Return to Eden

– future paths to sustainable, natural resources management

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A report from a study trip and workshop conducted by the Environmental Committee of the Royal Swedish Academy of Agriculture and Forestry in autumn 2007

Contents

There is no such thing as natural agriculture or forestry, writes Peter Sylwan in “Return to Eden”. Cultivation entails the modification of nature, and a concentration of plant growth to selected types.

When farming was “invented”, there were perhaps ten million people on Earth. The population subsequently rose sharply in pace with rising food output. Crop failure and plague occasionally took a major toll, resulting in periodic falls in population, but recovery occurred repeatedly. For every twelve children born, frequently only two or three survived. Prior to the emergence of modern medicine and the prospect of a “pension”, a sound strategy for old age was to give birth to many children, of whom a few survived to adulthood. This remains the case in many poor societies worldwide.

Medical care developed in our part of the world, leading to a steep rise in population. Economic development offered the potential to save, parallel with an extension of the social security system. Subsequently, the population growth rate began to fall simply because many people no longer needed to produce as many children, since those born had a greater chance of survival. In addition, Europe experienced considerable emigration.

Also in the poor regions of the world, medical care and medicines were introduced gradually; however, favorable economic development, social security and mass emigration did not emerge. Instead, very rapid population increases prompted and – continue to prompt – people to over-exploit their arable land and attempt to cultivate areas, such as slopes and semi-arid areas, that are totally inappropriate for agriculture, with disastrous results for output and the environment. But even in the affluent world, where the birth rate is low, development has given rise to considerable ecological scars.

What then is the way forward? How can land, energy, nutrients and the environment meet our food and heat requirements? Of the three paths outlined by Peter Sylwan, one is definitely anathema most of us, that is, to permit billions of people to die.

That leaves two alternatives: One of these involves the efficiency-enhancement of known methods; while the other focuses on the development of new energy sources, combined with innovative ways of extracting and circulating nutrients, combined with the development of cultivation techniques and new products from forests and crops. To say the least, this is a fascinating picture of the potential offered by the life sciences to solve the problems we face. And it is all based on sunlight: Directly through heating or solar cells for electricity; or indirectly through water, wave and wind power and, increasingly, through the inexhaustible efforts of the green cells.

We are beginning to get a detailed understanding of the growth process. The potential is enormous. Factory processes based on trees and other plants can do everything that is currently achieved by oil – plus a good deal more. As Peter Sylwan sees it, our century will be the century of biology, provided we focus, as we should, on research, development and education. The path is called the E5, which is a positive signature for Ethics, Ecology, Esthetics, Economy and Empathy. Secure people are generous people.

Åke Barklund,
Secretary General and Managing Director,
The Royal Swedish Academy of Agriculture and Forestry

The Anthropocene - the Age of Man

Is it a potential title of honor or the final warning of impending disaster? The Anthropocene – the Age of Man – is a term proposed by American geologists to describe the past 200 years. The concept likens Man to the forces that caused the landmass to rise above the plains and continents to sink into the sea, and the glaciers with their rock crushers, land planers and downslope winds at the ice edge, which blended together the fine-ground mass of minerals to form vast, fertile loess areas. Is it reasonable to compare us to the forces that built and rebuilt the entire globe? Seemingly. But even if the past 200 years represent the finishing line for our ongoing total global makeover, the starting point is more than 10,000 years back in time.

It was then we became farmers, meaning we started to cultivate the soil – and use it. There is no such thing as natural farming or natural cultivation. By definition, agriculture is essentially a violation of the natural order. As farmers, we literally tore up the soil and began to cultivate it instead of living from what already existed there. Cultivation is a conscious attempt to create our own monocultures. Without our intrusion, nature would never do this of its own accord. We stopped being just another ecological feature and commenced our own age as an independent ecological factor.

Our original agriculture was an attempt to utilize the fossil nutrients of the surface – much like our current efforts to utilize the fossil energy of the subsurface. What farming "extracted" from the soil were its fossil riches in the form of nutrients and salts from various types of weathered rock that had been organically bound for over millions of years. In our current, emaciated forest landscape, the field rotation system of the time rapidly drained the soil of its riches and the farmer was compelled to move to new tracts of land. On the plains, the soil was deeper, the minerals richer and the cultivation period longer, but even here nutrients were eventually exhausted. The meadow with its grazing livestock and the fertilizer they left behind or which was collected in winter and spread out on the depleted soil in spring made the meadow the mother of the arable field.

There is no such thing as natural agriculture. The farmer is part of the total global "makeover" that some US geologists refer to as the Anthropocene – the Age of Man.

Thanks to another fossil resource – the excrement of the Guanay Cormorant stored in the form of Chile saltpeter (sodium nitrate) – the meadow and livestock stopped being key nutrient suppliers to arable fields. The meadow could now be transformed into grazing land, forage land and arable land. And with phosphorus, potash and lime from mines and quarries, we became increasingly independent of the soil's natural mineral weathering. The major liberation from nature's own fossil nutrient resources derived from the art of extracting minerals from mines and fixing nitrogen from air and converting these components into plant nutrients. At about the same time, we also began to liberate ourselves from dependence on the fuel to our original work partner – plants. Oil-driven tractors and machinery replaced grazing cattle and horses.

When we lived on wild vegetables, roots, nuts and the odd carcass left by a predatory animal – and the occasional animal that we ourselves brought down – 50 to 100 hectares of land were required to support one person. Nowadays, the global distribution of farmland is as low as 0.25 hectares per person. The fact that well more than 800 million people currently live on or around the starvation level has nothing to do with a lack of soil resources or the capacity of the 0.25 hectares to produce even more food. In many countries worldwide, average harvests – even in areas with good soils and a favorable climate – are far below what farmers with modern machinery and commercial fertilizers have demonstrated that 0.25 hectares can produce. But the ecological footprints left by our agriculture are deep and the required resources are limited, so much so that we are compelled to find radically new paths for future sustainable natural resources management.

