176.51(98.64)	8,393.4(98.72)	2.43(1.36)	109.2(1.28)	178.94(100)	8,502.6(100)
	1983	170.54(98.45)	8,105.5(98.53)	2.69(1.55)	120.8(1.47)	173.23(100)	8,226.4(100)
	1982	165.34(98.58)	7,855.0(98.65)	2.39(1.42)	107.3(1.35)	167.73(100)	7,962.3(100)
Utilizable biomass	1986	5.74(73.12)	248.7(72.44)	2.11(28.68)	94.6(27.56)	7.85(100)	343.3(100)
	1985	5.78(74.01)	259.1(73.97)	2.03(26.88)	91.2(26.03)	7.81(100)	350.3(100)
	1984	5.99(74.32)	259.4(73.63)	2.07(25.68)	92.9(26.37)	8.06(100)	352.3(100)
	1983	5.84(71.83)	253.1(71.12)	2.29(28.17)	102.8(28.88)	8.13(100)	355.9(100)
	1982	5.47(72.84)	239.1(72.37)	2.04(27.16)	91.3(27.63)	7.51(100)	330.4(100)
Biomass being used	1986	2.82(57.20)	122.1(56.35)	2.11(42.80)	94.6(43.65)	4.93(100)	216.7(100)
	1985	3.18(61.04)	137.9(60.19)	2.03(38.96)	91.2(39.81)	5.21(100)	229.1(100)
	1984	3.99(65.84)	172.9(65.05)	2.07(34.16)	92.9(34.95)	6.06(100)	265.8(100)
	1983	4.40(65.77)	190.9(65.00)	2.29(34.23)	102.8(35.00)	6.69(100)	293.7(100)
	1982	4.34(68.03)	188.2(67.33)	2.04(31.97)	91.3(32.67)	6.38(100)	279.5(100)

* Numbers in parenthesis indicate percentage to total biomass.

Forest biomass, however, is renewable and shows high potentials for its products, and forest land in South Korea occupies about 67% of its total land area. Therefore, active biomass production system such as short-rotation intensive culture with fast-growing woody species should be practised to be free from future energy crisis.

B. Agricultural sector

1.The present status

a. Present amount of biomass

The present amount of fibrous agricultural by-products was estimated to be 11.42 x 10^6 M/T in oven dry weight (408.78 x 10" Kcal) in 1986(Table 6). By-products from rice plants such as straw and hull occupied 77.3% in oven dry weight (74.3% in heating value) and those from barley, fruit trees, pulse did 5.0%, 4.1% and 3.5% in oven dry weight(5.8%, 5.0%, and 4.0% in heating value), respectively. Those from other crops occupied more or less than 2.0%. Therefore, the planting area of rice and its productions influenced largely the biomass production in agricultural sector.

Table 6. Present biomass from each of crops in agricultural sector.

	Year	Rice	Barley	Potato	Misce-lloneous crops	Pulse	Special crops	Others	Fruit trees	Total
Oven dry weight (10^6 M/T)	1986	8.822 (77.26)*	0.574 (5.03)	0.206 (1.80)	0.220 (1.93)	0.399 (3.49)	0.225 (1.97)	0.501 (4.39)	0.472 (4.13)	11.419 (100)
	1985	8.632 (75.88)	0.721 (6.34)	0.236 (2.07)	0.234 (2.06)	0.438 (3.85)	0.190 (1.67)	0.468 (4.11)	0.459 (4.03)	11.376 (100)
	1984	9.076 (74.39)	1.018 (8.34)	0.261 (2.14)	0.270 (2.21)	0.524 (4.29)	0.186 (1.52)	0.414 (3.39)	0.453 (3.71)	12.201 (100)
	1983	8.503 (72.57)	1.020 (8.71)	0.300 (2.56)	0.250 (2.13)	0.517 (4.41)	0.196 (1.67)	0.481 (4.11)	0.449 (3.83)	11.717 (100)
	1982	8.140 (71.77)	0.987 (8.7)	0.322 (2.84)	0.283 (2.50)	0.535 (4.72)	0.186 (1.64)	0.455 (4.01)	0.435 (3.84)	11.341 (100)
Caloric value (10" Kcal)	1986	303.850 (74.33)	23.501 (5.75)	7.932 (1.94)	8.946 (2.19)	16.227 (3.97)	8.646 (2.12)	19.304 (4.72)	20.375 (4.98)	408.782 (100)
	1985	297.352 (72.81)	29.512 (7.23)	9.073 (2.22)	9.514 (2.33)	17.804 (4.36)	7.299 (1.79)	18.029 (4.41)	19.833 (4.86)	408.417 (100)
	1984	312.549 (71.16)	41.693 (9.49)	10.036 (2.28)	10.983 (2.50)	21.309 (4.85)	7.148 (1.63)	15.950 (3.63)	19.562 (4.45)	439.229 (100)
	1983	292.846 (69.28)	41.627 (9.85)	11.565 (2.74)	10.174 (2.41)	21.035 (4.98)	7.528 (1.78)	18.525 (4.38)	19.409 (4.59)	422.709 (100)
	1982	280.34 (68.43)	40.301 (9.84)	12.406 (3.03)	11.446 (2.79)	21.750 (5.31)	7.146 (1.74)	17.510 (4.27)	18.781 (4.58)	409.679 (100)

* Numbers in parenthesis indicate percentage to total biomass.

In the last five years(1982-1986), the total present amount of biomass in agricultural sector was hardly changed. By-products from rice plants did not change in its absolute amount, but its component ratio increased slowly. However, those from barley decreased in absolute amount and component ratio in relation to decrease in its consumption and planting area. By-products of potato and micellouneous crop also decreased in their absolute amount and component ratios. However, those from fruit trees increased because of increase in fruits consumption in relation to rise in national living standard.

b. Utilizable biomass and biomass being used

The utilizable biomass in 1986 was estimated to be 2.84 × 10^6 M/T(101.45 × 10" Kcal) which indicated 24.8% of the total present amount(Table 7). Hull from rice occupied 9% of the total utilizable biomass, while by-products of other crops and fruit trees did 91%.

The biomass being used was estimated to be 2.76 × 10^6 M/T(98.89 × 10" kcal), which showed 96.8% of the utilizable biomass

Table 7. Utilizable biomass and biomass being used in agricultural sector.

	Year	Hull		Others		Total	
		Weight (10^6 M/T)	Calory (10"Kcal)	Weight (10^6M/T)	Calory (10"Kcal)	Weight (10^6M/T)	Calory (10"Kcal)
Utilizable biomass	1986	0.251(8.85)*	9.067(8.94)	2.584(91.15)	92.385(91.55)	2.835(100)	101.452(100)
	1985	0.252(8.92)	9.077(8.96)	2.572(91.08)	92.258(91.52)	2.824(100)	101.355(100)
	1984	0.254(8.38)	9.188(8.42)	2.779(91.62)	99.916(92.04)	3.031(100)	109.104(100)
	1983	0.242(8.31)	8.739(8.32)	2.669(91.69)	96.280(92.14)	2.911(100)	105.073(100)
	1982	0.231(8.20)	8.368(8.22)	2.587(91.80)	93.430(92.23)	2.818(100)	101.798(100)
Biomass being used	1986	0.251(9.08)	9.067(9.17)	2.512(90.92)	89.819(90.83)	2.763(100)	98.886(100)
	1985	0.252(9.16)	9.097(9.21)	2.501(90.84)	89.695(90.79)	2.752(100)	98.793(100)
	1984	0.254(8.60)	9.188(8.64)	2.700(91.40)	97.141(91.36)	2.954(100)	106.329(100)
	1983	0.242(8.53)	8.739(8.54)	2.595(91.47)	93.606(91.46)	2.837(100)	102.344(100)
	1982	0.231(8.41)	8.368(8.44)	2.515(91.59)	90.835(91.56)	2.746(100)	99.204(100)

* Numbers in parenthesis indicate percentage to total biomass.

