PREMISES OF ENERGY FORESTRY IN SWEDEN

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THE FOREST INDUSTRY LECTURES

Forest industry in north-western Canada has cooperated with Alberta Energy and Natural Resources in providing funds to assist the Faculty of Agriculture and Forestry through sponsorship of outside speakers.

During the 1976-77 term a seminar course was developed, taught by Desmond I. Crossley and Maxwell T. MacLaggan. The contribution of these two noted Canadian foresters was much appreciated.

In the fall of 1977 C. Ross Silversides was brought in for a week to visit with students and staff. During this visit he gave several talks to students, and made one major address. Copies of this major talk are available on request.

W. Gerald Burch visited for a week in March 1978, also holding many discussions with students and staff. Copies of this major talk are available on request.

Dr. Gustaf Sirén spent the first two weeks of March 1979 at the University of Alberta, visiting with staff, students, and members of the Alberta forestry community. Travel from Finland was arranged by a grant from the Social Sciences and Humanities Research Council of Canada under its program to support Visiting Foreign Lecturers to Canadian Universities. We are pleased to be able to make Dr. Sirén 's major address widely available through this printing.

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Dr. Gustaf Sirén is currently Leader of the research project Energy Forestry at the Swedish University of Agricultural Science, in Stockholm, Sweden.

Dr. Sirén received his forestry education at Helsinki University, in Finland. He completed his Forestry Officer's degree in 1947, Master of Forestry in 1949, Licentiate of Forestry in 1952, and was awarded the Doctor of Forestry in 1955.

Dr. Sirén worked at Helsinki University from 1947 to 1976, at the Department of Silviculture. Since 1964, he has also held positions at the Royal College of Forestry in Sweden. In 1966, he became Personal Professor in Silviculture at Helsinki University. In 1976 he became Professor of Silviculture at the Forest Research Institute of Finland, a position he held for two years until he assumed his present one.

Dr. Sirén is a noted international scholar, having participated in numerous conferences and study tours abroad. Topics for these have ranged over a wide area of Forestry, including Minirotation Forestry (Romania, 1974), Tree Physiology (Germany and Austria, 1973), Reforestation Biology and Techniques (U.S.A., 1972), Nursery techniques (Norway, 1966, 1970), Tropical Forestry (East Africa, 1967), Forest Genetics and Tree Improvement (Sweden, 1963), Dendrochronology (U.S.A., 1962 U.S.S.R., 1975), and several others. As well, Dr. Sirén has been involved in Expert Missions to Mexico (Reforestation and Forestry Planning, 1961-62, 1973-1976) and Iceland (Forest Establishment and Planning, 1974.)

Dr. Sirén has published widely throughout his career. Recently, he has written papers in Tree Physiology, Nursery Practices, Dendrochronology, Forest Fire Ecology, and Energy from Forest Biomass, to name but a few. Dr. Sirén is noted for his personal energies and profusion of ideas.

PREMISES FOR ENERGY FORESTRY IN SWEDEN

Introduction

The realization that it is necessary to either exploit or produce domestic sources of energy to replace the imported oil has slowly but surely gained ground in ever widening quarters in Sweden during the years 1976-78. Agreement also seems to have increased somewhat concerning the potential exploitation of as many alternative production systems as possible. The diversity of such systems, i.e.: solar, wind, biomass, etc., both in size and type will help to spread the risks of energy supply to promote continued access to valuable oil in the future. These alternatives ought naturally to comply with reasonable demands for environmental protection and economic profitability. A certain proportion of the energy at present generated by oil will probably be replaced by nuclear energy if the remaining problems can be resolved. The supply of low-value energy for example household heating, motor vehicles, machinery in agriculture and forestry, vital reserve capacity and long-term storage for emergencies should, however, be secured by means of direct oil-substituting energy sources.

Domestic fuel, thanks to its versatile convertibility, becomes an interesting resource in this respect, rendering possible the cheap decentralized production and storage of energy with consequent reduced risks of a catastrophe. A fraction of the need can be met by known supplies of waste products from forestry, agriculture, and society in general - but a fraction only. The lion's share must consequently come from other resources. It is in this respect that energy forestry has appeared as a possibility for the production of raw material to replace oil. This alternative is completely and in all respects independent of foreign imports.

In the following I shall examine some of the most important premises for such an area-dependent production of biomass for energy.

