

# Food and Wood for a Sustainable Future

- Challenges for Soil Fertility Management



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# Food and Wood for a Sustainable Future

- Challenges for Soil Fertility Management

Report from the international conference  
at the Royal Swedish Academy of Agriculture and Forestry  
February 8, 2005



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## Preface

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Preserving soil fertility is crucial for sustainable agriculture and forestry. The Foundation for Swedish Plant Nutrition Research (SV), associated with the Royal Swedish Academy of Agriculture and Forestry (KSLA), has been working with this in focus during its 50 years of activity.

In order to manifest this, the conference Food and Wood for a sustainable Future – Challenges for Soil Fertility Management was organised.

Competent keynote speakers and distinguished lecturers were invited. We are much obliged to all of them and particularly to the speakers from foreign countries, Professor Eric Smaling from the Netherlands and Dr A. E. Johnston from the United Kingdom.

The main reason for establishing the Foundation was that plant nutrition research in Sweden in the beginning of the 1950s was restrained by limited resources. Soil fertility scientists repeatedly challenged the fertiliser industry for research funds.

After an investigation made by the director of the National Swedish Agricultural Institute, professor Erik Åkerberg, the three Swedish fertiliser companies established the Foundation in 1954 in order to “make clear” the rational use of fertilisers, particularly the chemical fertilisers. Its first chairperson was Professor Robert Torssell, Secretary General of KSLA.

Since then the fertiliser industry and sometimes other interested organisations have yearly contributed to the Foundation.

It is easy to find that many things have changed when looking into the past 50 years. It is much more difficult to foresee what will happen the next 50 years. One way to get an idea of the future is a conference like this one, where distinguished and forward looking experts contribute. A warm thank you to all speakers and participants.

*Bruno Nilsson  
Secretary General and Managing Director  
of KSLA and chairman of SV*

## Sustainable food security

ERIC SMALING, PROFESSOR, INTERNATIONAL INSTITUTE FOR GEO-INFORMATION SCIENCE AND EARTH OBSERVATION (ITC), ENSCHEDE, THE NETHERLANDS

KEN GILLER, PROFESSOR, PLANT PRODUCTION SYSTEMS GROUP, WAGENINGEN UNIVERSITY AND RESEARCH CENTRE, WAGENINGEN, THE NETHERLANDS

Professor Eric Smaling's keynote speech was based on a power point presentation. A summary of those pictures are published on the following pages.

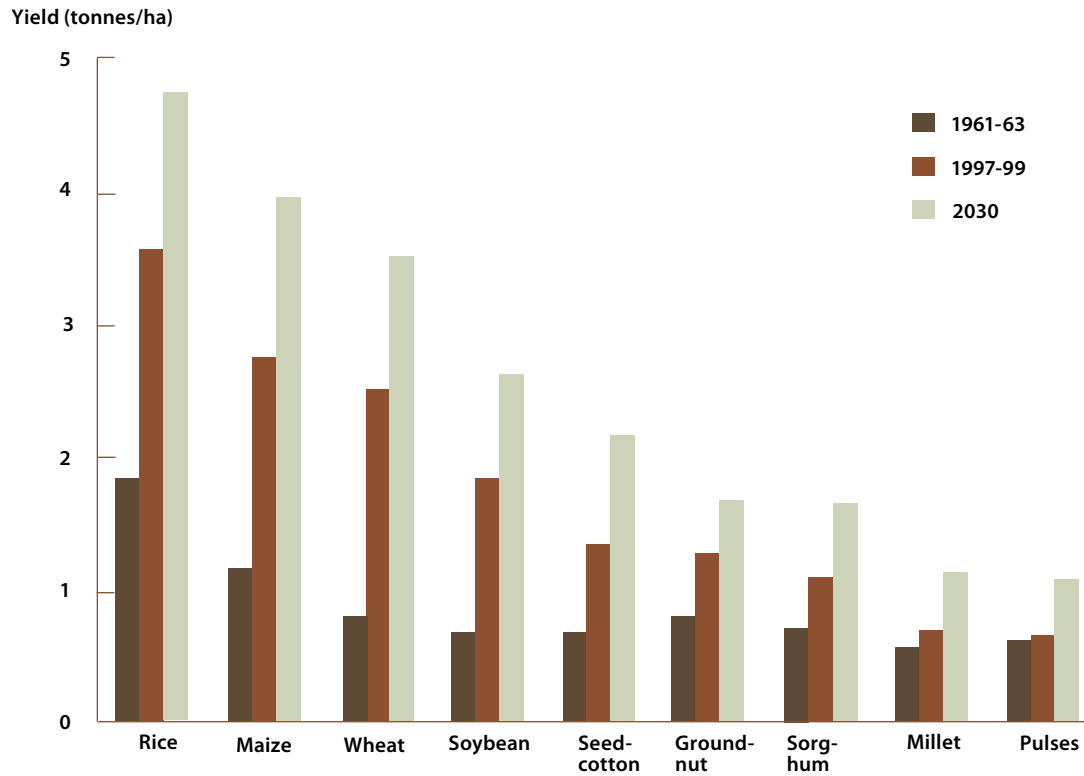
Professor Smaling stated that there are conceptual tensions:

- Sustainability: principle of 'intergenerational equity'
- Future resource quality should at least be equal to present quality
- Future food production should be 1.5 times present production
- Food chain is NOT a cycle: it leaks!

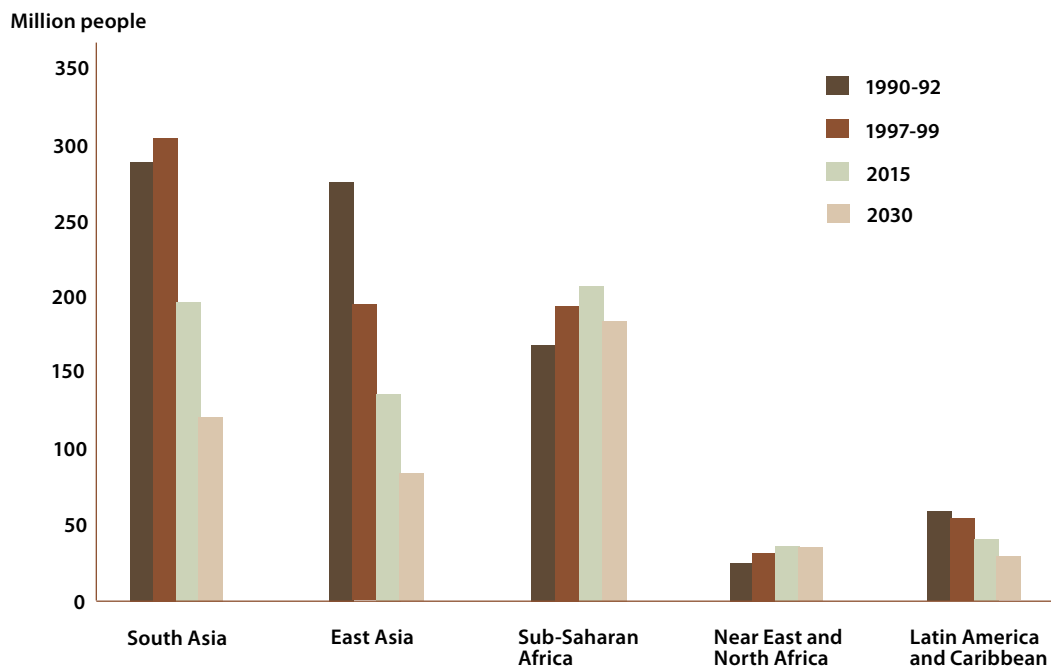
There are conceptual tension between production and conservation:

Production	Conservation
Direct incentives	Indirect incentives
Benefit/cost clear	Benefit/cost unclear
All costs are private	Private + social costs
Change is visible	Change less visible
Change can be quantum-leap	Change mostly incremental
Private sector interest high	Private sector interest low

## Yields increase but slower



## Malnourished people in the world



*Africa remains malnourished during the coming 25 years.*

### Achievements in African agriculture

- **Maize**  
47% of area improved varieties, yield gains 40%, 5-10 M small farms benefit.
- **Cassava**  
10-15 M small farms benefit, mosaic virus, mealy bug control, very high benefit/cost.
- **Horticulture**  
500 000 Kenyans benefitting, exports in Zambia (15 yrs) from 3 to 24 million USD.
- **Rinderpest**  
1.8 USD income/1 USD costs of vaccin program.
- **Banana**  
60 cultivars by mid-20<sup>th</sup> century, >25% of caloric intake in central highlands.
- **Cotton**  
Production and export growth 6.5% per year over past 40 years.
- **Rice**  
NERICA, SRI yield increases.