2. The future prospect

The present amount of biomass in agricultural sector dependent on total crop planting area and rice productions was not expected to change without any significant land reclamation. However, the utilizable biomass and the biomass being used are expected to decrease because of increase in diverse fuel sources the at rural areas and rice straw utilitation for feed.

C. Livestockes sector

1. The present status

a. Present amount of biomass

It was estimated to be 1933 x 10^6 m^3 in methane gas (116 x 10"Kcal) in 1986 (Table 8). The biomass excreted from Korean cows occupied 48.8%, and those of pigs, chickens, and milk cows did 21.1%, 18.7% and 11.3%, respectively.

Table 8. Present biomass in livestocks sector.

	Year	Korean cows	Milk cows	Pigs	Chickens	Total
Methane gas volume (10^6 m^3)	1986	944(48.8)*	219(11.3)	408(21.1)	362(18.7)	1933(100)
	1985	1056(54.7)	198(10.3)	347(18.0)	329(17.0)	1930(100)
	1984	990(54.4)	170(9.3)	360(19.8)	300(16.5)	1820(100)
	1983	845(48.3)	139(7.9)	449(25.6)	318(18.2)	1751(100)
	1982	511(42.5)	116(9.7)	274(22.8)	300(25.0)	1201(100)
Caloric value (10"Kcal)	1986	56.64	13.14	24.48	21.72	115.98
	1985	63.36	11.88	20.82	19.74	115.80
	1984	59.40	10.20	21.60	18.00	109.20
	1983	50.70	8.34	26.94	19.08	105.06
	1982	30.66	6.96	16.44	18.00	72.06

* Numbers in parenthesis indicate percentage to total biomass.

Although the trend varied with the type of animals, their biomass generally increased in relation to increase in consumption of milk, meat, and eggs as national living standard becomes higher. Especially, biomass excreted from milk cows increased rapidly in its absolute amount and in its proportion to total present amount. This trend will be expected to continue until the level of end-products consumption of South Korea reaches developed countries'.

b. Utilizable biomass and biomass being used

The utilizable biomass was estimated to be 729.9 x 10^6 m^3 in methane gas (43.8 x 10"Kcal), which occupied 37.8% of the total present amount (Table 9). The proportion ratio for each of the domestic animals differed between in the present amount of biomass and in the utilizable biomass ; Korean cows showed 50.8% in the present amount and 10.3 % in the utilizable biomass, igs did 21.1% and 33.8%, and chickens did 18.7% and 47.1%, respectively. The reason for the difference occured due to the small raising scale of Korean cows and the large raising scale of pigs and chickens. Such trend will continue because large raising scale is economically better than small scale.

The practical use of such biomass as an energy source was not frequent because of less economical efficiency. Most of them were used as raw materials for manure.

Table 9. Utilizable biomass in livestocks sector.

	Year	Korean cows	Milk cows	Pigs	Chickens	Total
Methane gas volume (10^6 m^3)	1986	75.5(10.3)*	65.7(9.0)	244.8(33.5)	343.9(47.1)	729.9(100)
	1985	84.5(12.7)	59.4(8.9)	208.2(31.3)	312.6(47.0)	664.7(100)
	1984	72.2(12.5)	51.0(8.1)	216.0(34.2)	285.0(45.2)	631.2(100)
	1983	67.6(11.1)	41.7(6.8)	269.4(44.3)	302.1(49.6)	608.8(100)
	1982	40.9 (7.8)	34.8(6.6)	164.4(31.3)	285.0(54.3)	525.0(100)
Caloric value (10"Kcal)	1986	4.53	3.94	14.69	20.63	43.79
	1985	5.07	3.56	12.49	18.76	39.88
	1984	4.75	3.06	12.96	17.10	37.87
	1983	4.06	2.50	16.16	18.13	36.53
	1982	2.45	2.09	9.86	17.10	31.50

* Numbers in parenthesis indicate percentage to total biomass.

2. The future prospect

The potential value of the biomass in this sector as an energy source will be higher by commercialization of livestocks raising and by increased demand for its products. Moreover, because those excretions are highly concentrated organic materials with lots of parasitic worms, it is urgently required to compeletely utilize them. The development of convenient fermentation device for the excreted biomass helps preventing streams and rivers from pollution.

D. Municipal and industrial wastes sector

1. The present status

a. Municipal waste

The present amount of biomass or the utilizable biomass from combustible municipal waste was estimated to be 7.47 x 10^6 M/T in dry weight (241.4 x 10" Kcal). The biomass being used was estimated to be 0.86 x 10^6 M/T in dry weight (27.7 x 10" Kcal), which occupied about 11.5 % of the total present amount (Table 10).

Table 10. Biomass in municipal waste.

	Year	Present biomass (or Utilizable biomass)	Biomass being used
Dry weight (10^6 M/T)	1986	7.47	0.86
	1985	6.90	0.79
	1984	6.37	0.73
	1983	5.89	0.67
	1982	5.44	0.62
Caloric value (10"Kcal)	1986	241.4	27.7
	1985	222.9	25.6
	1984	205.9	23.6
	1983	190.4	21.7
	1982	175.9	20.0

b. Living sewage and excretions

The present amount of biomass or the utilizable biomass from sewage and execretions was estimated to be 98.15 x 10^6 m^3 in the methane gas (5.89 x 10" Kcal). The biomass being used was estimated to be 10.48 x 10^6 m^3 in methane gas (0.63 x 10" Kcal), which occupied 10.7% of the total present amount(Table 11).

Table 11. Biomass in living sewage and excretions.

	Present or utilizable biomass			Biomass being used		
	Sewage	Excretions	Total	Sewage	Excretions	Total
Methane gas volume ($10^6 m^3$)	61.00(62.15)*	37.15(37.85)	98.15(100)	3.70(35.31)	6.78(64.79)	10.48(100)
Caloric value (10"Kcal)	3.66	2.23	5.89	0.22	0.41	0.63

* Numbers in parenthesis indicate percentage to total biomass.

c. Organic waste materials from industries

The total present amount was estimated to be 78.0 x 10^6 m^3 in methane gas (4.68 x 10" Kcal), of which 47% could be from alcohol producing industries and 38% from pulp industries (Table 12). Therefore, total present amount in this subsector depended on waste materials from these two industries.

During the last five years (1982-1986), biomass from alcohol producing industries varied inconsistently, but that from pulp industries increased rapidly as paper consumption, which is an indicator to the level of civilization, increased. Thus, total present amount also increased with increasing years.

The biomass being used, which is equivalent to the amount treated by recovery facilities, was estimated to be 14.9 x 10^6 m^3 in methane gas (0.89 x 10" Kcal). It represented about 20 % of the present amount in 1985.