Abiotic prerequisites

Of the complicated biological processes which give rise to forest stands photosynthesis provides the basic process for the storage of solar energy. Photosynthesis is nature's still unrivalled method for transforming the combustion products of water and carbon dioxide to energy-rich organic matter. Photosynthesis also requires certain abiotic and biotic conditions to render possible the life processes.

Of the abiotic requirements the macroclimate is on the whole unalterable. On the other hand, a forest farmer with some biological knowledge can influence the microclimate, primarily the degree of solar energy exploitation. In conventional conifer forestry at our latitudes (55°N-70°N lat) the average conversion of total incoming radiation to harvestable wood is only about 0.15 per cent. This corresponds to I thermal kWh m-2 (= 10 MWh ha-' = 2.5t DM ha-' year-' = 4-5 m3 solid volume ha-' year-').[1]

In young broad-leaved stands the conversion efficiency is somewhat better; annual yields in virgin willow stands may reach the magnitude of 10-15 cu. m or about 5-6 ton dry matter per hectare. The low level of present conversion does not depend in the first instance on

[1] DM = tonne dry substance (matter).

insufficient supplies of solar energy, carbon dioxide or total precipitation but has, as a rule, other causes. A short, cold growing season is however the dominant factor in the interior of Northern Sweden.

It is interesting to point out that if we could develop about 2 percent converting capacity of the solar energy available in the greater part of the country during the growing season (i.e. ca 600-700 kWh m-2), it would result in a harvest in the order of 24-28 tDM ha-' . This corresponds to about 1.5 percent conversion of the total annual incoming radiation. This is ten times greater than in conventional forestry, and the energy quantity converted corresponds to about 10 toe ha-' year.[2]

The basic working hypothesis of the energy forest project is that through a suitable choice of the species and clones together with ecophysiologically optimized cultivation methods, a net conversion of at least 2 percent of the total incoming radiation or organic energy in the form of harvestable wood can be achieved.

With regard to the climatic conditions within the country we can note that in both the coastal area of Northern Sweden and the whole of Southern Sweden the necessary combination of good light supply, heat and water is available over a sufficiently long growing season. A possible exception is the low precipitation during early summer in south east Sweden. Of course the occurrence of frost has limiting effects on the utilization of southern clones.

The soil water regime and the regional hydrology are other abiotic factors of great significance for the outcome of the harvest. Good continuous supplies of water to the crop means good provision of carbon dioxide to the relevant leaf tissue by way of the undisturbed functioning of the stomata.

The root zone of the soil should contain a rich supply of oxygen to ensure efficient root functioning and enable optimal uptake of water. This implies a simultaneous need for both a rapid gas exchange in the soil and good access to water. Carefully balanced drainage where there is a risk of a high ground water level, together with soil treatment procedures adapted to the structure of the soil can produce relatively durable soil structures which largely meet the requirements of the present working hypothesis.

If, in intensive cultivation, a suitable ground water level (40-70 cms) cannot be maintained during a long drought then some form of watering should be used. In order to save water and energy it is advisable to cultivate highly productive species and clones which have a low water requirement even with good functioning of stomata.

Rapid methods for the determination of the carbon dioxide and oxygen content of the soil's air supply have been developed, and a clear relationship between low wood production and low oxygen content (or high CO_2 content) has been found.

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[2] toe = tonne oil equivalent

The preservation of optimal physical soil conditions presupposes harvesting machines which exert as low pressure as possible on the ground. The possible detrimental effects of harvest-machines can also be reduced by suitable spacing. Long rotation periods likewise leave the soil free from overly frequent visits from heavy harvesting machinery and transport vehicles which would destroy both the roots and the soil structure.

Misgivings have been voiced over the hydrological problems that would result in certain regions from the heavy consumption of water that energy forestry entails. With respect to the water flow in the larger rivers of Northern Sweden the misgivings seem somewhat exaggerated and cultivation in the coastal areas can hardly influence the important water supply for the power industry in the upper reaches of these rivers.

In southern Sweden also the evapotranspiration effect can be expected to be marginal according to the present working hypothesis. Proportionally low land utilization combined with a relatively small increase in the water usage through energy forests can be assumed to lead to a barely measurable reduction in water flow during summers with normal levels of precipitation. The situation could, however, at least locally, be different during dry summers. By means of special hydrological studies it seems possible to prescribe the highest possible proportion of land to be given over to energy forestry and thereby reduce the risk for overexploitation of the water resources.