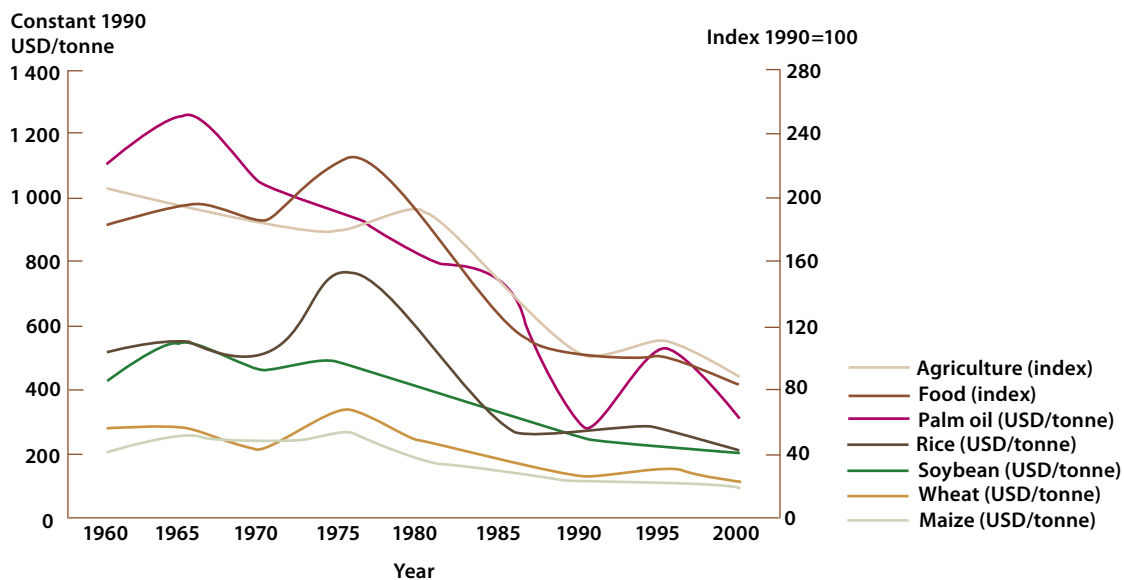


## Change in demand of meat and milk in North and South and export change from North to South

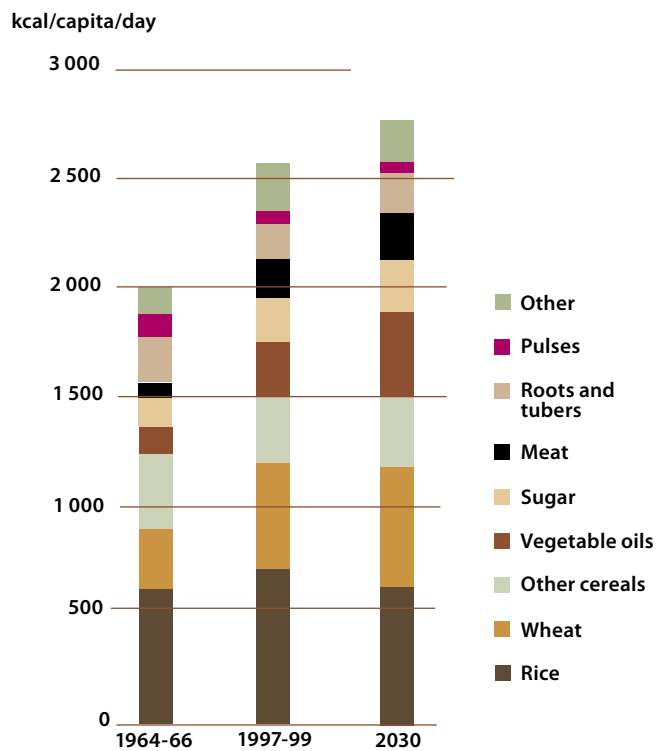
	Demand change (%)		Export change (million tonnes)
	North	South	North to South
Beef	+12	+92	+1.2
Poultry	+34	+131	+3.2
Pork	+8	+72	+1.4
Milk	+10	+84	+33.7

The demand of meat and milk and export of milk from north to south.  
Source: IFPRI (2001)

## Food is cheap



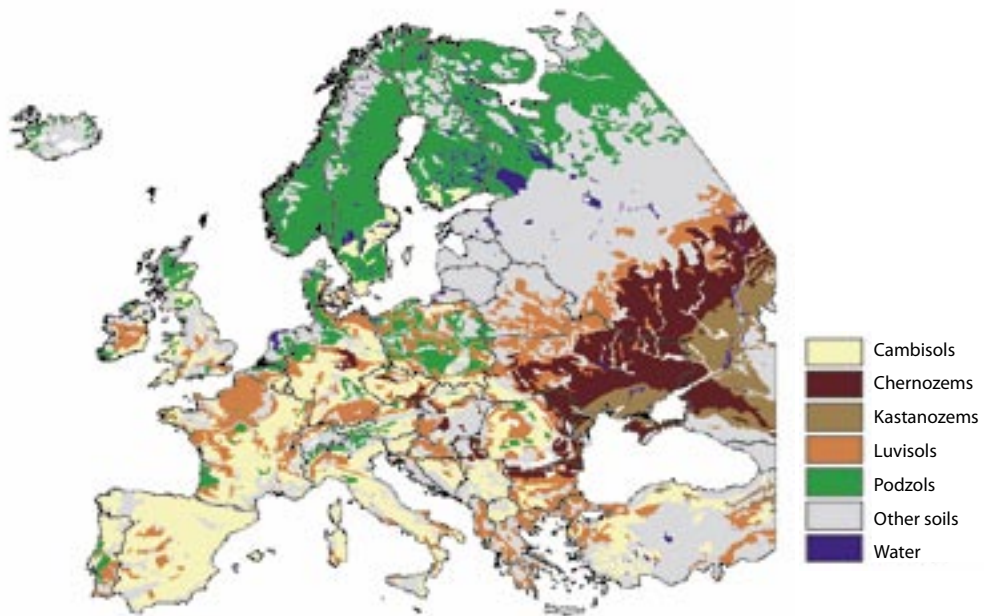
## Food habits change



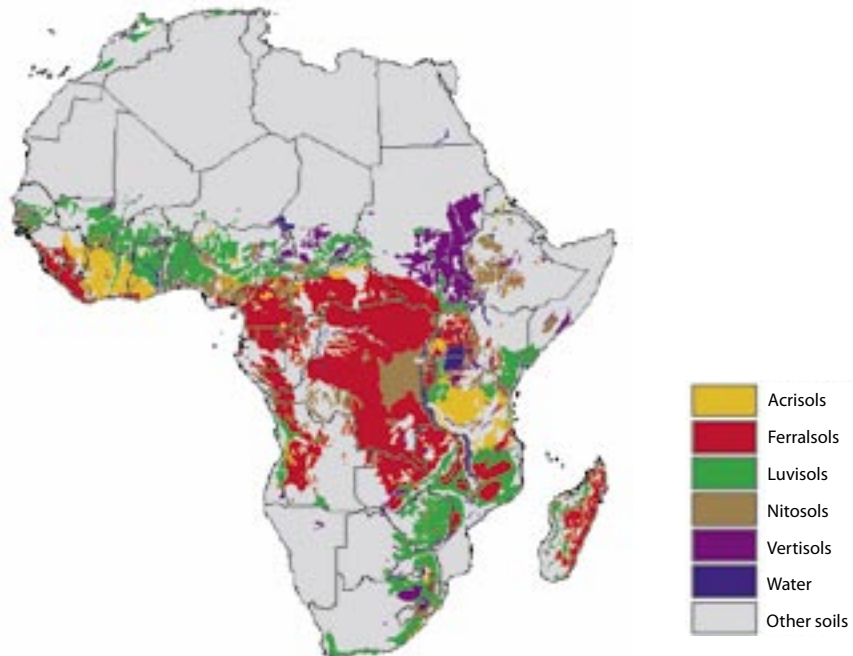
Drivers of sustainable food security:

- Natural resources
- Science and technology
- Trade liberalisation and markets
- Public goods and institutions
- Information and human capital

## Major soils in Europe



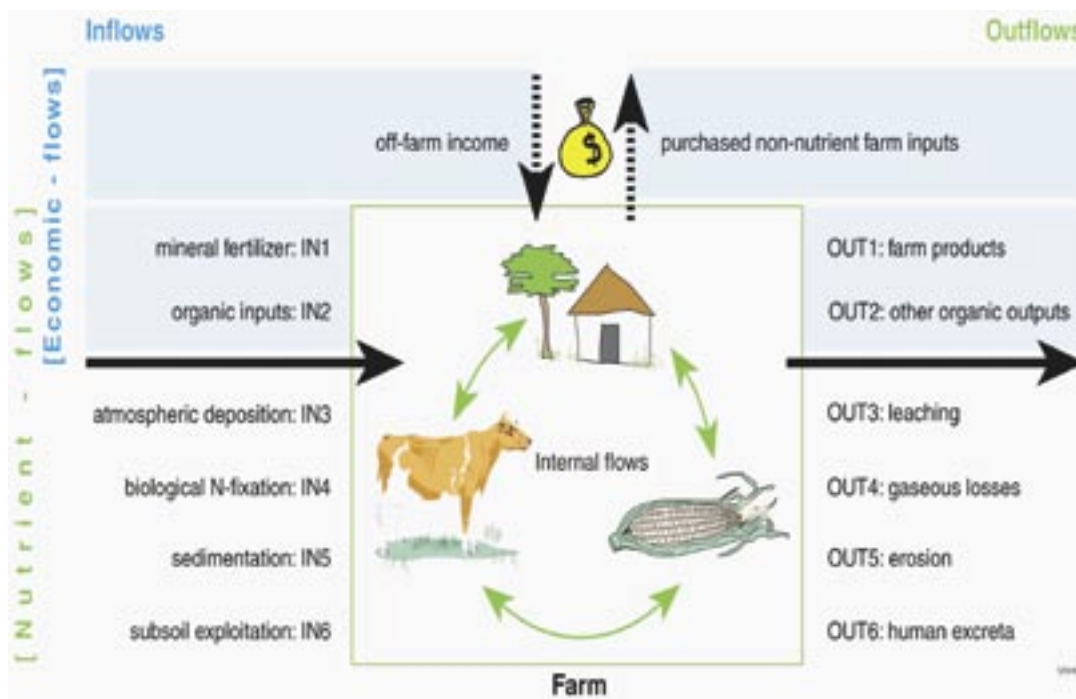
## Major soils in Africa



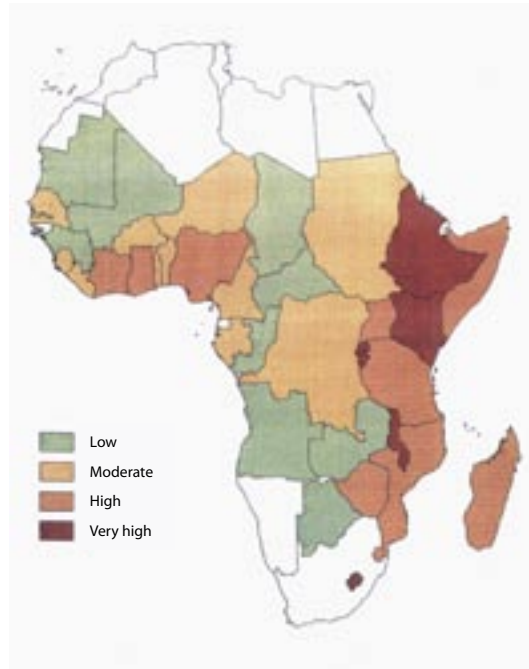
## Major soils in Europe and Africa

EUROPE	Area (* 10 000 km <sup>2</sup> )	Org. C (%)	pH
Cambisols	194	2.6	6.3
Chernozems	95	2.2	7.4
Luvisols	138	1.8	6.2
Podzols	201	10.0	4.4
AFRICA			
Ferralsols	420	1.3	4.9
Acrisols	86	1.0	5.0
Luvisols	256	0.6	6.1
Nitisols	114	0.8	5.4

## Nutrient flows and balance

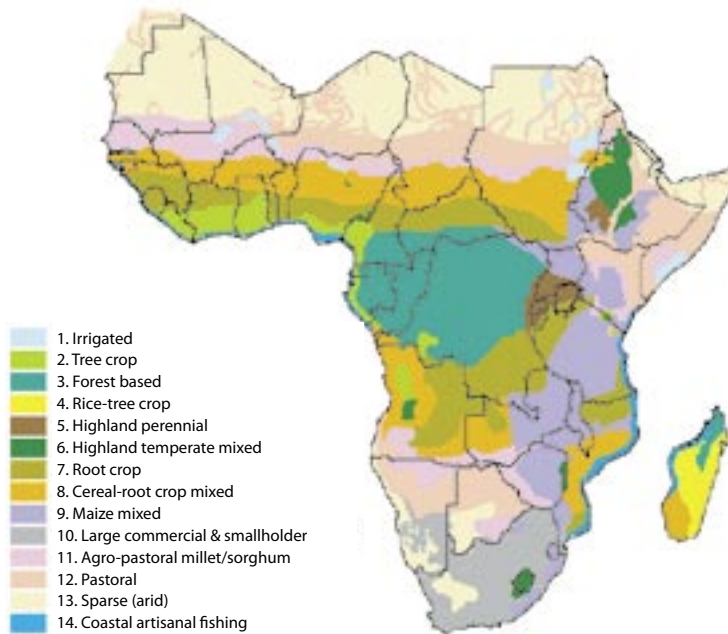


## Nutrient depletion in Africa



Source: Stoorvogel and Smaling (1990).