Table 12. Biomass in organic waste materials from industries.
(Present biomass or Utilizable biomass)

	Year	Alcohol	Beer	Glutamine	Orange	Pulp	Others	Total
Methane gas volume (10^6m^3)	1986	36.38 (46.68)*	1.04 (1.33)	10.25 (13.15)	0.72 (0.92)	29.36 (37.67)	0.19 (0.24)	77.94 (100)
	1985	35.15 (47.32)	1.02 (1.37)	9.90 (13.33)	0.64 (0.86)	27.39 (36.87)	0.18 (0.24)	74.28 (100)
	1984	38.88 (50.96)	0.98 (1.19)	9.26 (12.14)	0.56 (0.73)	26.43 (34.64)	0.19 (0.25)	76.30 (100)
	1983	35.82 (50.96)	0.91 (1.29)	8.17 (11.62)	0.46 (0.65)	24.76 (35.23)	0.17 (0.24)	70.29 (100)
	1982	34.34 (51.47)	0.81 (1.21)	6.83 (10.24)	0.50 (0.75)	24.08 (36.09)	0.16 (0.24)	66.72 (100)
Caloric value (10"Kcal)	1986	2.18	0.06	0.61	0.04	1.76	0.01	4.68
	1985	2.11	0.06	0.59	0.04	1.64	0.01	4.46
	1984	2.33	0.06	0.56	0.03	1.59	0.01	4.58
	1983	2.15	0.05	0.49	0.03	1.49	0.01	4.22
	1982	2.06	0.05	0.41	0.03	1.44	0.01	4.00

* Numbers in parenthesis indicate percentage to total biomass.

2. The future prospect

Municipal waste which consisted of most of biomass resources in this sector, will increase continuously as national living standard becomes higher. Its utilization will also increase with increase in energy-efficient power plants using combustible waste.

Total amount of biomass from living sewage and excretions will increase with rapid urbanization and higher living standard. Utilized amount of them will also increase to protect streams or rivers from water pollution by those wastes.

On the other hand, although the amount of organic waste materials from industries are less than those from the above two subsectors, its utilization is so easy that most of the industries try to convert them to an energy source. Therefore, the utilization of waste materials in this subsector is expected to increase in the future.

E. Total biomass in South Korea

The present amount of biomass, utlizable biomass and biomass being used in each of the sectors in South Korea are shown in Table 13.

Table 13. Present biomass, utilizable biomass and biomass being used in each of the biomass producing sectors by years.

(Unit : 10" Kcal)

	Year	Forestry	Agri-culture	Live-stocks	Cities and indus-tries	Total	Oil equi-valent weight (10^3 M/T)	Percent to Present biomass	Percent to Utilizable biomass
Present biomass	1986	9,266.9 (92.3)*	408.8 (4.1)	116.0 (1.2)	252.0 (2.5)	10,045.7 (100)	100,437	-	-
	1985	8,779.0 (92.1)	408.4 (4.3)	115.8 (1.2)	233.3 (2.4)	9,536.5 (100)	95,365	-	-
	1984	8,502.7 (91.9)	439.2 (4.7)	109.2 (1.2)	216.4 (2.3)	9,267.5 (100)	92,675	-	-
	1983	8,226.6 (91.9)	422.7 (4.7)	105.1 (1.2)	200.5 (2.2)	8,954.9 (100)	89,549	-	-
	1982	7,962.3 (92.3)	409.7 (4.8)	72.1 (0.8)	186.8 (2.2)	8,630.9 (100)	86,309	-	-
Utilizable biomass	1986	343.3 (46.0)	107.3 (14.4)	43.7 (5.9)	252.0 (33.8)	746.3 (100)	7,463	7.43	-
	1985	350.3 (47.9)	107.2 (14.7)	39.9 (5.5)	233.3 (31.9)	730.7 (100)	7,307	7.66	-
	1984	352.3 (48.8)	115.5 (16.0)	37.9 (5.2)	216.4 (30.0)	722.1 (100)	7,221	7.79	-
	1983	356.1 (50.6)	111.1 (15.8)	36.5 (5.2)	200.5 (28.5)	704.2 (100)	7,042	7.86	-
	1982	348.7 (51.7)	107.7 (16.0)	31.5 (4.7)	186.8 (27.7)	674.7 (100)	6,746	7.82	-
Biomass being used	1986	216.7 (62.8)	98.9 (28.7)	0 (0.0)	29.2 (8.5)	344.8 (100)	3,448	3.43	46.20
	1985	229.1 (64.4)	98.8 (27.8)	0 (0.0)	27.1 (7.6)	355.6 (100)	3,556	3.73	48.67
	1984	265.8 (66.9)	106.3 (26.8)	0 (0.0)	25.1 (6.3)	397.2 (100)	3,972	4.29	55.01
	1983	293.7 (70.1)	102.3 (24.4)	0 (0.0)	23.2 (5.5)	419.1 (100)	4,191	4.68	59.51
	1982	279.5 (69.8)	99.2 (24.8)	0 (0.0)	21.5 (5.4)	400.2 (100)	4,002	4.64	59.32

* Numbers in patenthesis indicate percentage to total biomass.

1. Present amount of biomass

The total present amount of biomass in caloric value in South Korea was 10045.7 x 10^{11}Kcal in 1986, which is equivalent to 100.44 x 10^6M/T in oil weight. This amount was about 1.6 times greater than total energy consumption (62.00 x 10^6M/T).

Forestry sector consisted of the largest proportion, 92.3% of the total present biomass. Of them, 4.1% was occupied by agricultural sector, 2.5% by municipal and industrial waste sector, and 1.2% by livestocks sector. During the last five years (1982-1985), total present amount of biomass generally increased with increasing years, and most of biomass increases were from the increased growth in the forests.

2. Utilizable biomass

Total utilizable biomass in caloric value was 746.3 x 10^{11}Kcal (7.46 x 10^6M/T in oil weight), which was equivalent to about 12% of total energy consumption in 1986. Forestry sector showed 46.0% of the total utilizable biomass. Of them, 33.8% was represented by municipal and industrial waste sectors, 14.4% by agricultural sector, and 5.9% by livestocks sector.

Total utilizable biomass increased with increasing years, and will increase with rapid industrialization and urbanization, and the necessity for protection from water pollution. Total utilizable biomass occupied 7.43% of total present amount of biomass, and this proportion decreased annualy because most of them were composed by forestry sector.

3. Biomass being used

Total biomass being used was 334.8 x 10^{11}Kcal in caloric value (3.45 x 10^6M/T in oil weight). Of the total amounts, forestry sector, agricultural sector, and municipal and industrial waste sector occupied 62.8%, 28.7% and 8.5%, respectively. Total biomass being used decreased due to decrease in forestry sector. That in agricultural sector did not change significantly year to tear, but that in municipal and industrial waste sector rather increased with increasing years. Biomass produced from livestocks sector was not frequently used as an energy source because of its low efficiency in conversion into methane.

In 1986, total biomass being used occupied 3.4% of total present amount of biomass and 46.2% of total utilizable biomass. This proportion is expected to decrease because such fossil fuel as oil, gas or coal which can be easily and economically supplied, meets demand for energy.

4. Potential ethanol yield from fibrous biomass in forestry and agricultural sectors

Today, general industry systems using energy sources have been designed to use either liquid or gas fuel. Ethanol, a liquid form of fuel, can be extracted from cellulose through a chemical process, and biomass from forestry and agricultural sectors consist mostly of fibrous materials. The potential amount of ethanol from these two sectors would be estimated to be 38.59 x 10^6 Kl for the present amount of biomass, 2.29 x 10^6 Kl for utilizable biomass and 1.75 x 10^6 Kl for biomass being used (Table 14).

Table 14. Potential ethanol yield from fibrous biomass in 1986.

(Unit : 10^6 Kl)

	Forestry sector	Agricultural sector	Total
Present biomass	35.05(90.8) *	3.54(9.2)	38.59(100)
Utilizable biomass	1.41(61.6)	0.88(38.4)	2.29(100)
Biomass being used	0.89(50.9)	0.86(48.1)	1.75(100)

* Numbers in parenthesis indicate percentage to total biomass.