There is a lowest common denominator in our previous transitions during our progress from the hunter-gatherer stage to chemicals-based farming. Each time we were close to hitting a ceiling, we found new ways to replace what was then a limited resource. The lowest common denominator in this process is new knowledge. When we as vegetable and carcass eating hunter-gatherers became too many for the limited wild lands available, our insight into crop rotation and cultivation replaced land as the key factor. When the fossil nutrients in the soil became limited, we circumvented this obstacle by using our knowledge that the meadow and animals play mother to the arable field. When the latter nutrient sources no longer sufficed, we gradually developed our expertise as regards fixing nitrogen from the air by means of industrial technology. And when human labor became a major limitation, our knowledge of steam power, machinery and engines came to the rescue.

Our age's most limiting and limited resources are many. Including once again the land – there is no more land available for cultivation. At least not sufficient acreage to compensate for all the land that annually disappears under burgeoning cities and expanding infrastructure. Or the land that is destroyed through desertification, salinification, water-logging and acidification. The land we currently have is all we will ever have! And it must be able to deliver more food with considerable lower inputs of other limiting and limited resources – such as fossil energy. Almost all energy used in arable farming is fossil-based. 30 percent is used by ploughs and harrows, 40 percent is used in the manufacture of fertilizer and 20 percent disappears in harvesting.

The third – and perhaps the most limiting and limited resources – are nature and the environment, notably water. We have not always viewed them in this manner, that is, that nature and the environment are resources that are utilized and must be included in our calculations.

The land we currently have is all we will ever have. We must make it produce more food with fewer inputs of fossil energy and at a lower environmental cost.

Trading in emission rights for carbon dioxide, which is now commencing, puts a price on what carbon dioxide emissions cost in terms of our atmospheric and climate stability. As yet, no pricing or trading in emission rights has been set for phosphorus emissions into the Baltic Sea, for instance. But progress in this direction can be expected. Not just because it would highlight the cost of damage to the Baltic Sea, it would also draw attention to the fact that phosphorus is itself a limited resource and keeping it where it ought to be, – in the soil and plants and not in the sea – should be rewarded.

The equation that governs how the available production resources – land, energy, nutrients and environment – are to cover requirements in terms of breeding, feeding, fiber and fuel has three conceivable solutions.

The first is to succeed in extracting more from what we already have, efficiency-enhancement in other words. Using this approach we can make progress, although not quite enough to ensure sustainability. The resources we now use are finite and the effect they have on their own and surrounding ecosystems are neither sustainable in the long term nor acceptable.

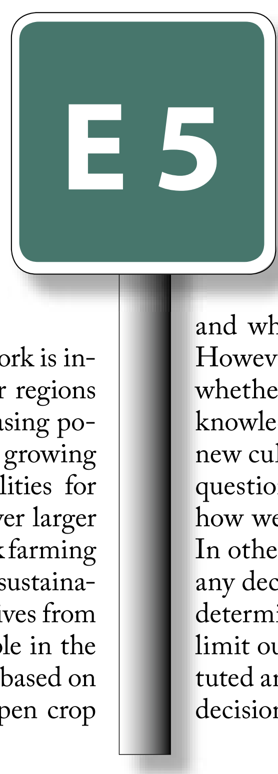
The second alternative is nature's own solution to the resource crisis, which is as equally effective as it is cruel and unacceptable, namely, the Malthusian catastrophe scenario in which hunger and war reduce the global population to the level that resources can support. Our age's milder variant on the theme involves a voluntary change of lifestyle in which consumption does not exceed what our resources can support. However, whether or not that solution is sustainable will not be determined by us in the West but by the attitude (in this case) of 1.3 billion Chinese, one billion Indians and all the others that have a long way to go before they attain Western consumption patterns!

Reducing resource requirements through changes in lifestyle is a tricky task. Demanding that those with little refrain from what others already have is hardly a conflict-free strategy. And how easy is it to defend morally? Certainly, we can make demands and, of course, there is scope for people in the West and North to change their lifestyles and use less by consuming less. But the affluent of the world are in a minority and each reduction in the North and West will be more than offset by a highly reasonable and legitimate increase in consumption in the South and East.

Thus, to solve the sustainability equation what remains to be done is to raise output while simultaneously reducing our inputs. The task for the forest owners and farmers of the Earth is to radically reduce the use of fossil energy, both in the use of machinery and the manufacture of fertilizer, and at the same time raise output and product quality, cut emissions to surrounding ecosystems to a sustainable level, restore what has been lost and create new natural values.

The third solution to the equation requires that we identify new, sustainable energy sources, new ways of obtaining the nutrients that crop growing requires, new cultivation techniques and new plant characteristics for the crops we grow.

For the same reasons that there is no natural agriculture, neither is there any natural livestock farming. All livestock farming – except perhaps for eating the remainder of other predators' hunting and our own hunting of wild animals in their natural environment – is a violation of the original natural order. Tamed, domesticated animals continue to have strong instinctive behavior that makes it very difficult to rear them in a manner that offers an outlet for their own nature. Perhaps with the exception of cats and dogs.



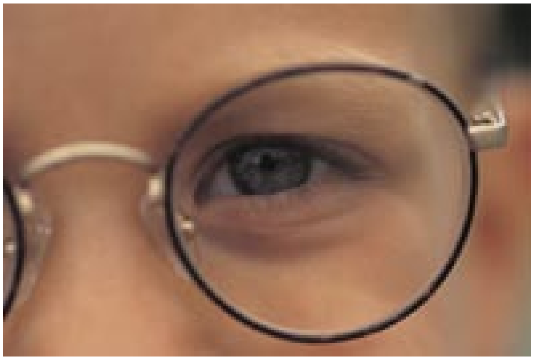
The demand for milk, meat and pork is increasing dramatically in many major regions worldwide in pace with rising purchasing power. As a result of rising demand and growing global competition, production facilities for milk, beef and pork are becoming ever larger and more efficient. Moreover, livestock farming is also based on resources that are not sustainable in the long term. Animal feed derives from crop production that is not sustainable in the long term. Milk and beef production based on feed concentrate and cereals from open crop production create more greenhouse gases than what grassland can capture.