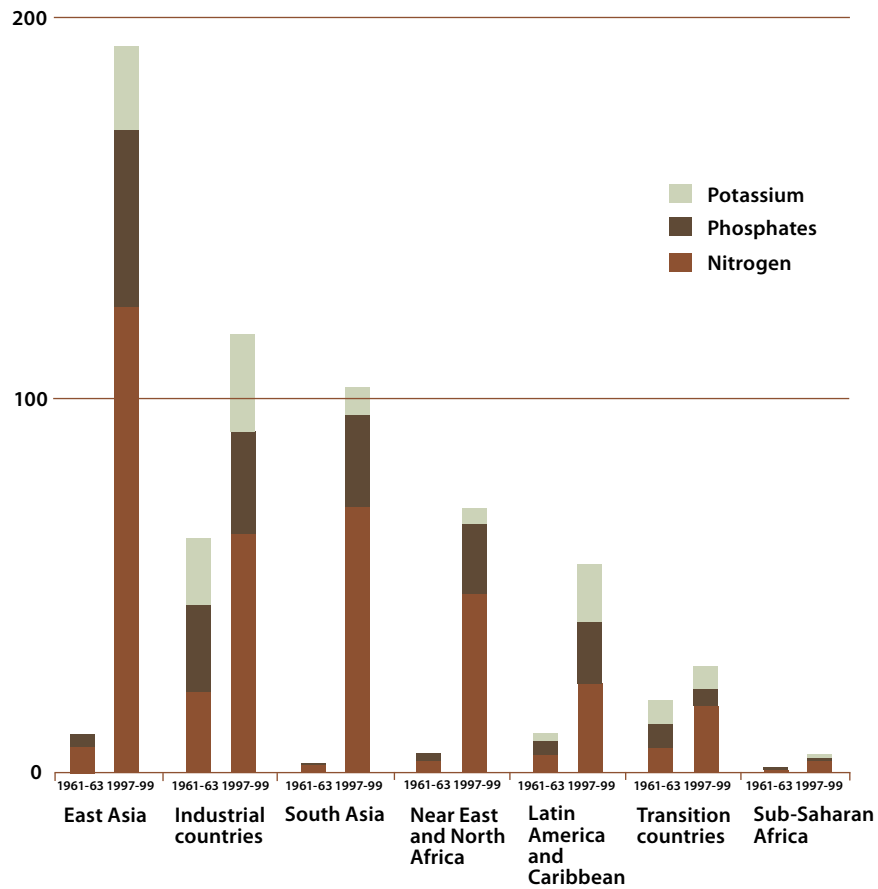
## Sub-Saharan African farming systems





### Fertiliser use in Africa is negligible

Nutrient applications (kg/ha)



### N<sub>2</sub>-fixation: Potential and reality

- Potential amounts of N<sub>2</sub>-fixed:
  - More than 90% of N from N<sub>2</sub>-fixation
  - Up to 300 kg N ha<sup>-1</sup> fixed in a growing season
- Actual amounts of N<sub>2</sub>-fixed:
  - Often only 25-50% of N from N<sub>2</sub>-fixation
  - Less than 5 kg N ha<sup>-1</sup> fixed each year

### N<sub>2</sub>-fixed on smallholder farms in Zimbabwe

Legume	N <sub>2</sub> -fixed	Area	Total fixed
	kg N/ha	ha/farm	kg N/farm
Bambara nut	52	0.08	4.2
Cowpea	47	0.03	1.4
Peanut	33	0.22	7.3
Pigeon pea	39	0.34	13.3

(Average farm size - 3 ha). Source: Chikowo, Mapfumo & Giller (2001)

### Towards sustainable food security?

#### Future for farming systems

- Area expansion
- Intensification
- Diversification
- Increased off-farm operations
- Exit-agriculture

- Policies
  - Information technology and services
  - Market access
  - Fertiliser subsidies
  - Capacity building

#### Options for investment?

- Science and Technology
  - Breeding and biotechnology
  - Water and soil management
  - Weed, pest and disease control
  - Integrated crop and soil management

#### Open questions

- Scale matters! General statements have no value.
- How to marry success story optimism vs. pervasive aggregate pessimism?
- Is 'structural food aid' looming in Sub-Saharan Africa?

# Is nordic forestry heading south?

BJÖRN HÄGGLUND, DEPUTY CEO, STORA ENSO, UK

## Is nordic forestry heading south?

New areas in the Southern hemisphere are becoming available for sustainable forestry in a broad sense of the word, i.e. economic, environmental and social sustainability. Is this a threat to the economic sustainability of the established forestry in the North?

Mr Hägglund underlined that the cost of production is the driving force in this movement towards the South. - "If we can sell something for 1 US dollar, it makes a big difference whether we can produce it for 92 cents or 95 cents".

The steadily increasing demand in the emerging markets is another key for the future (figure 1). In China, the consumption of paper and board will almost double from the year 2000 to 2015. In Brazil, the increase will be roughly 30% and in Russia consumption will more than double during the same time period. The interesting part is the large increase in per capita consumption. During these 15 years, the Russian population will actually decrease, while the total demand of paper and board will double.

## Demand growth in emerging markets

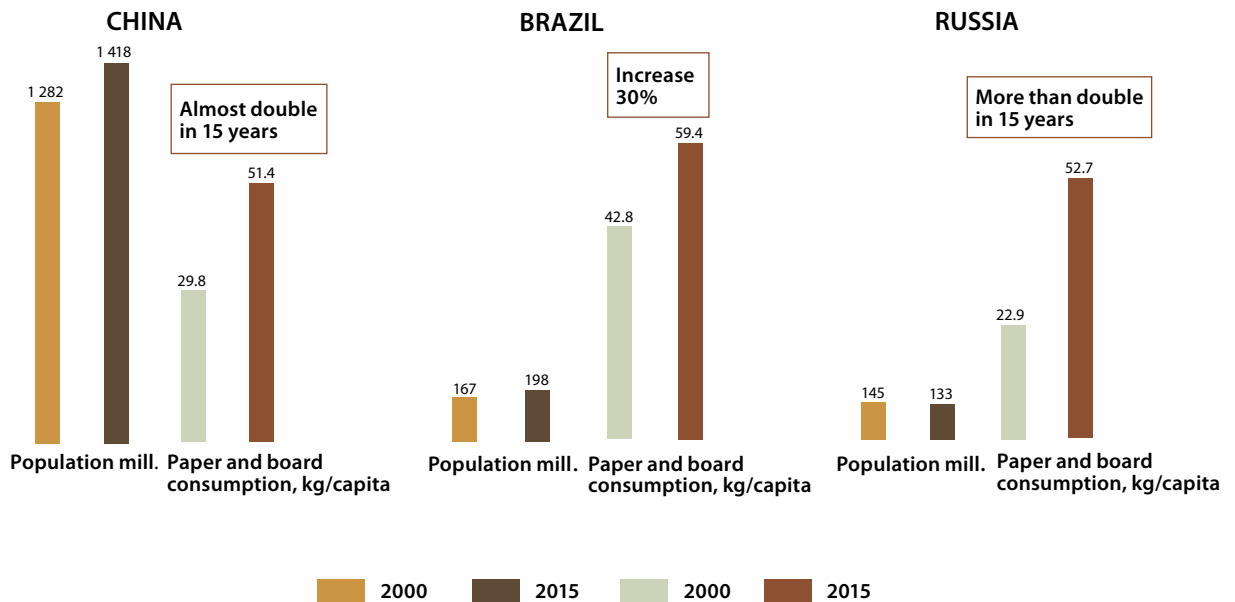


Figure 1 In China, the consumption of paper and board will almost double from the year 2000 to 2015. In Brazil, the increase will be roughly 30% and in Russia consumption will more than double during the same time period.



Because of increased consumption, there will be a dramatic increase in paper and board production in Asia, especially in China (figure 2). In China alone, the forecast is an increase in production of 30 million tonnes of paper and board. Sawn products will most likely be imported on a larger scale. However, China has very limited forest resources, so the wood, sawn timber, waste paper and pulp needed for expansion will most likely originate from South-East Asia, Eastern Russia and South America.

South America today offers the best possibilities for low cost wood production. Plantations of Eucalyptus are established and the trees are harvested after 5-7 years.