F. The potential value of biomass as an energy source in South Korea

To estimate the potential value, the ratio of total biomass energy to total energy consumption was calculated (Table 15). In 1986, the ratios for total present amount of biomass, utilizable biomass and biomass being used were 164.5%, 12.2% and 5.6%, respectively. That is, the amount of energy which can be potentially substituted with biomass, would be 6.6% of total energy consumption.

The absolute amount of present biomass and utilizable biomass are expected to increase, whereas its ratios to total energy consumption are expected to decrease because its increasing rates are slower than those of total energy consumption. Moreover, the absolute biomass being used is expected to decrese which, in turn, its ratio to total energy consumption decrease rapidly.

From all of the above results together, biomass resources show low potential value for energy supply in South Korea. However, this alternative energy resources should be developed to provide stable energy supply and substitute for fossil fuel. For the future, the establishment of short-ratation intensive culture system with high biomass producing woody species and the development of efficient technique in biomass conversion into energy are the most interested in South Korea.

Table 15. The ratios of biomass energy to total energy consumption.

(Unit : Oil, 10^3M/T)

Year	Total energy consumption	Absolute amount and ratio to total energy consumption of		
		present biomass	utilizable biomass	biomass being used
1986	61,065(100)*	100,437(164.5)	7,463(12.2)	3,448(5.6)
1985	56,689(100)	95,365(168.2)	7,307(12.9)	3,556(6.3)
1984	53,850(100)	92,675(172.1)	7,211(13.4)	3,972(7.4)
1983	49,770(100)	89,549(179.9)	7,042(14.1)	4,191(8.4)
1982	45,974(100)	86,309(187.7)	6,747(14.7)	4,002(8.7)

* Numbers in parenthesis indicate percentage to total energy consumption.

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THE USE OF RESIDUAL CHARCOAL FOR SMALL SCALE POWER GENERATION IN RURAL AREAS

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ABSTRACT

The paper highlights the practical experience and potential of using residual charcoal for small-scale power generation in rural areas. Trials conducted showed that with slight modifications, diesel and petrol engines can be adapted to work satisfactorily on producer gas. The conversion efficiencies of diesel (13 KW) and petrol (45 KW) engines working on producer gas was found to be 22% and 17% respectively. With its simple operation and maintenance, the downdraft gasifier was found to be suitable for providing a reliable and independent source of electricity and processed heat to the rural people.

INTRODUCTION

Solid biomass such as wood and charcoal can be converted into useful gaseous fuel by a process known as gasification. During the Second World War, producer gas from gasification was used extensively in Northern Europe and many countries in the Asian and Pacific region as fuel for driving buses, tractors, cars and other mechanical equipment (Anon, 1983). Since wood was abundantly available at that time, wood charcoal was the main feedstock. After the War, the availability of cheap oil led to a complete halt to the use of producer gas. However, the sudden increase in the price of fossil fuels in the 1970s and 80s has injected new interest in this age old technology. This has led to the development of new gasifiers that are safe, efficient and economical to use (Anon, 1985). Today, gasifiers are not only designed to use charcoal as feedstock but can also be adapted to utilise forestry and agricultural residues with relatively high efficiencies when compared with conventional gasifiers.

In Malaysia, producer gas technology has a good potential in the generation of mechanical and electrical power especially for some cottage industries in rural area which have been relying heavily on liquid fuel. At present, although it is still possible for the rural people to make use of conventional prime movers readily, it is still relatively expensive to depend fully on subsidised liquid fossil fuel. As a result, industries running on liquid fuel are facing the problem of high operating costs because of high fuel price.

Research and Development in charcoal gasification was initiated by the Forest Research Institute Malaysia in 1986. This work was partially supported financially by the Federal Republic of Germany through the Malaysia-German Forestry

Research Project (Graf, 1986). In this research area emphasis was placed on the development of producer gas systems that are easy to operate, maintained and fabricated using locally available materials.

The main aim of this paper is to highlight the performance of a 7 KW downdraft gasifier which has been installed at the Institute for trials.

CHARCOAL GASIFIER

The charcoal gasifier installed at FRIM consists of 4 main components:

a) A reactor made of stainless steel to generate the gases;
b) A cooler to condense the tar and impurities in the gas;
c) A cloth filter to filter the soot and ash;
d) A diesel/petrol genset to use the gas.

The reactor has the following specifications:

Height of reactor	85 cm
Diameter at nozzle level	20 cm
Primary air supply	3 nozzles
Height of reduction zone	24.5 cm
Insulation of reduction zone	Refractory brick lining
Gas cleaning	Cyclone
Gas cooling	Semi circular air cooled tubes
Capacity of reactor	0.09 m3

The reactor is a downdraft system, cylindrical in shape and lined with a thick refractory brick lining. On top of the reactor is a fuel feeding lid through which charcoal can be fed. When fully charged the reactor can contain approximately 7 kg of charcoal and the gasifier an then run for about 4 hours. However, the reactor chamber can be extended upwards if there is a need to put in more charcoal in order to reduce the recharging rate. Air for the oxidation zone is supplied through a valve located at the side of the reactor. In the reduction zone, a inspection door is provided for inspection and the starting of the gasifier. An ash door is located at the bottom of the reactor for periodic cleaning of the gasifier and removal of the ash. A shaker arm which can be rotated helps to loosen the burning charcoal at the reduction zone in order to prevent bridging.

The gas which passes through the grate moves upwards in a circular space around the reduction zone and leaves the gasifier via the gas outlet pipe. The gas is then passed through a simple cyclone which removes a large proportion of the dust carried with the gas stream. The temperature of the gas at this point is about 120^{0}C. The gas is then passed through a simple pipe cooler which cools the gas by natural convection. Moisture and wood tar condenses along the sides of the pipe which can be drained off at the bottom of the cooler. The gas temperature after passing through the cooler is 27 - 30^{0}C.

To further remove the remainder of the dust, the gas is passed through a simple cloth filter which is installed between the cooler and the genset. The gas temperature at this point is about 25^{0}C.

The diesel engine using a dual fuel system has the following specifications:

Type	Two cylinder, 4 stroke direct injection
Volume	2 litre, bore 87.5mm, stroke 110mm
Compression ratio	17.5:1
Power	13KW at 2000 rpm
Governor	mechanical
Cooling	water cooled
Starter	hand cranking

The petrol engine which is operated fully on gas has the following specifications:

Model	Toyota model 4K
Cylinder volume	1.29 litre, bore 75mm, stroke 75mm
Compression ratio	9:1
Maximum power	45KW at 5600 rpm
Cooling system	water cooled
Starter	electric starter

Both the engines are coupled to a simple generator which consists of the following specifications:

KVA	7.5
Rpm	1500
AC volt	415
AC amps	10.5
Frequency	50Hz

OPERATION OF THE GASIFIER

During all the trials the gasifier was fed exclusively with rubberwood charcoal produced by the transportable kiln (Hoi, Low & Wong, 1985). The charcoal used has a fixed carbon of 80 - 85%, ash content of 3 - 5%, volatile component of 10 - 15% and moisture of 7 - 10%.

In order to prevent bridging just above the nozzles the charcoal was broken into small pieces. The ideal size distribution of the gasifier fuel is found to be between 0.5 - 10 cm. As charcoal is highly hydroscopic, it must be stored in a closed shed to prevent re-wetting.