Consumer assessment of what are acceptable good ethics and esthetics in livestock farming will be key factors underlying the conditions for future livestock farming. They are also likely to be affected by our new genetic insight into the close relationship between animals and people.

The path we must follow to ensure long-term sustainability for agriculture, livestock farming and forestry involves reducing inputs, raising supply and quality while also meeting environmental, nature conservation and animal welfare requirements. The path runs along the E5 – the positive signature for all the variables, namely, Ethics, Ecology, Esthetics, Economy and Empathy. No other animal has the capacity comparable with that of Man in being able to comprehend other animals' life conditions, experiences and requirements.

To test the E5's accessibility in practice and theory, the Environmental Committee of the Royal Swedish Academy of Agriculture and Forestry set off on a combined study trip and scientific workshop in autumn 2007. The most urgent and challenging issue involved the original Fall of Man and whether there was a path back to Eden. However, this is far from being a question of whether we actually have or can acquire new knowledge, develop innovative technology and new cultivation methods. This is just as much a question of what are the conditions governing how we do things once we decide what to do. In other words, are we completely free to make any decision we like, or is our decision-making determined by certain laws and conditions that limit our ability to see how the world is constituted and, thus, hinder us from making sensible decisions?

Dependency of decisions



One-eyed and near-sighted with refractive error

In the best of worlds, we make decisions on the basis of conscious and careful consideration. Knowing what we think is important, we get the facts and then make a decision that approaches our values as much as factual data permit.

In reality, however, very different forces govern our decisions: Highly personal forces that are based not only on our life experience but also appear to be determined by inherited and inborn mechanisms.

"As decision-makers, we suffer from three serious problems: We are one-eyed, near-sighted and suffer from significant refractive error," explains Nils-Eric Sahlin, philosopher and researcher in decision-making and risk-taking.

One-eyedness is reflected by the fact that we are masters in seeking the information – right or wrong – that supports our conceptions of the world. Conceptions that are in turn based on our existing values as to how the world should look. But we are hopeless in accepting facts that contradict our image. We are good at verifying – but poor at falsifying – whatever we believe in, since that would be discomforting. Confirmation of our ideas is heartening; being forced to change our mind isn't quite as pleasant. In the causal chain from facts to values to feelings, the ideal sequence is that we first get the facts, and then allow them to influence our values and, finally, feel satisfied with the decisions we make.

In reality, the opposite sequence frequently applies. Firstly, we have a feeling about something, upon which we build our values and lastly we seek – in a very one-eyed manner – for the facts that confirm our values. Moreover, shortsightedness means that we select the facts we have in front of our nose, while time and effort are required to search for facts outside easily accessible sources. It's easier to select what is close at hand rather than what is more inaccessible. Maneuvering on the basis of a black and white color scale is closer to our heart than moving amid the multi-toned mosaic that makes up the world in which we live.

Refractive error makes the context a determining factor. A simple narrative leads our focus and thoughts in a definite direction. The classic example involves Linda, a young woman in her 30s. At university, she was active in the anti-nuclear power movement, socially conscious and graduated with a good degree. Having heard the story about Linda, how do we answer the question as to our opinion of Linda – that she is a bank teller or that she is a bank teller and active feminist? Most people respond that she is a bank teller and active feminist. The answer is a logically incorrect conclusion based on what we are told about Linda. Of course, on the basis of what we heard about Linda, we have no possibility to know anything for certain about her other than that she is a bank teller.

Another aspect of refractive error is that we are extremely bad at understanding and handling doubts when there are no simple answers to our questions. In particular, we are bad at understanding and forming a picture of what is meant by “probability”.

For example, how probable is it that a woman who has tested positive in a mammography examination really has breast cancer? We know that the tests provide a correct answer in 80 percent of cases. In other words, they show that eight out of ten women examined have cancer. We also know that 10 percent of all women examined show a false positive result, meaning that the test indicates a tumor although no cancer cells exist.

From statistics showing how many women actually get breast cancer, we know that the probability of a woman in her 40s being affected is about one percent. But if you undergo an examination and are then told that the test is positive, how large is the probability that you are actually carrying cancer cells if you are a woman in her 40s? Most people would answer 80 percent. But that is simply the probability that the test is accurate. It doesn’t indicate the probability that you have cancer. The actual probability is only 7 percent. To understand this seemingly unreasonably low figure, we must think in stages and people – not in percentages and theory. An explanation is required:

In a group of 1,000 women in their 40s, ten will develop cancer – as confirmed by statistics. Mammography identifies eight of them. Of those who do not develop cancer, that is 990, the mammography will nevertheless provide a false positive result for 99 women. So here is a doctor with a group of 107 women (8+99) all of whom have received the mammography results indicating cancer – but only eight of them that really have cancer, that is, 8/107 = 0.07.

Another aspect of refractive error is that we are often more convinced by our own opinions and standpoints than we have reason to be – we are simply “overconfident”. In our probably inherited and instinctive desire to be noticed and gain status among our peers, doubt is not a favorable signal. Those who radiate security and confidence gain higher status than those who show cautious doubts in the face of the multifaceted nature of life.