The industrial cost is four times lower in Brazil compared to Sweden. This is why the

money that the industry has earned in Sweden, Finland, Norway and Russia is being invested in the South, e.g. in Brazil. When deciding where to localize new pulping capacity, the following factors determine the choice:

	North	South
Wood cost	-	+
Labour cost	-	+
Energy cost	+	-
Distance to markets	+/-	-/+
Local skills	+	-(improving)
Political stability	+	-(improving)
Greenfield potential	-	+
Brownfield potential	+	-
Environmental risks	+/-	+/-
Social risks	+	-

These ten factors lead to two different paths

### Paper and board production - change 2001-2015, million tonnes

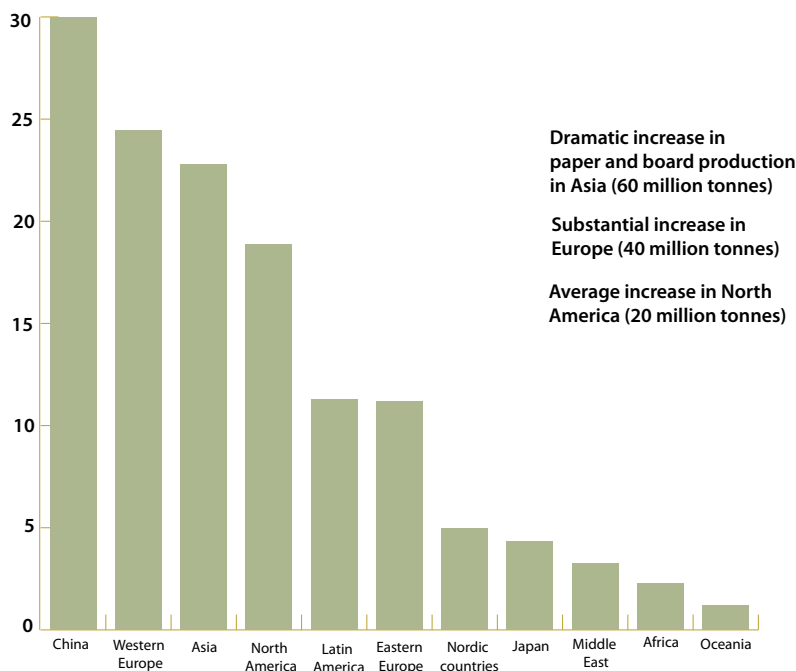


Figure 2 Because of increased consumption, there will be a dramatic increase in paper and board production in Asia, especially in China. Source: Jaakko Pöyry.

when discussing investments.

1) Existing capacity is run as long as it is cash flow positive. This means that existing capital-heavy industries in decent shape will continue to be run even when wood prices are high.

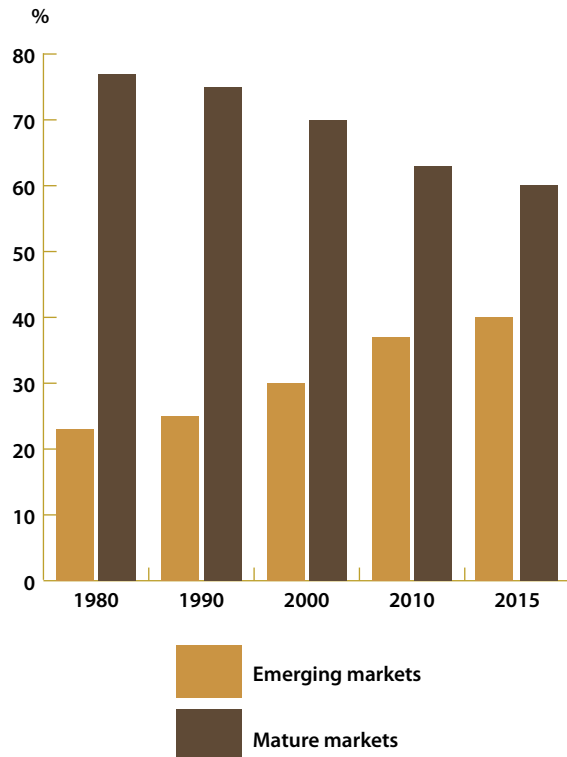
2) New capacity is built where total cost of product to market everything included is as low as possible.

This means that high wood prices will not immediately lead to the closedown of existing pulp and paper industries. For sawmills, where wood is a much higher part of the total cost, the sensitivity to high prices is more direct and

immediate. In addition, in all cases, when wood is too expensive, growth and renewal of the industry will take place somewhere else.

The question arises whether the Nordic areas are protected through the unique qualities of their wood. The answer is both yes and no. For timber, this protection is substantial to a large extent, but Russia will be a threat if its activity is increased. For paper and pulp, the big differences in costs between North and South will lead to big price differences between northern and southern pulps. This will in turn lead to substitution and R&D creating new pulps. A

### Paper and board production



### Market woodpulp production

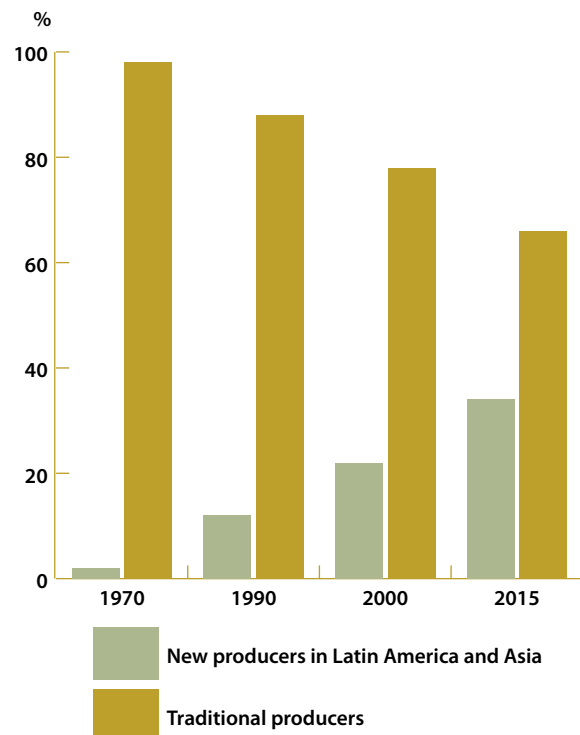


Figure 3. In paper- and board production, the mature markets contributed to approximately 80 percent of the production in 1980, whereas the forecast is down to 60% in 2015. The emerging markets have thus increased their share from 20 to 40%. Regarding wood pulp production, the situation is even more dramatic. From having produced only 2-4 percent of the wood pulp in 1970, more than 30% is predicted to be produced in Latin America and Asia in 2015. Source: Jaakko Pöyry Consulting.

conclusion regarding this is that there will still be unique niches for Nordic fibre, but they will shrink. Accordingly, there is a structural threat from low-cost production in the South. Pulp is produced at significantly lower cost (e.g. in Brazil) and paper is produced at somewhat lower cost (e.g. in China).

This threat has already changed the market situation. In paper- and board production, the mature markets contributed to approximately 80% of the production in 1980, whereas the forecast is down to 60% in 2015 (figure 3). The emerging markets have thus increased their share from 20 to 40%. Regarding wood pulp production, the situation is even more dramatic. From having produced only 2-4 percent of the wood pulp in 1970, more than 30% is predicted to be produced in Latin America and Asia in 2015.

Mr Hägglund concluded:

- Change will be slow. It will be an ongoing process but not discernible from day to day. An existing industry will run its economic life span.
- Competition and price pressure will be worst in commodities with a high wood content, which can be produced in low-cost areas, for example, hardwood pulps and bulk pine sawn timber.
- Advanced products with high and demanding specifications for wood supply and high-energy needs will have the best future, as things look now, for example liquid packaging cardboard and high-quality magazine papers.
- It is important that other input factors apart from wood, like energy and labour, are kept competitive if our forests are to be economically sustainable.
- Products and processes must be developed in the global front line. The Nordic Cluster, especially including extensive R&D resources, is an important factor here, which must be managed in a sustained way.

## Discussion about sustainability

JENS BLOMQUIST, AGRARIA ORD & JORD

*Following the first two keynote papers by Professor Eric Smaling and deputy CEO Björn Häggglund there was a general discussion about sustainability led by science writer Peter Sylwan and opened by Professors Arnulf Merker, SLU, Swedish University of Agricultural Sciences and Ove Nilsson, Umeå Plant Science Centre together with Dr Gitte Meyer, KVL, Royal Danish Veterinary and Agricultural University.*

Professor Arnulf Merker, Department of Crop Science at SLU Alnarp, began the open discussion with his personal comment on the preceding presentations on sustainability.

“Of course we want sustainability – what is the alternative?” he said.

Professor Merker then widened the conception of sustainability to comprise not only environmental but also economic sustainability.

### Perennial advantage

From his crop production point of view, there are many aspects of sustainability.

- Lower inputs of chemicals, e.g. pesticides and fertilizers
- Optimal yields, the 1 tonne per hectare produced in many developing countries is far too little
- Disease resistance in e.g. potatoes
- Perennial instead of annual crops

In the last area, he has performed his own experiments with oilseed crops undersown in spring barley.

“There are many advantages. Only one sowing, no tillage between crops, saving of energy and practically no leaching of nitrate”, explained

Professor Merker.

He is testing new wild oilseed species, trying to domesticate them for agricultural use.

“The challenge is that perenniality is a multi-gene character”, said Professor Merker.

### No pivotal question

The chairman Mr Peter Sylwan asked Professor Eric Smaling if a cultivation system including perennial crops could be of interest in Africa, on which much of his preceding presentation had focused.

“Certainly, we should aim at these systems. But at the end of the day farmers must want to change, otherwise there will be no step forward”, replied Professor Smaling.

Mr Sylwan then asked for Professor Smaling’s view on the role of science and technology in sustainability.

“Politics have larger impact than science and technology in general, but of course there are plenty of exceptions with success stories when one looks closer at African agriculture. But as a whole Africa is moving too slow”, he commented.

When Mr Sylwan proceeded with the question of subsidies in relation to sustainable development, Professor Smaling admitted that this is a problem for Africa, and added:

“We must bring Africa up to a start where it can look after itself, otherwise it will keep on being a problem”.

A deeper discussion followed of the problems encountered in Africa. Someone mentioned that the average fertilizer rate in Africa

is 8 kg nitrogen per hectare. One of the reasons for this is the cost, as nitrogen fertilizers cost four times as much in Africa as in Western Europe. The lack of infrastructure in the form of roads and harvesting facilities was also mentioned in the talks.

In conclusion, Mr Sylwan reiterated that technological solutions do exist and asked Professor Merker for the 'pivotal question'. However Professor Merker considered the situation to be more complex:

"I don't think there is one pivotal question", he said.

### Three billion more

Professor Ove Nilsson from Umeå Plant Science Centre then described his work on forestry plant development research, he began by defining the framework within which forest biotechnology is working. An extra three billion people will be requiring wood and wood fibre products within three to four decades, while at the same time, we will want to replace products based on non-renewable resources, such as plastic, steel and concrete, with products based on renewable wood fibres. Therefore the pressure on forestry as a producer of bioenergy will greatly increase as the price of oil rises.