Starting procedure

Before starting the reactor is first filled with about 2 kg of charcoal. A blower with suction operation is fixed at the flaring tube of the gasifier. The charcoal is ignited with the help of some burning material at the inspection gate. The fuel lid at this moment is left open and the charcoal is left to ignite freely. As soon as the charcoal in front of the nozzle is glowing well, the reactor is fully filled with charcoal. The lid and the nozzles are then shut tightly and the blower is then transferred to the primary air inlet valve of the gasifier with pressure operation. The gas produced can be tested at the flaring tube located at the top of the gas cleaner. The quality of the gas is determined by igniting it. A certain amount of practical experience is needed in order to assess the quality of the gas. A good gas is normally indicated by its almost transparent flame which burns steadily without blowing off. A bright yellow flame indicates that the gas is highly contaminated with tar and vapour and is unsuitable for the engine. Sparks in the flame mean that carbon particles are present in the gas and this indicates that the filter system is not working very well.

As soon as the gas burns consistently with a transparent flame, the engine can then be started. In order for the engine to work uniformly the volume of the gas provided by the blower must not be less than 30 m3/h.

RESULTS AND DISCUSSION

By using an estimated heating value of the gas to be about 4.5 MJ/m3, it has been found that the thermal efficiency of the gasifier is about 69%. This means that the conversion of the chemical energy in the charcoal into gas energy is 69%. The loss of combustible material (such as charcoal fines) in the ashes accounts for about 10% of the energy supplied by the charcoal. The remaining energy is lost as heat to the surroundings.

The results of the gasification trials using rubberwood charcoal as feedstock are summarised below:

	Diesel engine	Petrol engine
Power output	5.2 KW	4.0 KW
Fuel consumption	1.5 kg/hr	2.0 kg/hr
Start-up time	15-20 min	20-30 min
Refuelling cycle	4 hours	3 hours
Diesel displacement	75%	100%
Thermal efficiency	21.6%	12%

In general there have been no serious problems in converting diesel and petrol engines to work on producer gas. Diesel engines seem to be more suitable when there exists a constant load fluctuation. Petrol engines are however more suitable when a constant load is needed. It must be remembered that engines working on gas are extremely dependent on the moisture content of the feedstock. Wet charcoal with a moisture content of about 18% causes the output power of the petrol engine to be between 5-10% lower and the diesel replacement of the diesel engine to be reduced to 70%.

Charcoal with sizes larger than 3 cm has been found to be unsuitable as serious bridging occurs at the bunker area just above the nozzle resulting in poor gas production. When this occurs the fuel lid has to be opened (although it is extremely dangerous) and a stick has to be inserted into the fuel bed in order to relieve the passage of the nozzle.

The gasifier can be started easily with a battery and good gas gas production can be attained within 10-15 minutes. If the moisture content and sizes of the feedstock used are correct the gasifier system can be left to run for hours without much supervision. Refueling can be done with the engine preferably at idle. The charcoal bed in the reducing zone however has to be changed after every 20 hours of operation because the ash and fines will block the flow of the gas and the output power will be greatly reduced. This process normally takes about 1 hour.

The cloth filter has to be changed after every 20 hours of operation. The cloth filter can be reused after cleaning. The process of changing the filter normally takes about 1 hour.

In order to maintain a constant output power, the engines cylinder head, valve port and valve seating has to be cleaned after every 100 hours of operation. The time needed for this operation is normally 1 hour.

Because of high temperature at the reactor chamber, the asbestos gaskets in the reduction zone, fuel lid and the ah door has to be replaced after 300 hours. Failure to replace these gaskets can adversely affect the performance of the gasifier.

It has been found that the paint on the walls of the reactor will start to peel badly after 300 hours of operation. For the long term protection of the gasifier it is necessary to repaint the walls of the reactor and cyclone with heat resistant paint after every 300 hours of operation.

CONCLUSION

Studies on the gasification of rubberwood charcoal and the utilisation of producer gas in internal combustion engines has shown that it is possible to develop small inexpensive producer gas systems for rural applications by using locally available material. Downdraft gasifiers have been found to be suitable for the production of producer gas for internal combustion engines. The main constraint in the utilization of producer gas in engines is the cleaning of the gas so that it is free of impurities. So fas not much work has been done to develop a simple but efficient gas clean-up system for the gasifier.

The assessment of the results has shown that low power output systems fuelled by charcoal have tremendous potential for a number of rural applications (such as water pumping, drying of food and shaft power production) where charcoal is readily available. Apart from being reliable, these systems are easy to operate and maintain. The main problems in the utilization of this system lie in the inconvenience in the start up and the maintenance of the filter by the operator.

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RESEARCH IN CANADA ON FOREST BIOMASS PRODUCTION FOR ENERGY[1]

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ABSTRACT

Spurred on by the oil price crises of the 1970's, Canadian research on forest biomass production for energy began effectively in 1978. Over the period since then, many projects have been conducted in the fields of resource assessment, mechanization, environmental impacts of intensive biomass harvesting, intensive silviculture as a means of improving biomass productivity, and socio-economics. The Canadian Government has been a major funding source for this research which is performed by forest industry, universities, consulting companies, and government, as well as through international collaboration. Current strategy calls for continuing research to fully elucidate the knowledge and technology required to produce and collect forest biomass as an energy source in a effective, efficient and environmentally sound manner.

RESEARCH IN CANADA ON FOREST BIOMASS PRODUCTION FOR ENERGY

1. Introduction

Along with the rest of the western industrialized countries of the world, Canada was taken somewhat by surprise by the oil price crises of the mid- to late-1970's. Despite the fact that Canada has considerable reserves of oil and, particularly, natural gas, concern about the need for alternative sources of energy was sufficiently great that the federal government made a policy decision to investigate alternatives to petroleum products. An interdepartmental Panel on Energy Research and Development (PERD) was created in 1974 with funds to help many different government departments and agencies to conduct energy R&D programs. From the beginning, one of the major objectives has been to examine the opportunities of renewable energy technologies and, if possible, to promote their implementation.

Canada has vast forest resources, so it was only natural that these should be looked on as one of the potential sources of renewable energy. In 1978, as part of the PERD initiative, a program of contract research and development known as ENFOR (ENergy from the FORest) was established (Anon. 1984). The objective of the program was to generate sufficient knowledge and technology to realize a marked increase in the contribution of forest biomass to Canada's energy supply. The ENFOR program originally comprised two sub-programs: forest biomass production and forest biomass conversion. Both were originally administered by the Canadian Forestry Service, an agency of the federal government, but since 1983 responsibility for the biomass conversion component has been transferred to Energy, Mines and Resources Canada which no longer uses the 'ENFOR' title for this sector.

The federal government acts as stimulator and coordinator for these research activities. The actual research and development on forest biomass, however. is performed for the most part by other agencies - universities, industry, consultants, provincial government agencies. Some work is also undertaken through the medium of international collaboration under the Bioenergy Agreement of the International Energy Agency.

Ten years of Canadian research on forest biomass production has resulted in considerable progress in a variety of fields. These include assessment of the Canadian forest biomass resource; development of mechanical equipment for harvesting or collecting forest biomass; investigation of the potential long-term environmental impact of intensive biomass removal; intensive silvicultural techniques and testing of species, hybrids and clones to improve biomass productivity; and studies of socio-economic factors affecting the use of forest biomass for energy.

This paper describes the progress that has been made in the Canadian context in each of these fields. It indicates the Canadian contribution at the international level. Finally, it reviews the philosophy and future strategy for research and development in Canada on forest biomass for energy.

2. Canada - a forest nation

Canada has a total area of 992 million hectares, stretching from the Atlantic Ocean to the Pacific, and from 41°40'N latitude to the high Arctic. Within those bounds it encompasses a very varied topography and climate. The topography includes the much-indented rocky coastlines of Newfoundland and the Maritime Provinces, the fertile agricultural areas of southern Quebec and Ontario, the rolling hills and numerous lakes of the shallow-soiled Canadian 'Shield' in the central part of the country, the flat agricultural plains of the 'Prairies', and the rugged mountainous area of British Columbia. The climate is moist in the coastal areas and drier in the interior. Temperatures similarly are moderate in the coastal areas, but subject to much greater seasonal variations throughout the interior. In general, the Canadian climate is boreal or temperate, with a strong continental influence.