Biological prerequisites

The most important biological prerequisites for successful energy forest cultivation are the plants themselves. Through rigorous selection procedures extremely fast-growing, hardy, resistent, energy-rich and easily cultivated clones can be produced. These clones, which can be vegetatively propagated, are primarily from domestic deciduous species. They are characterized, among other things, by a high net effect of photosynthesis and practically waste-free nutrient utilization. Advanced ecophysiological research is dealing with the effect of both different combinations of varying levels of water and mineral nutrient access and also the light and temperature conditions on the fundamental organic production processes - i.e. photosynthesis and respiration. This is being carried out for various willow and poplar clones. Alders and birches will be included later on. These reseach efforts are expected to give important base information for the choice of initial clones for the imminent genetic breeding programme.

Efficient nutrient consumption is an important requirement for successful energy forest cultivation. By adapting the supply to the crops' actual ability to absorb nutrients, the risk for environmental contamination by minerals is reduced practically to nil. Since it is leafless trees that are harvested, the nutrients contained in the leaf litter remain in the biotope. By replacing the nutrients lost through the harvested crop, in the form of ash (+ complementary fertilizers), the natural cycle is assumed to be fully restored.

After the energy plantations have been established it seems possible, based on experience to date, to operate with lower quantities of added nutrient than are used in agriculture. With cultivation methods based on the recirculation of nutrients there is hardly any risk of impoverishment of the soil. Perhaps an important question should be put to the manycritics who have so willingly lent their voices to the spread of negative information about assumed impoverishment: How does one impoverish low quality peat?

It is in fact the case that the energy forest is expected to become to a large degree the crop of the peat bogs. Many cultivators in the country are masters of the art of cultivating on enriched peat. Forestry plants have successfully been cultivated on peat without a hint of soil impoverishment when relevant knowledge of soil biology has been heeded.

The nitrogen supply is an important factor in this connection. In order to avoid unnecessary losses of nutrients the supply of nitrogen and other fertilizers has been quantitatively regulared by the clone-specific growth rate of the leaf area index. Nitrogenous fertilizers are however expensive, as is the repeated distribution of water-borne nutrients. The basis for a biologically durable, environmentally safe, and economically profitable energy forestry would probably increase in a decisive way if the required nitrogen could be supplied to the growing crops continually by means of biological nitrogen fixation. The answer to this important problem may eventually be the cultivation of consecutive populations of blue-green algae, shade tolerant legumes, alder, and other higher plants. This solution presupposes that no unexpected side effects occur with this point cultivation. These questions are literally under the microscope within the energy forest research project.

Biological and Technical Prerequisites for Cultivation

It has previously been mentioned that rigorous selection procedures have given rise to extremely productive clones. However, different cultivation environments make varying demands on species adapted to different biotopes. It is therefore necessary to quickly broaden the sample of clones, especially with respect to climatic hardiness, wood density and root functioning in unfavourable environments. Good rooting propensity is a desirable but not definite requirement since this can be achieved by short term external measures and hormone treatment.

What is important is that the imminent clone collection campaign planned to take place over the whole country gives good results, especially in the north of Sweden. The need for drainage can be considerably reduced by the use of wetland clones with effective air conducting tissue in the roots.

These clones can enable drainage to be dispensed with completely in certain wetlands, for example in those that border on areas where the need for nature protection prohibits any hydrological changes in the vicinity.

Effective selections of domestic clones yields substantial advantages compared to the introduction of foreign ones. These advantages primarily concern climatic hardiness and resistance but also include the use of polyculture which subsequently blends more easily into the natural landscape. Only plantations for the production of cuttings need to strictly follow the rules for extremely pure monocultures.

The establishment of energy forest stands must fulfill certain minimum demands. To avoid the use of environmentally unsuitable weed killers the cultivation plots must, after possible water regulation, be fallowed with great care. A well tended fallow allows the use of short cuttings and mechanized planting. Otherwise long cuttings (50 cm) and probably manual methods must be used. Direct seeding may be a cheaper option in the case of fast growing birches, especially if the seed is produced in germination promoting orchards.