"My conclusion is therefore that we must increase forest production dramatically and stimulate the use of forest-based products. But we must do this in a sustainable way. One way to achieve this would be to use modern forest biotechnology as a tool for many", argued Professor Nilsson.

### Different purposes

He then listed a range of purposes for which forest biotechnology can be used, where most of the applications do not require the transgenic modification of trees:

- Conventional breeding and selection of high-yielding forest species can be speeded up
- Survival of forest plants can be improved
- New applications for wood pulp can be developed, e.g. waterproof cellulose
- Increased growth and decreased rotation time
- Specially tailored trees to suit the end-user – quality paper, building material, etc.

The first seeds of genetically modified forest tree species may be on the market by 2009. Sweden is in the front line in the area of using the biotechnological tools within forestry.

"However, forestry is 15 years behind agriculture so we have to evaluate both possibilities and risks with the use of genetically modified trees in field trials over the next ten years. Before this is done, there is no way whatsoever we can give an opinion on potential", stated Professor Nilsson.

The chairman Mr Sylwan turned to Björn Häggglund, deputy CEO of Stora Enso, to hear if biotechnology sounded interesting at all from his industrial perspective.

"Yes, an adaptation will come gradually. One advantage will come with shorter rotations. It is easier to see improvements with rotations of 6-7 years as in Brazil than with 80 years. But so far we know too little about costs and benefits. However, public opinion has not changed and therefore we don't feel ready to say yes or no, which makes us say no to GMO until further notice", Mr Häggglund argued.

### Use all tools

However, Mr Karl-Erik Olsson, a former member of the European Parliament seemed encouraged by the perspectives revealed by Professor Nilsson. He expressed cautious optimism.

“We are facing enormous challenges regarding the production of food, energy and raw materials from agriculture and forestry. The markets are increasing and the interesting part is not only the size of the Chinese population, but also how they eat and what products they consume, as was shown earlier. Therefore biotechnology can be of help to us”.

Professor Nilsson agreed and added:

“We need to consider different purposes for biotechnology and will have to use all tools”, he said.

He then concluded by criticising the ‘Swedish model’, which means that all forest land is used both for production and to achieve environmental targets, leading to decreased production and inadequately fulfilled environmental targets.

“Use different forests for different purposes instead. If production is increased considerably on one area of forest land, then large areas of forest can become nature reserves with maximum biodiversity”, argued Professor Nilsson.

### Different notions

The third speaker was Dr Gitte Meyer from the Danish Centre for Bioethics and Risk Assessment at KVL. She had a background in science journalism before entering the academic world. She described herself as someone who had ‘changed sides’. She also described the problems she would have encountered if her task had been to write about the event as a journalist.

“There were two very interesting presentations but it is impossible to combine them”, she said and continued:

“I would have followed up Erik Smaling on the African theme for an interview on poverty and malnutrition”.

She then turned her attention to the biotech-

nology route described by Professor Nilsson. Five years ago, Dr Meyer participated in carrying out a study on public dialogue in relation to plant biotechnology. Attitudes among scientists were made the object of study, and these attitudes were compared to findings, made by social scientists, about attitudes in the public at large.

“The social scientists had problems finding any positive supporters of GMO”, she said.

It was one of the conclusions of the study, that the public and the scientists did not use the same denotation and connotations of two words associated with the discussion on gene transfer, namely ‘risk’ and ‘usefulness’. The public in general tended to adopt a broad notion of the risk concept, while scientists generally had a much narrower notion: they tended to associate ‘risk’ with hazards that might be measured by way of scientific methods.

“So the public and scientists are not talking about the same thing”, Dr Meyer said.

### Same language

The opposite situation was found regarding the word ‘usefulness’. A broad, commercial notion was common among scientists, whereas a narrow, moral notion was common among the public. For example, GM technology in relation to crops and food was only justifiable in the eyes of the representatives of the public, taking part in the studies, if it could be used to prevent malnutrition and poverty in Africa.

“If we want a meaningful dialogue, we must speak the same language”, concluded Dr Meyer.

Professor Smaling contributed to describing the problem of a common language by referring to a Gallup poll on GMOs carried out in the Netherlands, which posed the question: ‘Do you prefer tomatoes with or without genes?’.

“That illustrates just about how well the public is informed”, he said.

Dr Meyer did not seem surprised, but argued that “people may be wise on purposes even though they are poorly informed in a technical sense.”

She ended off the first discussion by stating:

“We must discuss the purposes of using science”.

# Trends in soil fertility - future challenges

## Forest soils

KAJ ROSÉN, PROFESSOR, SKOGFORSK, SWEDEN

### Introduction

In my presentation I would like to discuss soil fertility in an applied sense. Soil processes are one group of processes very much affecting the productivity of a given forest ecosystem. But they are not the only ones. I will discuss soil fertility in relation to the concept of site index and the way we define and measure that.

Site index is an indirect measure of forest productivity. It is often translated into a “site quality class” which is a measure of the potential forest production in  $\text{m}^3 \text{ha}^{-1} \text{yr}^{-1}$ . In my presentation I will consequently use the term site index to represent both these definitions.

The fertility of forest soils is not meaningful to discuss without taking a broader perspective, also including other processes influencing the forest growth, for example light, temperature, precipitation and other climatic processes. With this it is also said that soil fertility is not meaningful to discuss without taking the forest growth itself into account.

The utilization of the forest biomass production is to a large extent dependent on the functioning of “the ecosystem processes”. Not until the last decades intensive forest management methods have been used in order to increase forest production. Silviculture was introduced in Europe some hundred years ago, mainly with the aim to improve the timber quality. This means that the utilization of the forest resource, since the start of organized forestry, is mainly dependent on historical conditions for site productivity.

Foresters have a legitimate need for having control over their production possibilities. This

need is not only a need for knowledge about the forest resource, but also a need to implement the most efficient silvicultural and management methods to the respective production sites. There is a strong interdependence between the effects of a specific management choice (for example selection of tree species, thinning or fertilization) and the fertility of the soil.

### Site index – a concept to question?

Site index is a traditional concept in forestry. It is used to describe the potential of forest production at a given site. The site index describes “the natural potential for wood production, measured as cubic meters of wood produced per hectare and year”. Site index is defined as “the mean increment, as it culminates for a stand which is established and maintained to get the highest possible volume production”. Most forest stands do not fulfil these criteria. That is why site index in reality describes a potential, not realised ideal situation/condition. The site index constitutes an important reference for the forest owner and should be compared to the actual mean increment of the stand. The objective of the management of the forest has so far been aiming to achieve a forest growth which approaches the potential growth of the stand (site index).

Even if we take into account permanent and durable soil fertility related parameters like soil depth, mineralogy, and soil texture along with topography, hydrology and climatic variables we are unable to measure site index directly through these variables. Usually we use the increment of the trees as an indirect way of measuring site index. This implies that the site index is dependent on the development of the crop, in this case the tree species.



As an example, in Sweden Norway spruce indicate a higher site index on fertile soils compared to for example Scots pine.

Without going into details of different methods on how site index has been estimated over time, it is obvious that it is dependent on a number of ecosystem processes such as temperature, light, water, nutrients, competition, etc. The definition of the concept “site index”, as used in the Nordic countries, implies that these variables are stable over a long period of time, or at least are possible to estimate under “natural”/“pristine” conditions. This is not the case today. Mankind’s activities in the forests (for example selection of tree species, selection of regeneration material) as well as the large scale impacts like CO<sub>2</sub> and other emissions, have an impact on the forest ecosystems. These changes affect the very basic conditions for the estimation of site index. The intensity of the ecosystem processes which are the driving forces behind tree growth have changed as a result of man-induced activities. Many of these changes result in an increasing tree growth.

The result is an increase in site index, which was supposed to remain stable over time.

This means that the underlying objective of the concept “site index” (at least in the way it is used in the Nordic countries), namely to describe “the natural potential for wood produc-

tion at a given site”, has become unstable in a way that do not reflect the original meaning of the concept. Even if the main reason for this statement is explained by our inability to apply accurate methods to measure site index, one can conclude that the concept of “a naturally given maximum wood production potential”, at least partly has lost its meaning. Despite that, site index is still a useful tool for forest owners as a way of ranking their stands and to get some decision support on how to manage a given stand. One should, however, be aware of that today’s methods to measure site index also include ongoing long-term changes in many of the underlying ecosystem processes.

### Long-term changes in ecosystem processes

I will just give some few but obvious examples of long-term changes in ecosystem process which are induced by man.

#### Acid deposition

The main constituents of acid deposition has so far been sulphur and nitrogen compounds. Both originate to a large extent from fossil fuels, however, nitrogen deposition also from agricultural and domesticated animal production. While sulphur emissions and deposition has been reduced considerably during the last

SITE INDEX (m <sup>3</sup> ha <sup>-1</sup> yr <sup>-1</sup> )			
<b>Method 1</b>			
	68-72	73-77	78-82
Sweden	4.2	4.5	4.5
<i>Swedish National Forest Inventory</i>			
<b>Method 2</b>			
	1984	1990	2002
Sweden	5.5	5.6	5.8
S. Sweden	9.2	9.6	9.7

decades, nitrogen deposition is still at high levels.

Acid deposition has resulted in soil acidification. The most obvious effects are decreased pH-values and a decreased base saturation in forest soils. The effects on tree growth of soil acidification are not sufficiently documented. So far, empirical data show that acidification of soils, with some exceptions, have not affected tree growth negatively. The possible explanation for this is that tree growth under Scandinavian conditions is mainly controlled by the availability of nitrogen, which is not affected by a decrease in base saturation. In the long run there are, however, fears that the decreased base saturation might affect tree growth if any of the base cations are lowered to levels below the need of the stand.

Nitrogen availability is what determines forest growth in Scandinavia. All present knowledge supports the observations that the increased nitrogen deposition has increased forest growth, although it is difficult to prove with direct observations. Indirectly, nitrogen fertilization experiments clearly show the positive effect of nitrogen on coniferous forest growth, also in those sites where nitrogen deposition is high.

#### Climate change

The basic reasons behind climate change are similar to those of acid deposition, namely the use of fossil fuels. The resulting CO<sub>2</sub>-emissions are considered to be the main reason behind predicted increases in mean temperatures. If these temperature changes already have occurred is debated, but the predicted effects on the forest ecosystems are complex. An obvious effect is that climate-based vegetation zones will move north, with increased forest growth as a result. However, many other effects might occur, such as changes in the behaviour of pathogen- and insect populations, changes in rainfall amount and patterns, wind climate etc.