The forests of Canada occupy a total of 441 million hectares, or approximately 44 percent of the total land area (Anon. 1987a). The forest types vary according to the geographic region and growing conditions. Boreal coniferous forests predominate in the north and east, with mixed hardwood and coniferous forests in the Maritime Provinces on the Atlantic coast and in the central parts of Quebec and Ontario. Very little remains of the former temperate hardwood forests of southern Quebec and Ontario. West of the Rocky Mountains, the forests are dominated by coniferous species and are composed by and large of different species from those farther east. These western forests are also by far the most productive in the country (Rowe 1972).

The vast majority (94%) of Canada's forest land is classed as 'Crown' land, owned by either provincial or federal government. Only 6 percent is privately owned, though the proportion is much higher in the eastern provinces than in the west (Anon. 1987a). Forest industry companies generally operate under some form of long-term agreement whereby they obtain the rights to harvest the timber in a specified area in return for payment of a stumpage fee and some arrangement for sustained forest management.

Canada's vast resources of virgin timber are a thing of the past. Most forest operations are now based on second-growth forests or forests which have already been previously harvested for selected products such as large saw-timber. On these lands, more intensive forest management practices are being adopted. The responsibility for forest management in Canada rests with the provincial governments. The federal role in forestry is one of research, and financial support to the provinces to assist them in forest management.

In considering the forest resources of Canada as a potential energy source, it is important to note that the majority of the population of the country which would use the energy is not located close to the resource. The vast majority of the Canadian population of 26 million is located within 150 km of the United States border in precisely that part of the country where there are new forests. Those that do exist tend to be privately owned or reserved for some use other than biomass production.

Renewable energy, including energy produced from forest biomass, the largest single contributor to that category, currently accounts for 6 percent of Canada's primary energy needs, double the estimate of just 10 years ago. The bulk of our energy needs are supplied from our large non-renewable energy sources of oil (including oil sands and heavy oil), natural gas and coal. About 18 percent of Canada's end-use energy demand is supplied by electricity (Office of Energy R&D 1985).

3. Forest Bioenergy Production R&D

a. Resource Assessment.

The first major task of forest bioenergy production research in Canada was to determine how much forest biomass might be available for energy use. Traditional forest inventories in Canada had focussed on commercial wood volume production and ignored other tree and stand biomass components such as foliage, tops, stumps, bark and submerchantable trees. These other components make up 50 percent of total tree volume. A major program was undertaken to collect tree data to construct tree biomass equations in order to estimate the biomass components (Bonnor 1985).

Like other aspects of forest management in Canada, forest inventory is the responsibility of the provinces. Each province takes a somewhat different approach to its inventory, requiring different methods to convert the timber inventory to a biomass one. Two basic conversion methods were used: an equation approach, and a factor approach. In the equation approach, tree biomass equations are applied to inventory field survey data resulting in the production of biomass stock tables. In the factor approach, used where detailed plot data were not available, volume data of merchantable stem wood were converted to mass (using wood density data) and tree volume equations were used to develop factors which when applied to merchantable stem mass, gave the mass of other components (Bonnor 1985).

Provincial forest inventory data cover the most important, productive forest lands. For the biomass inventory, these data were supplemented with additional information specially collected from less productive or unproductive (in a commercial sense) forest areas. In addition, access data were superimposed on the biomass data to give some measure of the amount of forest biomass that could be economically harvested (Bonnor 1985).

The total amount of forest biomass in Canada is at least 26 billion oven-dry tonnes, equivalent to 82 billion barrels of oil, or enough to meet all the country's energy needs for 55 years. This figure excludes biomass on lands which are reserved for purposes other than wood production and harvesting, for example, national parks (Bonnor 1985).

Some other statistics on Canada's forest biomass:

<u>Land productivity</u>	
Biomass on productive forest land	82 %
Biomass on unproductive forest land	18 %
<u>Access</u>	
Biomass with access through a near-by transportation corridor	60 %
Biomass without access through a near-by transportation corridor	40 %
<u>Biomass components</u>	
Merchantable wood	49 %
Residue from merchantable trees (branches, bark, foliage)	32 %
Small, submerchantable trees	19 %
<u>Species</u>	
<u>Picea</u> spp.	35 %
<u>Pinus</u> spp.	17 %
Other coniferous	33 %
<u>Populus</u> spp.	10 %
Other deciduous	10 %

<u>Productivity</u>

Average forest biomass	62 t/ha
Productive forest lands only	89 t/ha
Highest provincial average (British Columbia)	178 t/ha
Highest average for individual forest types	1100 t/ha

Taking a realistic look at the quantity of forest biomass that might be available for energy purposes, we would consider only the nonmerchantable portion of merchantable size trees growing on productive, accessible forest land. This is only 16 percent of the total forest biomass, or 4 billion tonnes. Nevertheless, this biomass could supply about 25 percent of Canada's annual energy requirements on a sustained basis (Bonnor 1985), compared with the present usage of about 6 percent (Office of Energy R&D 1985).

b. <u>Mechanization</u>

Most of the currently available timber harvesting and handling equipment is not suited to dealing with forest biomass for energy purposes. Instead of relatively uniform logs, we have to deal with whole trees, ranging in size from young whips to full-grown mature trees, or irregular woody material in logging debris in the forest, or on landings or sorting yards. Each situation may require a different approach. Canada has considerable expertise in forest engineering and equipment development. That expertise has been drawn on in the forest biomass production R&D program.

An obvious source of woody biomass is harvesting residues which remain on the ground after logging. A prototype machine was designed and developed under contract by the Forest Engineering Research Institute of Canada (FERIC) to pick up and comminute slash left on cutovers. The machine incorporated a special rotary shear, the 'RECUFOR', which gave its name to the machine. The same rotor was also incorporated in a subsequent system intended to operate at roadside landings, in conjunction with or following full-tree processing. The RECUFOR system was also used in the 'Logging Residue Processor' which was designed to process residue from the delimbing and topping of full trees (Du Sault 1985a, Novak 1986). In the absence of an immediate commercial market for any of these machines, none was taken beyond the prototype stage and initial testing.

Much of the research effort with mechanization has been concerned with improving the handling characteristics of woody biomass. Chipping the material is one approach. Another approach tried by FERIC was to crush and squeeze the water out of solid roundwood bolts. Based on equipment developed by the

Tennessee Valley Authority, the 'Roll Splitter' was taken to the stage of a second prototype. The intention here was to reduce the solid woody biomass quickly to a usable fuel stock for direct combustion (Du Sault 1985b).

On the west coast of Canada, large concentrations of waste biomass exist in logging sortyards. Unfortunately, the biomass is intimately mixed with inorganic debris and so is not immediately usable. FERIC, under contract, was able to design, develop and test a 'Separator-shear system' which successfully separates the biomass from the unusable material, and divides the large pieces into manageable chunks (Sinclair 1984).

Many forest sites in Canada are occupied by woody brush which will never support a commercial logging operation. This is, however, a prime source of biomass for energy. The 'Crabe Combine brush-harvester', based on the Pallari cutting principle developed in Finland, was designed, developed and successfully field-tested in Canada for such conditions. This machine acts as a biomass harvester, cutting and chipping brush and small trees. It is also a valuable silvicultural tool for preparing brush-covered sites for planting. Some commercial interest has been shown in this machine, primarily for right-of-way clearing (Elms 1984).