Add to that the characteristic that perhaps gives us the most serious refractive error of all: We seek not only the meaning of life – we also create it. Quite simply, we appear to have difficulty in coping with what seems meaningless and are most willing to arrange life in line with what we think we know, and we do so in patterns of meaning that comply with what we believe is useful or what we are convinced represents a danger or what we feel we can control. That applies in particular when we conduct risk assessments. Nuclear power, mobile telephony masts or nanotechnology are phenomena that far away, with an elusive direct benefit and beyond our own control. These factors are high on the risk scale of people who –with absolutely no trepidation – can talk for hours on a cell phone, smoke, or drive a motorcycle or car.

White men – and rose-colored glasses

“White men view the world through rose-colored glasses,” notes Nils-Eric Sahlin, while describing “The White Male Effect”.

A study conducted by two American social researchers (Finucane and Slovic 1999) has shown that white (well-educated) men in the US and Europe consistently view the world as less risky than white women or men who describe themselves as Latin American, Asian or African. That applies to all the issues and dimensions studied. It is important to realize that these white (well-educated) men in the US and Europe have dominant roles in decision-making organizations and exert influence in international negotiations involving agricultural projects and the direction of research and legislation.

"If these men view the world as less risky, and are also near-sighted, one-eyed and suffer from refractive error, we can be fairly sure that they will take incorrect courses of action. And then it's a just question of just how wrong such courses of action are," adds Nils-Eric Sahlin.

Neither is it difficult to figure out that the decisions – irrespective of how correct they may appear from every conceivable perspective of security and future social benefit – will contradict the values of many other groups, which have their own visual defects. There is, of course, only one way out of this dilemma, namely, a continual, open and critical dialog supported by facts and arguments from similarly candid and critical scientific research. And all accompanied by functioning democratic institutions, organizations, unrestricted Internet and active media.

A human face

Emotion is the governing factor. The mechanism underlying visual defects is emotion, which colors and distorts. Thus, it is emotion that helps – or hinders – us when we need to make crucial and correct decisions.

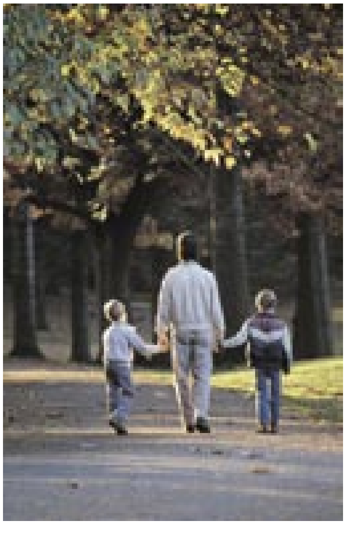
"Why don't we do anything about Darfur, for example," asks Nils-Eric Sahlin.

He points to the fact that during the 20th century, people have killed their fellow men in one genocidal campaign after the other: Two million Armenians in the early 1900s, six million Jews during the Second World War, thousands in the former Yugoslavia, Rwanda and so forth. And always – or almost always – we closed our eyes or reacted too late or too passively.

The explanation he offers has its roots in our evolution. To react, we must see individual fellow men, not just anonymous groups, who in any case are frequently demonized by their enemies. It's no coincidence that aid organizations use photos of individuals – notably children – when pleading for our assistance. Suffering must have a face so that we can understand and react, it must not be clothed in anonymous numbers.

A good deal of psychological research indicates that we are born with an instinctive ability to protect and assist those close to us – our family, relatives and the group – those who have a face and with whom we feel affinity. Without an inborn talent to learn to show solidarity with the group, we could never have survived as people. The fact that a person sentenced to death is brought to the gallows in a hood or given a blindfold in front of the execution squad has nothing to do with the condemned person. It is to ensure that the executioner, soldiers and spectators do not suddenly need to look another human being in the eye, making them feel like murderers and perhaps refusing to participate.

Belonging to a group is – and especially



We are born with an instinctive ability to learn to protect and support "our own". Without group solidarity, we could never have survived as people.

in the past – has been literally essential. It affects our feelings in making decisions, tending to make us opt for the choices that we expect will be approved by and earn the respect of the group to which we belong.

"What would you choose?" asks Nils-Eric Sahlin: "You have two refugee camps. One of them holds 100 refugees, of whom you can save 80 percent. In the other, there are 1,000 refugees, of whom you can save 20 percent. What would you opt for if you only had a single alternative? Research (Paul Slovic) shows that the vast majority of people say 80 percent of the hundred, although the second alternative would save an extra 120 lives. And why do we make such an obviously incorrect decision? Because we lack an intuitive feeling for absolute numbers. Magnitudes must be related. Thus, we feel we gain more respect from others if we manage to save almost all, which is 80 percent of 100 compared with just 20 percent of 1,000."

Sustainable decisions

Making the right decision is difficult. Being one-eyed, and nearsighted with refractive error does not make it any easier. Neither is it any easier because we are so profoundly human that we find it difficult to understand abstract magnitudes and by the fact that the problems we are to solve are most easily understood if they have a human face.

The sustainability equation that the Earth's forest owners and farmers must solve in the immediate decades is – to put it mildly – rather intractable. Within the next 50 years, they must do their bit to produce 50 percent more food at prices that people can pay, despite the fact there is no more virgin land available for cultivation. Parallel with this, they must cut their consumption of finite resources – water and energy – and reduce the adverse environmental load, as well as restoring and recreating substantial nature values. The equation will not easily be solved without research to develop new insight into how nature functions. Also, the resulting know-how must be capable of being used in innovative technology that permits large-scale application. This will not be possible unless the options underlying decisions are part of a narrative that takes into consideration our vision defects and our humanity.