#### Forest management

The way we manage our forests will in itself affect the ecosystem process. Management practices are naturally used in order to increase tree growth. Tree growth in itself, followed by harvesting, results in an export of nutrient from the forest site. Along with the acid deposition harvesting of trees not only result in a decreased base saturation, but also export of nitrogen. Nutrient export through intensive growth and increased biomass utilisation has in the long run to be compensated, primarily by adding nitrogen, but in the future also other nutrients might be of interest.

Other management practices like selection of tree species and the use of genetically improved regeneration material will continuously and in the long run have a positive effect on forest growth, thereby affecting the site index.

#### Ways ahead?

Used methods to estimate the site index are based on empirical knowledge, i.e. they are based on observations of actual stands. These observations reflect the environmental conditions to which the stand has been exposed during its period of growth. In Scandinavia this is typically a period from 40 to 120 years. However there are also methods adapted to younger stands, but also these methods have had the ambition to reflect the "natural" potential for wood production. But nothing is "natural" anymore!

There are two main groups of models that can be used to predict for example tree growth:

1. Models based on empirically collected data and
2. Models based on causal knowledge about the processes resulting in tree growth.

The first category, on which for example the site index estimation is based, has been success-

fully used over a long period of time in forestry. As long as the historical, empirical relationships are stable and valid, empirical models have proved to be superior in their ability to predict the future for forest growth under the assumptions that are made for future management regimes.

The stable conditions which are a prerequisite for the concept of site index are, however, not there anymore. The accuracy of these empirical findings are decreasing as a consequence of increasing environmental changes.

The way ahead lies probably in process based models. Although they still suffer from many drawbacks and limitations, they are the only kinds of models that have the potential of incorporating both long-term and short-term changes in the processes driving forests growth.

The main problems with process-based growth models are limitations in the deeper understanding of many single, but important processes that need to be incorporated into the models. Another problem is the practical and economical possibilities which relate to data acquisition and data collection.

### **To sum up**

The process-oriented models are still under development. From the practitioner's point of view, they still suffer from deeper understanding of single processes, from their complexity and also from limitations concerning data requirements. The process-oriented growth models are still not very accurate when it comes to predictions of future development.

The traditional empirically based growth models are simpler, and therefore easier to implement in the practical situation. So far, they have proved quite reliable for prediction of future tree growth, but there are obvious signs that they now and in the future will be unable

to predict forest growth, due to man-made impact on the ecosystem processes that determine biomass growth.

However, I am certain that the traditional site index models will be used also in the foreseeable future, simply due to the fact that foresters will have a need for a tool which they can use as a decision support system for forest management purposes, for example to rank stands from a fertility point of view and thereby have the possibility to choose between known silvicultural options. Traditional site index models will also continue to be used, simply because of the fact that there still are no reliable and practical alternatives. The awareness of the limitations of the traditional empirical site index models must, however, increase among foresters.

# Trends in soil fertility - future challenges

## Agricultural soils

.....  
A.E. JOHNSTON, DR, ROTHAMSTED RESEARCH, UK

Dr. Johnston's speech was based on a power point presentation from which these pictures are published.

### Future challenges

- Need to identify appropriate farming systems for the climate, soil and management skill of farmers.
- Ensure that all inputs are used as efficiently as possible.

### Farming systems

- A farming system must be financially viable and environmentally benign.
- Financially viable for farmers and the infrastructure that both serves them and is dependant on them.
- But, financial viability:
  - must be socially and legally acceptable.
  - must not cause irreversible damage to the soil resource, e.g. soil erosion, irreversible build of soil pests and diseases.

### Viable farming systems require fertile soils

Soil fertility depends on many, sometimes little understood interactions between the biological, chemical and physical properties of soil.

Future challenges:

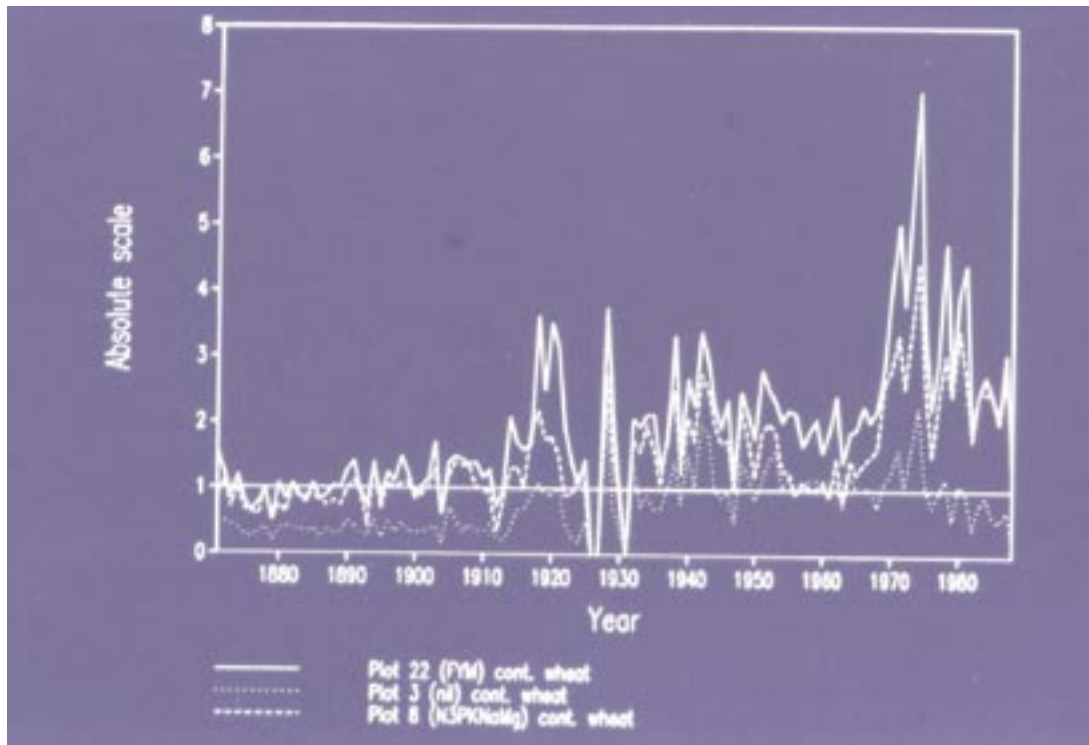
**Biological** - to identify and assign functions to the components of the "black box" that is the soil microbial biomass. Relate dissolved organic matter to agricultural productivity.

**Chemical** - to identify "critical" plant available levels in soil for each plant nutrient.

**Physical** - to identify optimum conditions for soil structure to ensure adequate nutrient and water availability.

The challenges are to maintain optimum conditions for both agricultural production and the well being of the environment.

## Effect of fertilisers on continuous wheat

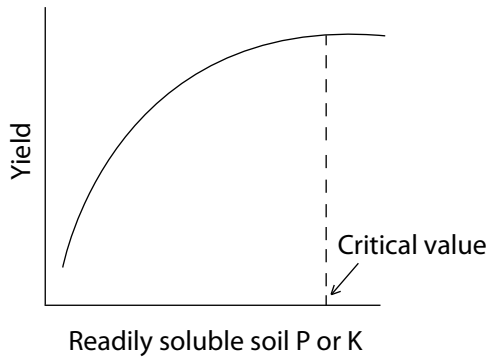


Result from the field of continuous wheat growing (Broadbalk) at Rothamsted. Farmyard manure (FYM) and inorganic fertilisers (N, P, K, Na and Mg) is compared with no fertiliser or manure since 1843.

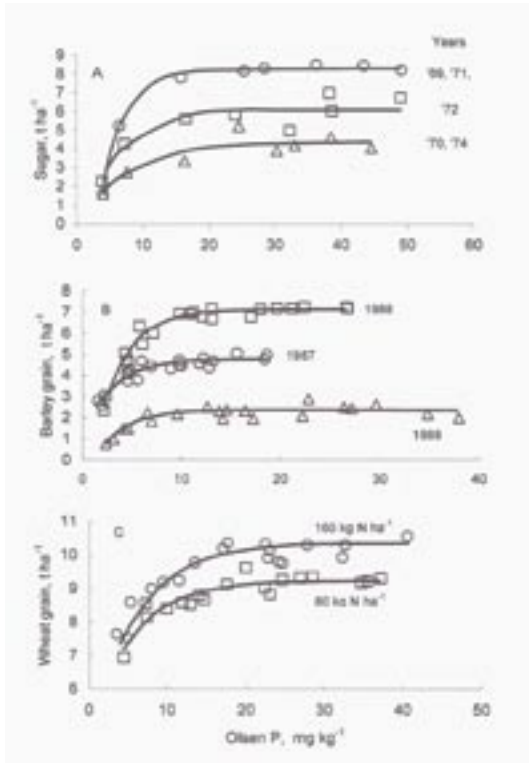
**Can we identify optimum soil conditions for both agricultural production and environmental benefit?**

The optimum will not always be the same for all agroecological environments.