Short rotation energy plantations present entirely different mechanization problems. Considerable work has been done in designing and developing equipment to mechanize all aspects of such plantations. This was undertaken by the Bioenergy Program of the Division of Energy of the National Research Council of Canada (NRCC). Equipment was designed to clear brush, to harvest and bundle hybrid poplar whips for cuttings, to plant the cuttings in dense plantations, and to harvest the plantations either as individual trees or as continuously-harvested coppice (Golob 1986). This ambitious program was developed with field cooperation of the Ontario Ministry of Natural Resources and their 'Fast Growing Forests' program which emphasizes culture of hybrid poplar plantations. Unfortunately, the NRCC program was eliminated in a government austerity move before it could be brought to completion. Only the harvesters and the planting machine were developed to the field testing stage. The 'FB-7' harvester, designed for plantations on a 5-year rotation, is now in the process of commercialized by a company in New Zealand.

Machine development is costly. In this period of reduced funding for forest bioenergy research, the present philosophy is not to invest research funds in mechanization activities unless there are immediate commercial prospects. Since such prospects are not presently in evidence for much of the work, Canada is no longer active in this field. We do, however, continue to collaborate in technical exchanges in this field through the medium of the International Energy Agency. We feel that this is the best way we can contribute at present.

c. Environmental Impact.

From the initiation of the program, concerns were raised about the possible long-term impacts on forest site conditions of the intensive removal of biomass envisaged in harvesting for energy purposes. Potential immediate short-term impacts on the environment were also of concern.

The ENFOR program has given considerable emphasis to the development and calibration of the FORCYTE model. FORCYTE (FORest nutrient CYcling Trend Evaluator) is an ecologically-based forest management model developed, largely under contract, by Dr. J.P. Kimmins, at the University of British Columbia. Over its nine years of development, the model has been developed through 11 stages (Kimmins 1988).

FORCYTE is a hybrid between the traditional inflexible historical bioassay yield predictors, and purely biological process-oriented models. It is similar in general approach to models such as TASS, PROGNOSIS, and FORET. Potential applications of the model are many, and range far beyond the long-term impact of intensive biomass harvesting to include short-rotation forest planning, agroforestry, climate change and education. International interest in FORCYTE has been extensive. Copies of FORCYTE-10 or -11 have been tested or used in 11 different countries. Within the Canadian Forestry Service, researchers at several locations are calibrating and testing the model for their local forest and site conditions.

The current thrust of this work is to develop a definitive 'benchmark' version of FORCYTE-11, with full documentation of the model's philosophy, assumptions and computer code. A complete data-set for the model is being assembled, and the hope is to validate the model scientifically using an independent data-set.

More specific studies have also been undertaken of various potentially serious adverse effects of harvesting forest biomass for energy. These studies have looked at potential effects on soil nutrient status, microbiology, organic matter content and nitrogen transformation, on wildlife (including reptiles and amphibians), and on other components of the forest ecosystem. In general, the conclusion is that the short-term effects of biomass harvesting would not have a seriously adverse effect on the environment. However, in the longer term, the overall loss of nutrients could have a negative impact on site productivity.

Currently increasing emphasis is being given by the ENFOR program to investigation of potential environmental impacts of biomass harvesting. Studies are underway on the effects such harvesting might have on soil physical properties and soil erosion. It is also proposed to investigate possible effects on vegetation and site dynamics, and to develop and test methods of alleviating or reversing the potentially negative impacts by modifying harvesting practices or adopting silvicultural procedures which will improve site productivity.

d. Intensive Silviculture

Although Canada has extensive resources of forest biomass which might be available for energy purposes and which is not presently being utilized, most of that biomass resource is located at some considerable distance from where the energy is needed. It also tends to be diffusely distributed rather than being concentrated in discrete locations, and so presents economic and technical problems in collection, and transportation.

An alternative approach needs to be considered. This is provided by intensive silvicultural techniques aimed at increasing the concentration and productivity of biomass on selected sites. Such sites would logically be located reasonably close to where the energy is needed. Several types of intensive silviculture have been tried in Canada, including short-rotation plantations, the use of nitrogen fixation to improve growth, and modifications to more traditional silvicultural techniques.

Several agencies in Canada have investigated short-rotation intensive culture, including the University of Toronto and the Ministere de l'energie et des ressources of Quebec. At both of these institutions, considerable work has been done on selection, testing and hybridization of hybrid poplars (and willows, at the University of Toronto).

However, the principal program is the 'Fast Growing Forests' program of the Ontario Ministry of Natural Resources in eastern Ontario. Since its inception in 1976, this program has concentrated on hybrid poplars, but has also more recently looked also at willows (Salix spp.), alders (Alnus spp.) and fast-growing conifers such as Larix spp. There has been an extensive and intensive program of selecting and testing species, hybrids and clones of these genera. Considerable emphasis has been placed on matching clones of poplar to specific site conditions. Site preparation, nursery production, planting and cultural practices for plantations have all been investigated (Anon. 1983).

From an operational point of view the 'Fast Growing Forests' program has been oriented primarily towards the production of pulpwood. It is noteworthy for the level of cooperation with forest industry and local agricultural landowners which this provincial government program has managed to achieve. However, despite the pulpwood orientation, the technology which has been developed could readily be applied to the production of biomass for energy.

Within the ENFOR program, one of the major thrusts in intensive silviculture has involved the use of the nitrogen fixation properties of Alnus spp. with mycorrhizal relationships to improve forest biomass growth. Studies have included the selection of improved strains of Frankia which forms the mycorrhizal relationships, and tissue culture for mass propagation of selected Alnus genotypes (Fortin et al 1983, 1984). This work has reached the stage that specially-inoculated alders are being interplanted with coniferous species in field test plantations. Obviously, the results of this research have application much beyond the field of bioenergy. This is true of much of the intensive silviculture aspects of the program.

Other efforts involving intensive silviculture have included studies of techniques for managing natural hardwood stands, of birch (Betula spp.) or aspen (Populus tremuloides Michx.), after biomass harvesting. Regeneration development studies have served to indicate that such stands can continue to be managed for biomass production, though the long-term maintenance of productivity remains a question. Regeneration treatments have also been shown to help in expanding good clones and inhibiting poor clones of aspen (Horton 1984).

e. Socio-economics

Socio-economic and institutional factors relating to the availability and utilization of forest biomass for energy have been investigated under the ENFOR program. Surveys of biomass supply and use have been conducted in several regions of the country. For example, a 1985 survey showed that approximately 7.5 million cubic metres of hog fuel were produced in that year in the south coastal region of British Columbia, most of it being utilized for production of steam or power (Appleby 1988). For the Province of British Columbia as a whole, estimates have been made of the economic availability of forest biomass fuel in 1990. These indicate that 9 million oven-dry tonnes of mill residue should be available at a cost of less than $15/ODT. On the other hand, 11.65 million ODT of logging residue and 17 million ODT of noncommercial hardwood stands and brush should be available, but mostly at a cost exceeding $60/ODT (McDaniels & Manning 1987).

Costs of harvesting such hardwood stands have been investigated. One study in 1981 in Alberta estimated that mechanical felling and chipping of aspen could be accomplished at a cost only half of average wood harvesting costs, but concluded that such wood could still not be converted to energy in wood gasification plant at a cost that would be competitive with natural gas, of which Alberta has an abundant supply (Coban Institute 1981). Similar studies have been conducted in British Columbia, Prince Edward Island and Newfoundland.