In addition to fertilizing poor quality soil it is advisable to adjust the pH value to around 5.5-6.0 before establishing stands, in order to optimize nutrient uptake. Fertilizing according to the increase of leaf area index can be undertaken after shoot formation. It remains however, for present and future field trials to determine whether nutrient supply is in practice to be water borne or through the more or less conventional spreading of solid fertilizers and ash - e.g. just before predicted rains.

As far as the use of sewage sludge is concerned, suffice it to say that pilot studies (carried out in conjunction with a fertilizer company on sites recommended by the relevant authorities) justify continued efforts in this direction. Sludge application on land which does not hold ground water for human consumption, repeated at intervals of several years, should probably increase the land area available to energy forestry by several tens of thousands of hectares. At the same time it would provide a cheap and lasting solution to a social-hygenic problem as well as recirculating otherwise waste materials. Sewage sludge can be spread over the stump fields in established plantations after the snow has melted.

The spacing of the plantation is governed not only by the size of the cuttings but also by the harvesting intervals and rotation period. Sparse spacing (i.e.<10,000 cuttings/ ha) gives low establishment costs but a long establishment period and small harvests during the first years. On the other hand it is not ruled out that the rotation period can be longer than the oft quoted 30 years. Re-establishment of stands which show too many expired stools can probably employ new (and hopefully better) clones after the necessary ground preparation and nutrient control. Consistent management of the natural nutrient cycles should prevent not only impoverishment of the soil but also imbalance between the nutrient components themselves.

The practical management of established energy forest stands has a single main aim: to optimize production. This implies in practice a certain level of weed control during the period after establishment as well as control and regulation of the land's water economy and nutrient supply. The need for ecophysiological and technical knowledge on the part of the cultivator is substantial but not unreasonable. Training courses for all categories of proposed cultivators is expected to be an important requisite for successful cultivation.

Something can now be said concerning preventive measures against various kinds of calamity.

Clones which are attacked by leaf-destroying fungi during the actual growing period are already rejected at the preliminary clone selection stages as are clones which show a propensity to be attacked by pests. Bearing in mind future cultivations the relationship between insectivorous birds and energy forest stands will be documented and exploited. If the results from research under way in Finland are positive then even the control of excessive vole populations is expected to fall to biological methods: that is, through the use of half domesticated ferrets in southern and central Sweden and of weasels and stoats in northern Sweden. With the exception of possible shelterbelts against snow and wind erosion the energy forest plantations are hardly likely to increase the frequency of wild animals along main roads. Detailed studies carried out by wildlife management experts will in time provide information on increased accident risk.

From among the other oft quoted environmental consequences I will but concern myself with two phenomena with socio-medical implications. The first concerns allergies. Pollen has allergic effects on certain people. If anti-allergen medicine proves to be inefficient then actual energy forest cultivation can be limited to annual crops, or if longer rotation periods prove to be necessary then clone selection can concentrate on highly productive female clones. Increasing distance from the plantation probably has a certain favourable effect too. The second problem concerns the fear that minerals will soak through to the ground water and other water courses. A central feature of the research project which today is fully employed in the study of various aspects of energy forest cultivation has been to effectively prevent such leakage. Some of the relevant questions have been taken up earlier. One viewpoint should however be added: by establishing energy forest cultivations on organic soils (for example peat land and sedge mires) the risk of leakage is further reduced - especially if unavoidable local drainage can be carried out by means of a suitable type of tunnel ditch.

My remarks have now brought me to a problem which has aroused a great deal of interest during the last few years and has attracted contributions of varying value: the question of biotope selection and available area. The areas of peat land and wetland suitable for energy forest cultivation comprise 1.4 million hectares; the areas of suitable productive forest land (including abandoned agricultural land) comprise 1.5 million hectares, giving a combined total of 2.9 million hectares. (Fig. 1).

In previous evaluations a concern over nature and environment protection and over the raw material base for the existing forest industry has greatly reduced the potential land judged to be available. The evaluations based on existing inventories have mainly applied to peat land and abandoned agricultural land. The only forest land included in the total area, which at different times has varied between 1.3 and 1.6 million hectares, has been a rough estimate of marginal areas difficult to regenerate, e.g. frost-plagued land, herb-rich fertile land, etc. Certain wetland low-productive land can increase the total somewhat.