Lean and green

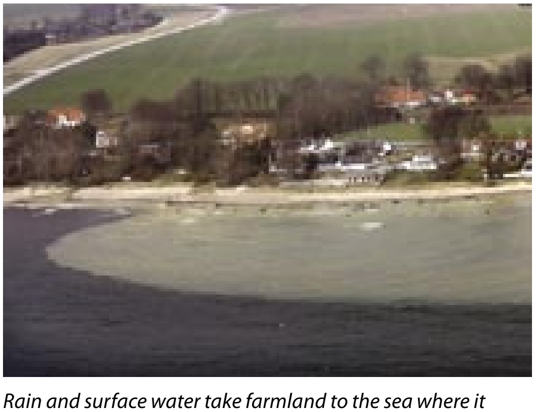
Is this where the challenges lie – to be able to see the right proportions notwithstanding all our vision defects? To be able to see where the really major challenges are in our efforts to create sustainable natural resources management?

Probably few Mediterranean tourists have wondered why modern archaeologists are compelled to dig so deep to extract the theatres and palaces of antiquity. Why did Troy and Knossos lie buried under such deep layers of earth and sand? When Evert Taube, the Swedish troubadour and poet, sang about "Angel soil and heavenly land that fell from the skies", he was really extolling one of human culture's worst environmental catastrophes. The soil that hides the remains of antiquity was blown there from mountain faces that were laid bare when forests were felled for fuel, boats and buildings and made way for grazing cattle, sheep and goats. The black humor of agricultural researchers refers to the Mississippi – the third largest river worldwide – as being "...too thick to navigate but too thin to cultivate."

Researchers believe that some 50 percent of the valuable topsoil of farmland worldwide has been carried out to the sea over the past 100 years and that at least 40 percent of the world's farmland is subject to serious soil degradation – primarily erosion, salinification and waterlogging.

The problems in Sweden are not quite so serious. But even here all watercourses that run through farm landscape become filled with sludge as soon as it rains during the seven months when the land is black and lies fallow. Or when the spring melt water takes topsoil with it to the sea. In the province of Skåne, (southern Sweden), farmers exchange soil with each other during rather troublesome dust storms almost every spring when high pressure in the East, plus drought and fresh winds combine to hit the area before spring crops have grown sufficiently high to protect the land. Everything blown away must be replaced. The soil that disappears is generally also that with the most nutrients. It moves towards the sea where it fertilizes algae and kills the seabed. And farmers must spread new nutrients on the depleted fields.

Now, however, energy prices are rising. Not only is it more costly to run farm machinery, the cost of fertilizer is also rising. This trend confirms an old self-evident fact: Most of the requirements imposed on the pro-environmental adjustment of farming also offer a financial gain if they are met. Each kilo of nitrogen per hectare that does not leach from farmland but instead ends up in crops represents SEK 13 in lower costs. If a 100-hectare farm using about 200 kilos of nitrogen per hectare can reduce its nitrogen fertilizer by ten percent, with no reduction in the harvest, it makes a saving of SEK 2,000. Not much you might think – but who would unnecessarily throw away SEK 2,000?



Rain and surface water take farmland to the sea where it fertilizes and kills it.

In addition, there is also a saving on fuel for farm machinery. In crop growing, about a third of energy consumption is attributable to soil preparation and a third to fertilizer. With a crude oil price of USD 127 per barrel (May 19, 2008) and a diesel price at the pump of more than SEK 13, interest is rapidly growing in finding methods to cut fertilizer volumes and reduce soil preparation in crop production.

Protecting the soil

This trend has been easy to predict for decades. But few have any great opportunity – or reason – to adjust to forthcoming change before it actually happens. Unless, you're a government researcher, of course, with the task of creating contingency programs ahead of impending changes. Well, at least that's how Christer Nilsson and his colleagues interpreted their mission when 15 years ago they commenced studies to identify growing methods that required fewer inputs but nevertheless provided equally large harvests.

With a sharp eye for proportions, he first checked the implications of one of the major items in the financial and environmental budget, namely, large heavy machinery and soil preparation work.

"It transpired that plowing had an equally negative impact as pesticides on all useful insects," he notes. "When we plough we essentially create a desert."

Plowing the land is a brutal incursion into the soil's ecosystem. Soil microbes that thrive in the subsurface are turned up to the surface; while and those that thrive on the surface are buried in the subsurface. The insects are presented with radically new life conditions, while the seagulls get a readymade meal of our essential partners – earthworms, which the Swedish poet Harry Martinsson referred to as "The Underground Farmer".

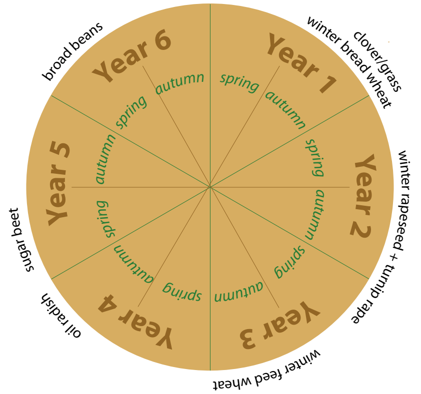
The farmer ploughs his land for two reasons. Originally, it was to eradicate other plants that competed with those he wished to grow and to get a loose surface soil in which he could plant his seed (the cereal types we sow are pioneer plants that cope best in an open landscape). Nowadays – because of all the heavy machinery that repeatedly crosses the fields – the plough must also be used to break up the compact soil and offer the roots a better chance of reaching the surface.

Plowing turns the soil's ecosystem upside down. Soil microbes find themselves in the wrong environment, while the gulls can delight in a readymade meal of earthworms.

Clover ley provides nutrients for the subsequent crop.

If you sow and harvest on soil that is not at all compact, in the best cases you'll get a 25 percent higher harvest using the same fertilizer input – or the same yield with 25 percent less plant nutrient. Other calculations indicate that today's cereal harvests could be 10–20 percent higher with the same inputs if the soil's structure and physical properties were as good as 40 or 50 years ago, before heavy machinery arrived on the scene.