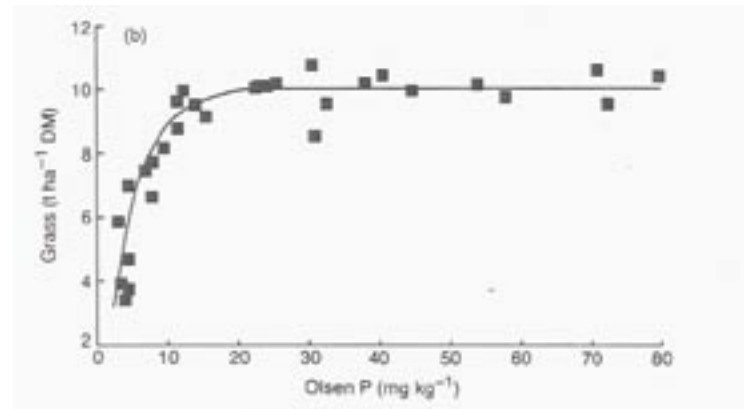
RELATIONSHIP BETWEEN YIELD AND PLANT AVAILABLE SOIL PHOSPHORUS



EXAMPLES OF "CRITICAL" AVAILABLE SOIL PHOSPHORUS LEVELS

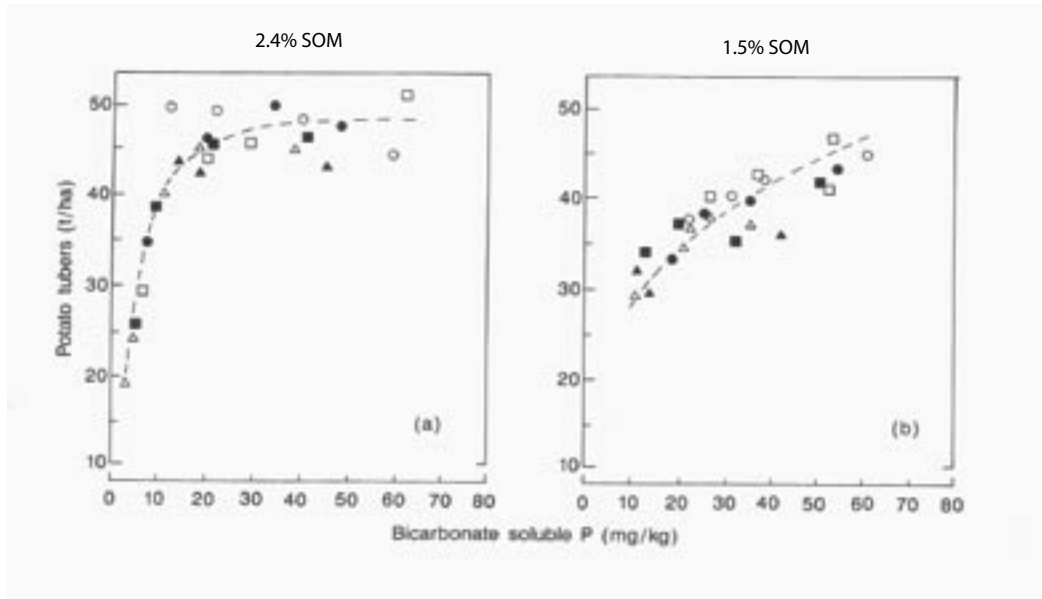


"CRITICAL" SOIL PHOSPHORUS LEVEL FOR GRASSLAND



"Critical" levels of available soil phosphorus, levels for respectively sugarbeets, barley and wheat. The "critical" levels are found in the interval 10-20 mg kg<sup>-1</sup> Olsen P.

EFFECT OF SOIL ORGANIC MATTER (SOM) ON CRITICAL LEVEL FOR SOIL P IN POTATOES

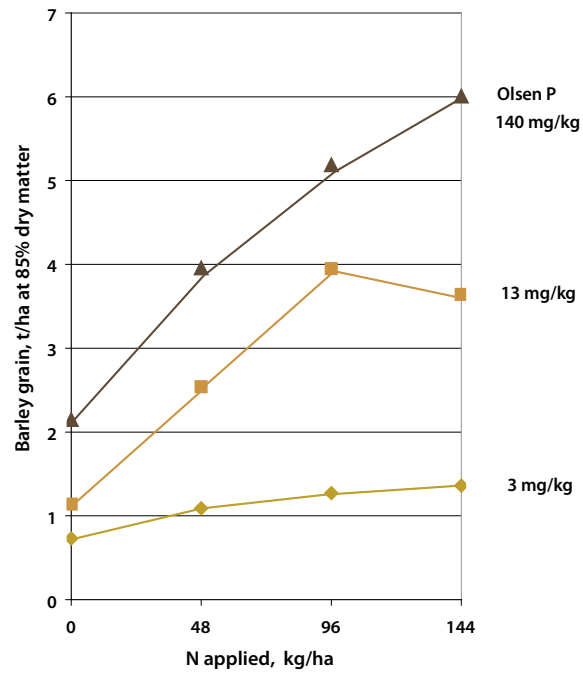


EFFECT OF SOIL ORGANIC MATTER ON RELATIONSHIP BETWEEN YIELD AND OLSEN P

	SOM %	Yield t/ha (asymptote)	Olsen P mg/kg (at 95%)	% variance accounted for
Spring barley, grain	1.5	4.4	45	46
	2.4	5.0	16	83
Potatoes, tubers	1.5	44	61	72
	2.4	45	17	89
Sugar beet, sugar	1.5	6.6	32	61
	2.4	6.6	18	87
Grass in pots, (dry matter)	1.5	6.5*	25	82
	2.4	6.5	23	96

\*g/pot

EFFECT OF PLANT AVAILABLE SOIL P ON THE RESPONSE TO N

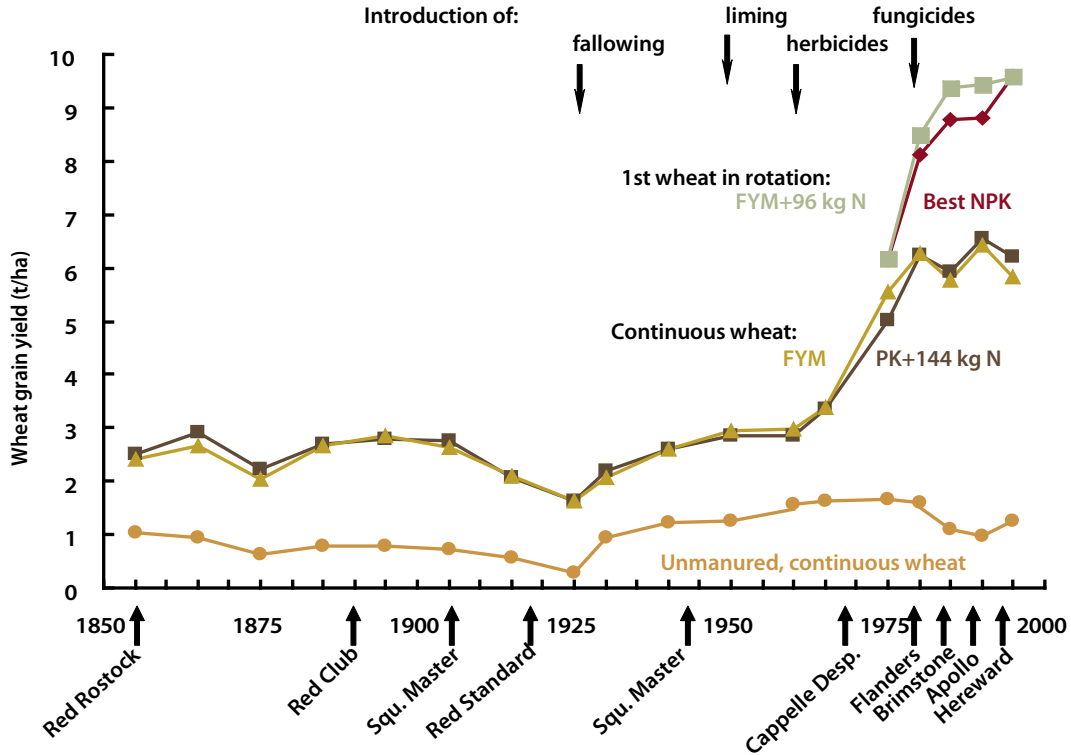


% RECOVERY OF LABELLED N (<sup>15</sup>N)

		PK	no P, no K
Winter wheat, 96 kgN/ha	1980	64	46
	1981	61	39
Spring barley, 140 kgN/ha	1986	53	36
	1987	53	48



## Can we identify suitable farming systems?



Result from Broadbalk continuous wheat growing field in Rothamsted. Comparison between farmyard manure (FYM), inorganic fertilisers (N, P, K, Na and Mg) and no fertilisers or manure since 1843 with introduction of different crop production factors like fallowing, liming, pesticides etc as well as, from time to time, modern varieties of wheat.

## Summary of discussion

JENS BLOMQUIST, AGRARIA ORD & JORD

*In the afternoon there were two papers on Trends in soil fertility by Professor Kaj Rosén, SkogForsk, the Forestry Research Institute of Sweden and Dr A. E. Johnston, Rothamsted Research. These papers were followed by a synthesis and open discussion led by science writer Peter Sylwan and opened by Director General Lars-Erik Liljelund, Swedish Protection Agency, Managing Director Torbjörn Lovang, Lovang Agriconsultants, Professors Pelle Gemmel and Hans Andersson, SLU, Swedish University of Agricultural Sciences and vice president of KSLA, chief forester Jan-Åke Lundén, Södra. These five people shared their personal reflections on issues such as stagnating yields in agriculture and increasing fertility in forestry. Other issues raised included the aesthetics of planting forestry on agricultural land, the risks associated with the precautionary principle, and soil fertility as a result of human actions in combination with cultivation techniques.*

First to speak was Mr Torbjörn Lovang. He is Managing Director of Lovang Agriconsultants, an independent and private advisory service based in the province of Östergötland, which provides advice and support to farmers actively managing a total of 32 000 ha agricultural land. He started by agreeing that there is a problem in Swedish agriculture, with stagnation in crop yields. He admitted:

“As an advisor I feel ashamed, as the problem is at least partly mine”.

### No yield increase

Mr Lovang constructed his argument on yield statistics obtained from the group of farmers

with whom he works. Statistics for the period 1981-1999 provided a strong basis for discussions on the theme of stagnating yields.

“For the past 10 years, yields of winter wheat have not increased”, revealed Mr Lovang.

The same situation applies for all other crops grown in the advisory group except winter rye. With the same amount of plant nutrients then and now, one ought to be able to detect a yield increase. Mr Lovang showed a photo of a seed bed on a heavy clay soil where the winter wheat seeds hardly could be seen among the clods.

“The machinery of today can handle cloddy soils and farmers therefore do not put enough emphasis on creating an optimal seed bed. This results in inferior plant establishment is inadequate for high yielding crop performance”, said Mr Lovang.

However, according to him there are other reasons too for the lack of increase in crop yields. Those he mentioned included:

- Restricted crop rotation, with very few break crops between winter wheat crops.
- Soil compaction, with it becoming increasingly difficult to cultivate soils.
- Advisors focusing on the wrong factors, with too much discussion on seed rates and fertilizer and pesticide doses.

### Back to basics

Instead of concentrating on traditional and conventional topics, advisors and farmers together should devote greater efforts to more fundamental plant production factors, argued Mr Lovang. His list of recommendations included:

- Green manuring
- Increasing soil humus content
- Varying the crop rotation
- Avoiding intense soil compaction
- More efficient use of field machinery
- Good soil drainage status
- Liming for better soil structure
- Good plant establishment, suitable soil particle size distribution
- Non-ploughing system where appropriate

One of the problems that exist in daily field-work for Mr Lovang is the lack of a tool that can measure soil changes over the years.