To be confronted in this connection with expert opinions concerning the potential area available for cultivation from e.g. social psychological quarters, generously amplified by the media, is perhaps typical of our time but hardly of great moment in the factual debate. The claim that Sweden must wait until the next interglacial period to find suitable areas is naturally entertaining but ought to have quite limited effect on Swedish energy production in the 1990's. This type of negative information can, with some likelihood, have serious consequences, a point to which I will later return.

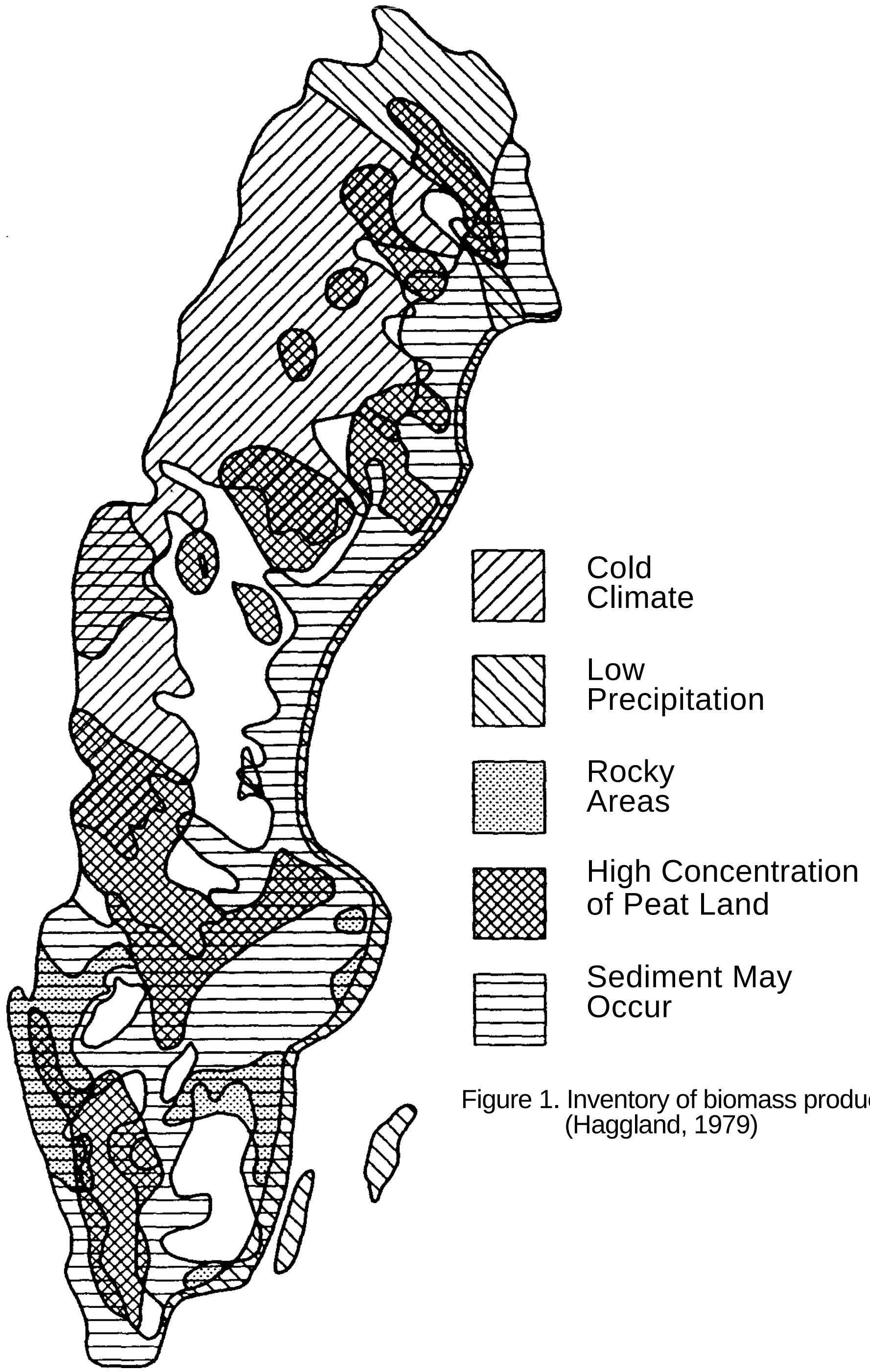

Figure 1. Inventory of biomass production land (Haggland, 1979)

Technical and Economic Prerequisites

It has been clear from the beginning that eventual energy forest cultivation on a large scale must be based on highly mechanised cultivating and harvesting techniques. Concrete contacts and cooperation have already been established to exploit this knowledge but need to be further broadened. This applies, among other things, to the net energy output from intensive cultivation and profitability analyses of energy forest cultivation in micro, macro and intermediate scales. A preliminary cost analysis of large-scale intensive cultivation shows that good profitability compared with heating oil is achieved even with production as low as 10 ton DM per hectare. This presupposes short distances <10 miles from plantation to point of consumption and favourable growing conditions, both of which reduce costs. Certain information on profitability is available in Figure 2.