Consequently, Christer Nilsson has devoted a large share of his career as a researcher to new crop growing methods in which the farmer should preferably refrain completely from soil preparation, and for which the soil is never, or at least seldom, without a protective covering. This is how Christer's crop sequence is configured:



Christer Nilsson's crop sequence

The first year: winter bread wheat is sown together with a blend of clover and grass. After harvest in autumn, the grass and clover receive light and can begin to thrive. The fact that we associate clover with riches originates from the period when clover was almost synonymous with ready cash. Clover can fix nitrogen from the air and convert it into nutrient for itself and the subsequent crop. A farmer with a rich clover field was literally richer – and could get a better harvest – than the farmer who only had cereals or grass on his land.

So the clover/grass field that appears after winter provides a harvest of livestock feed as well as nutrients, and thus reduces the fertilizer requirement for the crop sown immediately after late summer or early autumn when the clover is harvested.

Following the harvesting of the ley in late summer or early autumn, the land is sown with winter rapeseed with some input of a close relative, turnip rape, which flowers a little earlier than the rapeseed. The turnip rape buds attract the blossom rape beetle and absorbs their attacks. When the beetles then show an interest in the rape, the latter is no longer as sensitive to attacks and the beetles need not be combated using chemical agents. Apart from being an additional environmental gain, this also represents an energy and financial saving.

After the winter rapeseed, which is harvested early in the autumn of year three, winter feed wheat is sown immediately, which provides a harvest in autumn of the fourth year.

Following the harvesting of the feed wheat in the autumn, an oil radish crop is immediately sown, which spouts very rapidly, grows fast and provides large leaves and deep roots also during the brief growing period in the autumn. The oil radish is planted only for the purpose of covering the land, absorbing excess nutrient and storing it in its plant mass for the following spring and for the next crop, which will be sugar beet sown in spring.

The sugar beet crop is harvested so late in autumn that there is no scope for a new crop during the autumn. Not before spring is the last crop sown, which consists of broad beans, which apart from providing beans is also a plant that fertilizes itself with nitrogen and leaves nitrogen-rich plant residues for the sowing of winter bread wheat and clover/grass that subsequently completes the entire crop sequence cycle.

Thus, the harvesting of the sugar beet is followed by the only period in Christer Nilsson's plant sequence when the land is uncovered during the winter until the broad beans begin to emerge from the soil and cover the land. This is less important at this stage than in other stages of the plant sequence, as the sugar beet is taken up so late. With an increasingly warmer climate, we will soon be able to also sow winter cereals after the sugar beet. The strong taproots of the broad beans, radishes and red clover also create a better soil structure and at a deeper depth than the plough.

Banning the plow

At no time during this six-year plant sequence do heavy tractors with rather powerful plows appear on Christer Nilsson's farmland. Soil preparation is done in a light form just to shuffle the soil surface.

Spilled seed and weeds are left alone to sprout and turn the field to autumn green. These are later destroyed during the planting of the next crop. Plow-free cultivation requires a little more chemical combating of perennial weeds, but frequently the annual weeds are fewer and easier to control. The need for chemical pesticides for dealing with weeds and fungi does not decline substantially. Less use of chemicals would be desirable, but that calls for other inputs instead, while chemical pesticides are a resource-efficient means of retaining control of the development of the farmland ecosystem.

Whether this is a benefit or drawback depends on your attitude to chemical agents. Are chemicals better or worse than the damage caused by the plow? What are the types of chemicals – are they environmentally hazardous or environmentally friendly? Do they give rise to residues in food? How is biological diversity affected and so on?

The answer can also be weighed against the fact that his crop sequence saves energy, fertilizer and the hazardous agents that are not required because there are more surviving useful insects that devour hazardous insects, which would have to be combated otherwise.

The harvests in the crop sequence are as large or larger compared with other plant sequences and the economics is more attractive. This approach provides savings of some 20 percent of fossil fuel for machinery for certain crops. Moreover, large farms also make savings in wages and taxes/social security expenses for employees no longer needed for crop production. The fertilizer requirement declines by

The Svarte River flows into the Baltic Sea – and takes farm soil with it to the sea. The soil lost is that which is richest in nutrients.

some 20 percent or more for certain crops. On the other hand, the costs of seed and pesticides increase slightly – but only marginally.

Christer Nilsson's future vision also includes the farmer being able to precisely control plant nutrients for plants on a "just-in-time" basis, when they are most required. This method includes fixed tracks in the soil and GPS-controlled machinery – perhaps even without drivers – that can work around the clock. This permits much smaller and lighter machinery. Soil compaction is almost entirely eliminated, partly because the machinery is lighter and runs consistently in the same tracks year after year. This eliminates heavy machinery from the rest of the soil – except during harvesting, but this is generally when the soil is least sensitive to compaction. But even in this case there are hopes that the farm machinery industry will develop threshers that harvest faster and have lower ground pressure. He then points to a key advantage of farming according to his model:

"Soil that is not compacted by heavy machinery more easily lets air and water through. This reduces the risk of soil damage, the water cannot leach out the nutrients from the soil and convey them to drainage. And less nitrous oxide is formed when the organic material decomposes," he adds.

The latter point is quite significant. Nitrous oxide is a powerful climate-changing gas. It is about 300 times more destructive than greenhouse gases such as carbon dioxide. Another interesting aspect of Christer Nilsson's crop sequence is that it absorbs more carbon dioxide from the air than farmland that is plowed each year.

Greater interest

Interest in plow-free farming is increasing in pace with rising oil prices. During the past year, Christer Nilsson talked with more than 500 farmers on the subject of "lean and green", meaning the minimization of soil preparation and resource-efficient farming with substantial harvests. On the Continent, there are new and growing networks of farmers pursuing plow-free farming and Christer was recently involved in establishing a Swedish network.