Much interest has focussed on integrated harvesting of traditional forest products, particularly pulpwood, and biomass for energy. Trials in the eastern part of the country have met with considerable success, and a number of pulp and paper companies now routinely utilize harvesting residues for production of process steam or energy in their mills. On the west coast, a 1985 study concluded that with the oil price scenarios then envisaged, there is potential for an integrated residual wood fuel and fibre industry on the coast of British Columbia, employing 300 to 570 people and providing $9-17 million in wages (Nagle et al 1987).

Other economic studies have looked at the role of forest biomass within overall energy strategies. In Atlantic Canada, over the period 1978 to 1983, a substantial volume of oil was displaced through the use of wood biomass fuels in commercial and industrial applications (Northland Associates Ltd. 1984). The vast majority (89%) of the biomass consumed by the commercial/industrial sector in that region was used by the pulp and paper industry. The report noted that small commercial and industrial users face an inherent problem of security of supply and stability of price. In British Columbia, a study of the pulp and paper industry there showed that between 1974 and 1984, an annual fossil fuel savings equivalent to about 3.5 million barrels of oil was achieved, through improved energy efficiency, process changes and increased hog fuel consumption (Robinson Consulting & Assoc. Ltd. and C.E. Wetton Assoc. Ltd. 1985). Most indications now suggest that Canada's forest industry has gone about as far as it can, under present economic conditions, in improving energy efficiency and in utilizing forest biomass for energy.

There is a need to repeat periodically some of the economic studies and surveys in order to maintain their relevance. This results from the changing significance of the various components of the total energy picture, such as oil prices, fuel alcohol markets, and the overall forest industry economic situation.

4. International Collaborative Research and Development

In addition to the research carried out by agencies within the country, Canada also participates in the international collaborative research effort on forest biomass production for energy. The channels for this include the International Energy Agency (IEA), and the International Union of Forestry Research Organizations (IUFRO).

Canada, through the Canadian Forestry Service, is a signatory to the Bioenergy Agreement of the IEA, which involves 10 other countries, primarily in northern Europe, as well as the United States and New Zealand. The work of the Agreement is organized in three Tasks, dealing with i) biomass production and growth in short-rotation forestry, ii) harvesting, transportation and pretreatment of biomass from conventional forestry, and iii) biomass conversion. Research and development are conducted through international collaboration on a series of agreed activities.

Canadians have been particularly active in Task II on short-rotation biomass production, in which the activities have been led by Dr. L. Zsuffa as Operating Agent. These activities have included the selection, evaluation, breeding and propagation of species and clones of poplars, willows and alders, the biology of production, the management, tending and protection of plantations, and the ecological problems associated with short-rotation forestry. We have also been involved in work on the mechanization of planting and harvesting of short-rotation plantations (Anon. 1987b).

In Task III on conventional forestry harvesting, Canada has made important contributions in the area of recovery of fuelwood from forest residues and integrated harvesting systems, and in evaluating ecological consequences of biomass harvesting using computer simulation methods. We have also been involved in activities on recovery of fuelwood from conventional forestry, on storage, drying and handling, and on evaluation methods (Anon. 1987b).

The present Bioenergy Agreement is the successor to an earlier IEA Forest Energy Agreement which came into effect in 1978 and in which Canada also participated. The present three-year Agreement terminates at the end of 1988, but will be succeeded by a similar three-year Agreement. This will be concerned with improvements in energy-dedicated biomass production systems, including forest biomass production systems (as well as agricultural/herbaceous production systems), and genetic improvement of selected woody crops. In the area of biomass supply, emphasis will be given to conventional forestry systems, to wood preparation, and to economic analysis. Canada will participate in most of these activities.

Several working groups of IUFRO are concerned with forest bioenergy. However, with respect to forest biomass production research, the group under whose auspices the present workshop is being held - P1.09.00 "Integrated research on biomass for energy" - is most important. This group is led, of course, by a Canadian scientist, Dr. Zsuffa. This is another important forum for exchange of information and research findings in this field.

5. Future Strategy

As a result of successful programs of energy conservation, and improvements in the oil price situation in recent years compared with the outlook 10 years ago, the level of interest in alternative energy sources in Canada has declined. However, on the world scale, energy demand is likely to continue to increase, particularly as the developing countries strive to increase their standard of living. In Canada, we need to keep all our energy options open, particularly with respect to renewable energy sources like forest biomass of which we such a large supply. We intend to maintain research and development in the field of forest biomass production for energy, in order to improve the level of knowledge and technology. The federal government's interdepartmental Panel on Energy R&D, mentioned at the beginning of this paper, has indicated its desire to continue funding this research at present levels.

The Canadian Forestry Service has recently developed a strategic plan which will guide its forest bioenergy research activities for the years until 1992. Three main types of activity are envisaged: wrapping up activities, continuation of on-going long-term studies, and increased emphasis or new thrusts.

Major progress has been made in the past in the area of resource assessment. The strategy foresaw a few remaining related activities which were required to bring the work to a logical conclusion. These have now largely been completed.

On-going long-term studies will be continued in the areas of environmental impact and intensive silviculture. This involves particularly the work on nitrogen fixation and short-rotation plantations. Following the completion of the current work on developing a 'benchmark' version of the FORCYTE model, strategy for further development of the model will be reviewed carefully. Economic studies of biomass availability and utilization for energy will continue to be undertaken, taking into account regional variations in economic and production conditions.

Increased emphasis will be given to environmental impact studies. The possible effects of intensive biomass harvesting on vegetation, soil and site dynamics will be investigated. Means of alleviating or reversing any potentially negative impacts will be developed and tested.

New efforts will be made in the area of technology transfer. Over 10 years of the ENFOR program, considerable information has been generated, much of which has not widely disseminated. The results produced and the technologies developed must be brought to the attention of potential users, or at least made available in a format which will be readily accessible as and when the economic situation enhances the attractiveness of forest biomass as a source of energy in Canada. Technology transfer will be accomplished through improving access to the factual information already produced. One or more summaries of program accomplishments will be published. Participation by researchers in seminars and workshops, such as this one, will be encouraged.

Prompted initially by skyrocketing oil prices in the 1970's, Canadian research on forest biomass production over the past ten years has resulted in the development of considerable knowledge and improved technologies in this alternative and renewable energy source. This research and development will continue to fully elucidate what is required in order to produce and collect forest biomass for energy in an effective, efficient and environmentally sound manner.

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CONCLUSIONS AND RECOMMENDATIONS

Joint Workshop of IUFRO P.1.09.00. and IPC/FAO Ad-Hoc Committee on Biomass production Systems in Salicaceae, Beijing, September 5-7, 1988.

CONCLUSIONS AND RECOMMENDATIONS

1. Multipurpose tree production systems are not well defined. This creates problems in proper application and delays the creation of a necessary data base. We propose, therefore, to:

   a) establish a framework of multi-purpose tree production systems;

   b) develop biological and engineering criteria for model systems which meet the requirements of productivity, environmental improvements and socio-economics;

   c) identify locations for model-system development and demonstration;

and

   d) identify gaps in knowledge pertaining to model systems and design research to establish a data base.

2. It is generally agreed that multipurpose production systems lack properly designed planting stock. We recommend therefore, to:

a) identify ideotype planting stock parameters for system components; and

b) initiate cooperative projects in breeding of ideotype planting stock.

3. We express our concern for the rapid deterioration of our global environment. Efficient multipurpose tree production systems can play a major role in reversing this trend. We recommend that the IPC addresses FAO with the need to support programmes in intensive reforestation, alerts public awareness of this problem and its solution, and emphasises the role which fast growing trees, such as Salicaceae, can play in this urgent major effort.

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