Energy balance studies show that the input-output relationship is 1:10 for intensive energy forest cultivation.

Prospects for harvesting machines to operate on solid ground seem justifiably linked to processors of sugar-cane harvester type. Wetlands will however require harvesters exerting low pressure on the soil and for the case that harvesting has to be carried out on unfrozen ground. On the establishment side a highly effective planting machine is needed. A prototype exists - if 15,000 cuttings per man-day is satisfactory. Higher productivity seems possible however.

The possibilities of micro and small scale energy forest cultivation can only be mentioned here in passing. In an energy conscious future there will be a place for the cultivation of fuel for household needs. Hedges and wind shelters can be made to produce extremely good harvests per unit time and area.

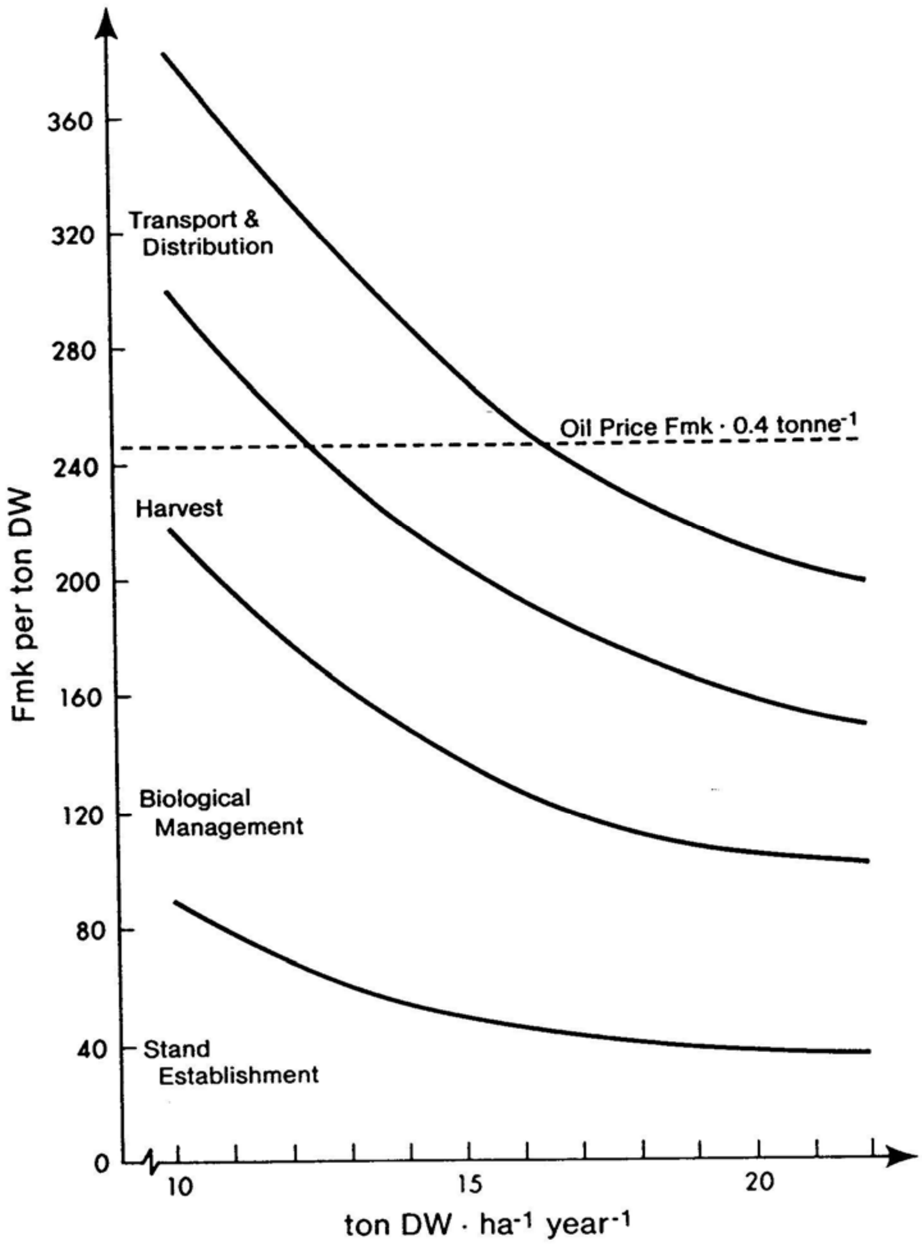

Figure 2. Price-production relationship in energy forestry
average transport distance 70 km

Social Prerequisites

It ought to be taken for granted that large scale energy forest cultivation should come to have a substantial effect on employment in country areas. A plantation in the order of 100 hectares would probably give full employment to 2-3 people in the primary production phase from planting to the final delivered raw material. Of this crew, one would be employed for conversion and local distribution. A million hectares would in other words offer 20,-30,000 