If you want to progress further on the resource-efficient path, you can emulate an approach that appears to be gaining popularity in Finland, namely, planting directly without preparing the soil. A seed sower for this task simply cuts a small groove in the unprepared soil and the vehicles behind place the seed in the ground along with the fertilizer required during the crop's initial first phase. The technique requires the combating of weeds using

Field pepperwort, an oilseed plant, has the potential to be a perennial crop.

chemical agents before the sprouts emerge from the ground or the growing of crops that are not affected by spraying. Is this like choosing between the plague and cholera? This again depends on your view of chemicals and the particular chemicals involved.

In the future – which as yet can only be perceived on the drawing board, or in the laboratory and with pilot crops –even more exciting visions appear, namely, crops that emerge each year from the same roots. Perennials that can be harvested year after year without having to plow, harrow or sow – one glimpse of that vision is presented by the field pepperwort (lepidium campestre), which is being used in crop trials at the Alnarp research facility of the Swedish University of Agricultural Science.

Field pepperwort is a wild oilseed plant that sprouts one year and provides seed in the second year. There are good prospects of developing this into a multi-year plant with high seed harvests each year and the same oil quality as other oilseed plants, plus generally good growing characteristics.

Research is also in progress to provide new insight into how plants defend themselves against pests and how their utilization of soil, water and nutrients can be improved. In the best of worlds, all the bits of the puzzle fall into place. When they are in place, perhaps we can get an agricultural sector in which crops do not need to be sown for a number of years, have a built-in defense against insects, mold and fungus, outperform weeds, need less fertilizer or are, indeed, self-fertilizing. In other words, a type of farming in which the soil is protected all year round by plants and thus does not leach nutrients or loose soil to wind or water and in which biological diversity increases both above and below ground. A type of agriculture in which the farmer perhaps needs only one machine – a driverless GPS-controlled harvester – that can move all day during harvest and is run by biogas from the farmer's farm.

Will we ever see such crops in the future? Christer Nilsson doesn't think so.

"We relocate continually," he says, referring to the fact that functioning crop production is based on changing the crop each year.

Each crop has its particular specialized enemies, which you retreat from simply by changing field. Growing the same crop each year provides a readymade meal for its enemies. Realizing the dream of perennial crops requires that plant breeders succeed in putting together an enormously complex puzzle with numerous different characteristics. But, of course, it is worth a try.

Land covered with plants all year round is more sustainable for a number of key reasons. It acts as an effective carbon sink. Growers who switch from open land that is plowed and harrowed each year to permanent grassland free up the atmosphere from more than one ton of carbon dioxide for each hectare in grass – and do so each year as long as the grassland is kept. Trials run at the Rothamsted Experimental Station in England and at Sweden's Swedish University of Agricultural Sciences confirm this.

While waiting for it to be a possibility, a further development of Christer Nilsson's vision has made some progress: Direct sowing in the autumn of winter-tolerant and highly resistant crops in which weeds can be controlled using environmentally friendly pest-control methods. This is about as close as we can get to the advantages of perennial crops and, perhaps, it could bind up to six percent of Sweden's total carbon dioxide emissions annually. But that vision requires that crop growers and farmers can capitalize on the potential of genetic engineering.

Eden's herbary

"If any problems arise, we'll solve them." Preben Bach Holm, plant breeder at the Department of Genetics and Biotechnology at Aarhus University, Denmark, is almost provocatively optimistic about the potential of research.

But he is by no means alone in highlighting the power of life science research – both positive and negative. A consensus is beginning to emerge among modern life science researchers, namely, that bioscience research in the current century will play an equally large role as research in physics and chemistry did during the previous one. The latter research role encompasses quite a lot – from the marvels of industrial society to the threatening Armageddon of the climate change catastrophe. Between which we had two world wars and the detonation of two atomic bombs. But also the image of the Earth as it rises above the horizon of the moon; an image that more than any other stimulates a commitment to the global environment.

But the vision of bioscience researchers has a decisive, almost dramatic, and different point of departure compared with how we were compelled to apply 20th century know-how and technology.

In the transition from an agricultural landscape to an industrial landscape, the key factors were size, weight and volume. Few imagined that gigantic industries, large cities, intensive farming and extensive transport would lead to an ecological cul-de-sac. Now that we are forced to clean up, cleaning up is really the operative term. We are subsequently applying a good deal of the same to fix whatever went wrong. Now, however, in the transition from the industrial society to the IT, service and knowledge society, a new perspective is emerging. Everything we want to spend our resources on uses ever-lower energy and materials and we have also gained new potential to start designing production and communication with sustainability as the starting point.

And this is where life science researchers enter the picture. Their ideal models are factory processes, transport activities, services and products that have rolled on for millions of years without destroying the base from which they emerge and serve. It is difficult to find anything more sustainable. What we humans achieve by means of noisy machinery, high temperature, high pressure, hazardous chemicals and troublesome emissions that must be dealt with, nature achieves without any other resources than solar energy, water from the soil, the salts of the land and the "word of life" – the genetic code concealed in the heredity of organisms. DNA in other words. And nature has a great deal to offer.

The most highly productive farmer on the best farmland in southern Sweden comes off badly compared with a good forest on productive land. A hectare of winter wheat managed by a skilled farmer can convert sun, wind and water into 13 tons of straw and cereal seeds – calculated in terms of biomass dry substance. On the same surface, a flourishing forest of hybrid aspen with the same solar power, wind, and water can create 17 tons of tree trunks, branches and leaves. And all this (almost) without anyone plowing, harrowing, sowing, fertilizing or using chemical agents and without any devastating nutrient leakage to surrounding ecosystems. And the forest is almost totally uncultivated, whereas wheat has been refined over hundreds, indeed thousands, of years.