“I have nothing to relate to. We need a soil index so that we can compare soils from one year to the next”.

These ideas seemed attractive to the chairman Mr Peter Sylwan, who asked if the discussion was not primarily relevant for organic farmers.

“No, organic and conventional farmers correspond very well in these matters”, Mr Lovang replied.

Dr. A.E. Johnston agreed on both the problem and the factors identified by Mr Lovang, and added a further contributory factor:

“The increasing size of farms means that the workload cannot be carried out with good timing”.

Mr Lovang agreed with this and concluded his remarks with the following observation and challenge:

“Farmers have forgotten some things about good plant establishment. They should think more about basic data in the field”.

### Improved soil fertility

Mr Lovang was followed by Professor Pelle Gemmel from the Southern Swedish Forest Research Centre, SLU Alnarp. He started his presentation with a photo of a newly planted

field of spruce and claimed:

“This is the most important crop in Sweden, covering approximately 10 million hectares”.

He then revealed that prior to the devastating storm with hurricane force winds that hit southern Sweden between 8 and 9 January 2005, there was a six-fold higher volume of spruce in the region (Götaland) compared with 75 years ago. Overnight, the number was reduced to a five-fold higher volume today compared with three-quarters of a century ago. The active cultivation of spruce has created a new forestry profile compared with a mere two generations ago.

Professor Gemmel showed data from Tönnersjöheden in the province of Halland in southwestern Sweden. The area was originally planted with spruce on sandy soils on former heathland at the end of the 19th century.

“The site index has changed completely from the first to the second generation. After 40 years of growth, the increase in yield is 25 percent”, concluded Professor Gemmel.

So from his forest production point of view, there is no fear about soil fertility:

“I can’t see any signs of fertility declining”.

The reason for the increase in yield is that soil fertility has improved, according to Professor Gemmel, and it is the growing forest that has actively improved the soil. Over the years, between the first and second generation, the forest has built up a humus layer that is promoting the growth of the latter generation.

“So the question is not if we can, but if we want to, improve productivity”, argued Professor Gemmel.

### Fertilizer triples output

He then gave examples of what he meant.

“By using *Pinus contorta* instead of *Pinus silvestris* in northern Sweden, we can increase

productivity by 30-40 percent. And with hybrid aspen we rocket the production by 20 cubic metres over the rotation”.

He then described results from trials with fertilization of young spruce forests up to 35 years of age, showing an increase in production of 80-350 percent. The further north in Sweden the trial is performed the higher the response to fertilization.

“Björn Hägglund did not mention this in his presentation on paper pulp production in Brazil this morning, but by fertilizing the plantations in Brazil there is a considerable augmentation in production and as I showed earlier we actually get a tremendous increase in growth also in Sweden using fertilizer”.

Mr Sylwan expressed his surprise at the results presented:

“So the capacity of biomass production is bigger in forestry than in agriculture, and now you claim that you can double the production by using fertilizer?” he asked.

This diverted the discussion onto a different path and raised the issue of planting forestry on agricultural land, currently a relevant topic in Sweden against the background of proposed revisions of agricultural policy, which will probably increase the economic pressure on agriculture and increase the interest in planting forests. Mr Sylwan turned to Professor Ove Nilsson from the Plant Science Centre in Umeå and asked if he could make hybrid aspen and birch as productive as spruce.

“We can increase the wood fibre length by 20-30 percent by biotechnology. That would make wood from hybrid aspen and birch more similar to wood from spruce, but the spruce fibres are still longer”, Professor Nilsson replied.

### **Beauty of production**

However, this was not something that appealed to Professor Pelle Gemmel.

“The solution is not other tree species, but other management systems, in other words silviculture. We don't have to exchange one species for another. Every species has its role and we should not put all our eggs in one basket!”, he warned.

The aesthetics of having agricultural crops versus forest on agricultural land triggered the debating urge in the auditorium. All is not black or white according to one contributor, who wanted to see variation in the landscape but also saw the necessity of planting forest. Dr. Gitte Meyer of the Danish Centre for Bioethics and Risk Assessment in Copenhagen described how beauty lies in the eye of the beholder and is related to values and ideas about the good life. She related how the grandfather of her Norwegian husband found level and rather uniform fields of barley to represent the utmost beauty. The grandfather was a peasant from the wild and mountainous landscape of Norway. To him efficient agriculture was beautiful.

“With his background, there was nothing lovelier to him than an enormous field of barley, because it represents such high productivity”.

### **Growth means trees**

The third speaker was Jan-Åke Lundén, Chief Forester at Södra. He began by stating the four conditions he considered necessary for achieving future sustainability:

1. Maintenance of soil fertility
2. Improvement of plant material – “genetic modification of plants is a good tool in production”
3. Optimal use of fertilizer
4. Introduction of new crops

These conditions apply to both forestry and agriculture, according to Mr Lundén. He stated some important factors for economic development of agriculture and forestry, namely suit-

able infrastructure, available markets - not only local, but also even regional, national - and international and just trade conditions.

He went on to expand his views on soil fertility in a wider perspective.

“Forest is a natural succession on agricultural land”, he said.

By that he meant that a soil that has a poor fertility value for agricultural crops can be excellent for forest.

“And planting forest brings about an improvement of soil conditions.”

The global dynamics of forestation and deforestation were also discussed.

“This is related to the social structure and the economic situation. In developing countries most of the available land is used for agricultural purposes. That was the case also in Sweden a hundred years ago. In connection with the industrial revolution vast areas of devastated land were transformed to forestland. Today we can see the corresponding process in other parts of the world, for instance at Vera Cruz in Brazil. Afforestation comes with economic growth”, claimed Mr Lundén.

### Think next generation

Following Jan-Åke Lundén, Lars-Erik Liljelund, Director General of the Swedish Environmental Protection Agency, said that the title of the seminar ‘Food and Wood for a Sustainable Future – Challenges for Soil Fertility Management’ immediately led his mind from a political level to an operational level.

“The important issue is how we take the step from concept to practice”, he said.

The secret to this is a far-sighted approach.

“It is always good to think how the measures we undertake today may come out in the next generation. But this is complicated”, acknowledged Mr Liljelund.

An overarching idea should permeate the work of making sustainable development operational, according to Mr Liljelund.

“This is the way we use our soils!”

He emphasized the importance of not considering soil management in isolation and pointed out that soil and water issues are closely integrated.

### Three clusters meet

The utilisation of natural resources within the EU seems to be increasing at present, not through increased domestic consumption but for example by companies transferring their manufacturing to low income countries. This not only exports the consumption of resources but also the disposal of environmentally challenging substances.

“We in the European community are outsourcing our problems. This means we are leaving our footprints around the world”, observed Mr Liljelund.

Decisions on issues of this nature are formulated and agreed in a triangular interplay between three actors, according to Mr Liljelund. Three clusters – the political cluster, the scientific cluster and public opinion – meet and interact. An example of this is sewage sludge and the debate on how it can be used. The political cluster and public opinion are shifting rather rapidly. However, the scientific cluster has problems due to a lack of long-term funding.

“That poses a risk because it leads to a weaker foundation for those making the final decisions”, warned Mr Liljelund.

### Hard to predict

The discussion that followed Mr Liljelund’s comments raised the issues of general husbandry and the precautionary principle.

Dr A. E. Johnston began the discussion with the following warning:

“I must underline the danger of starting to use new things, as we always seem to create problems”.

He referred to the introduction of phosphorus into fertilizers some 100 years ago.

“Who could have foreseen that we would end up with problems with cadmium?”, he wondered.

That prompted the chairman, Peter Sylwan, to ask:

“What happens if you combine the precautionary principle with the idea of consensus, which are the two basic principles guiding this country?”

“Stagnation of mankind”, replied Dr Johnston.

### **Risky life**

The final speaker was Professor Hans Andersson, Department of Economics, SLU, Uppsala. He began by concluding the debate on the precautionary principle and observed:

“Being alive is running a risk!”

That prompted Mr Sylwan to add:

“Most people die from it!”

As a response to Mr Lovang’s deliberations on why yields are not increasing quickly enough, Professor Andersson provided a review of preceding crop effects.

“Restricted crop rotations and a lack of break crops can be part of the explanation. I think we have to go back to basic knowledge”.

The next step for an economist is to place these pre-crop effects within an integrated economic analysis. Using data from an undergraduate dissertation, Professor Andersson illustrated the benefits that arose when two neighbouring farms – one arable and one dairy – cooperated by pooling their acreage and using the same

crop rotation. The effect was an increase in profits of between 200 and 400 Swedish crowns per hectare for both farms. This demonstrates the value of the crop rotation.

### **Decisions by farmers**

Professor Andersson also summarised his impressions of the day’s discussions on the theme of soil fertility from a business economics perspective. The principle of leaving something better behind for the next generation can also refer to soil fertility in both agriculture and forestry, according to him.

“The results from Rothamstead on agricultural land and from the forests at Tönnersjöheden clearly show that soil fertility can be increased if the right measures are undertaken”.

That reasoning implies that soil fertility can be both improved and diminished by human hand.

“Plenty of examples from the former Soviet Union show that a natural resource such as soil can easily be destroyed”.

Soil fertility and long-term productivity are therefore determined by the human factor in combination with the available cultivation technology.

“I believe that success originates at the entrepreneurial level of the individual farmer. The decision-making level is crucial. Soil productivity is a matter of farming systems in a broad sense”, concluded Professor Andersson.

## Utgivna nummer av Kungl. Skogs- och Lantbruksakademiens TIDSKRIFT (KSLAT)

(Titlar markerade med \* publiceras endast elektroniskt på KSLAs hemsida [www.ksla.se](http://www.ksla.se))

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- Nr 10 Värdet av strömmande vatten \*
- Nr 11 Grön bioteknik för framtidens odling \*
- Nr 12 Food and Wood for a Sustainable Future - Challenges for Soil Fertility Management

For several decades, the agricultural yields have increased tremendously and further increase is needed. Presently, however, there are signs of stagnation. What are the reasons? Are we approaching a yield limit? What importance has soil conditions or biological, economic and agricultural policy factors?

The forest soil fertility has to improve in order to create conditions for future supply of wood. Also, the depletion of nutrients, pollution, nutrient recycling etc. have to be dealt with.

The long-term sustainable management of soil fertility is a crucial factor for both agriculture and forestry.

The future challenge is to develop and apply the best management practices to reach both production and environmental objectives.



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