people the chance of profitable employment in their own neighbourhood. Work, moreover, that has many highly activating qualities: personal control over one's working situation and awareness of one's relation to the overall project, variation and social contact in daily routine, the possibility of choosing one's immediate surroundings and above all, the chance to experience responsibility and the pleasure of working with growing crops. Such work requires solid training but should no less for that suit many young people, who accept working in the open.

Here in Alberta, I wish to end my presentation showing a few slides, which may give the audience some information about the present position. The selection of clones has so far resulted in approximately 10 superclones that are supposed to produce >20 tons DM ha-' year-' (Fig 3). The best five may reach the level of >25 tons, which corresponds to 10 toe ha-' year^{s} . However, we are still in the initial stage of our research project. Whether our results have any applicability or not to the conditions here in Alberta is far outside my competence to judge. I wish however that you may get a good solution to the utilization problem on your large aspen forests as soon as possible.

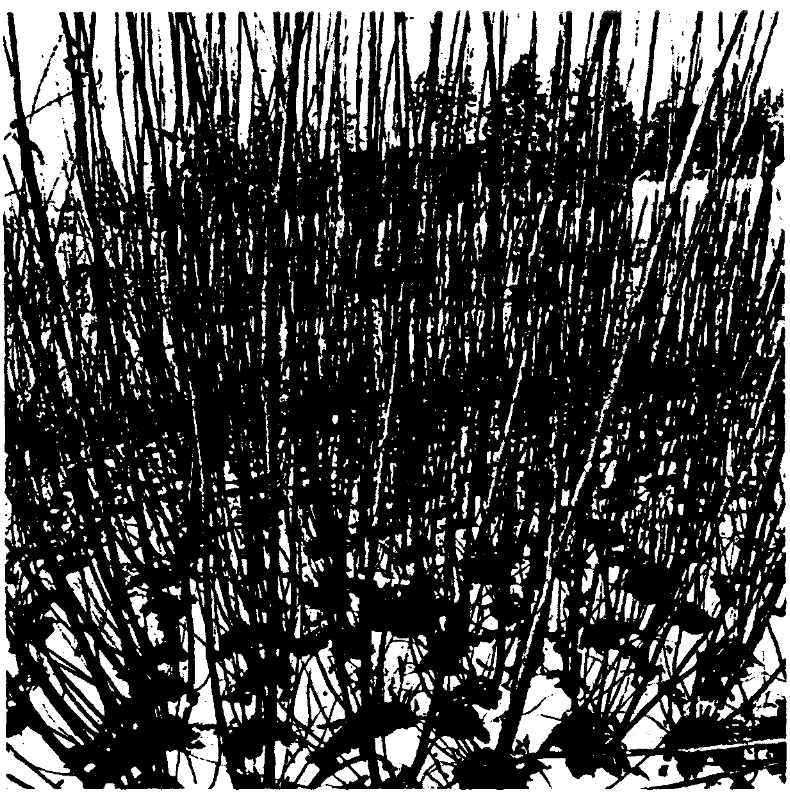

Figure 3. One-year old *Salix viminalis* stand on three-year old stools. Annual dry matter production exceeds twenty tonne per hectare. Central Sweden

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