With the help of the plow, the harrow, fertilizer, chemicals and old-fashioned gene research

A hectare of winter wheat can convert sun, wind and water to 13 tons of straw and grain, calculated in terms of biomass dry substance.

and plant cultivation, during the past 40 years we have doubled harvest volumes from arable land. Half of the increase can be credited to genetics and plant cultivation, and the other half to chemical science and technology. On the debit side we have soil degradation, plus pesticide residues in land, water and food, in addition to altered and blighted life conditions for animals and nature, as well as erosion, salinification and water-logging.

The challenges facing the world's farmers are to restore all these features by 2050 and to supply three billion more people with, preferably, the same living standard that we enjoy today. For example, cereal output worldwide must increase 50 percent by 2030. In addition, there are increasingly urgent demands and hopes that arable land should not only produce forage, food and fiber, it should also produce fuel for cars, boats and aircraft and replace raw materials in the petrochemical industry.

As Preben Bach Holm sees it, that equation will simply not solve without another green revolution. A revolution that must be twice as green: Firstly, in the sense that it fills in the previous green revolution's ecological footprints and tire tracks and, secondly, that it does not leave any new tracks and footprints.

The virtual forestland

Can we cultivate land as if it were virtual forestland? Can plant breeders give us perennial crops?

"Certainly," responds Preben Bach Holm. "Just give us the task and the time."

And, of course, the funds I hasten to add – plant breeding is a costly process. Nevertheless his optimism is scientifically well based. In fact a type of barley that is sown already in autumn is available in Sweden. This was previously just a dream. All barley sown in Sweden in the 1950s and '60s was planted in the spring. Winter barley has long been available in milder climates. But plant breeders have gradually evolved plant characteristics to suit northern climes. The success of a plant in coping with one winter may be viewed as the first step towards it surviving several consecutive winters and becoming a perennial. At the University of Gothenburg researchers are cooperating with the Swedish plant breeding company Svalöv Weibull to develop a type of oat that can be sown in autumn. The plant breeding company Syngenta, based in Landskrona in Sweden, has made good progress in cultivating a sugar beet that can be sown in early autumn, hibernate and then be harvested in late summer or early autumn of the following year. Both of these examples bring

Christer Nilsson's vision closer to reality – a vision entailing that farmland never lies bare and unprotected.

What makes Preben Bach Holm so optimistic in fulfilling his dream – crops that grow year after year from the same roots – is the rapid development in plant genetics in recent years. Plant science is becoming better and faster at drawing complete DNA maps of an increasing number of plants. Corn and rice have had their genes charted all the way down to each individual building block. Wheat is next on the list. And what is emerging in the wake of the success of genetic cartographers is remarkable to say the least. Our crop plants appear to carry the entire history of their evolution in their genetic luggage. Generally, genes don't appear to disappear or emerge from nothing. The genes that exist in, for example, modern-day wheat or give wheat its characteristics have always existed in one form or other in a wild relative. And what is more remarkable is that the genes of all the wild varieties appear to remain in the types we grow today. The genes ignored by plant breeding have not disappeared; they have simply hibernated and can be revived, perhaps.

If some original wild relative had been good at living on the brink of dehydration, surviving in saline soil, defending itself against insects and fungi, outperforming weeds, superior at extracting soil nutrient, had more antioxidants and/or particularly interesting proteins – or was a perennial – the genes underlying these characteristics remain to this day. Most of them are dormant in the now cultivated wheat's genome. This is certainly the case among the wild relatives that continue to exist in the "Fruitful Crescent", the fertile area between the Euphrates and Tigris, where agriculture emerged more than 10,000 years ago. And there's a good deal to choose from.

The closest relatives to cultivated wheat exist among a part of the grass family called Triticeae. In this family alone, there may be 500 different sources for genes that can be transferred to barley, rye and wheat. But at the top of the scale of remarkable discoveries in modern genetics there are, however, all the genetic duplicators, switching points, alarm clocks, accelerators and brakes that researchers find.

The genes in modern wheat types have always existed in some of their earlier wild relatives.

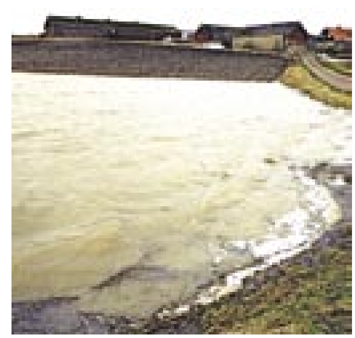
It appears that all live on Earth represents variations on one single life form. The commonality of all living things on Earth becomes clearer and greater the deeper we look. What differs Man from wheat is not so much how many genes we have[1] but how they are governed. And it is this control mechanism that researchers are now charting. This offers the possibility of departing from the old and controversial method of moving genes among species. That approach, namely, to mix what God once created as individual species – people and animals, trees and

1) The wheat genome is three times as large as that of Man.

The Pinne River, which flows through forest and grasslands, reflects the blue sky, having considerably overrun its banks.

fish – has perhaps been the most forbidden, We can now avoid this. With their new molecular precision tools, plant breeders can work more freely with the plants' own genes or with genes from close relatives. Whether or not it will be less controversial remains to be seen.

There are several fairly immediate and concrete sustainability issues that modern plant breeders should and can deal with. For example, phosphorous – one of the key factors underlying the recurring and worsening algae blooms in the Baltic Sea. The green revolution in Sweden after the Second World War was actually black. This was when farmers changed from long-term leys, which provided feed for dairy cattle and for hog feed based on cereals sown in the spring on black arable fields plowed by horse-drawn machinery. Cattle also received more cereals in their feed. Thus, streams and rivers running through farmland had to handle ever-increasing volumes of sludge in autumn, winter and spring, when rain and melt water swept topsoil and phosphorus to the sea. The grain, which represents the primary hog feed, also contained high amounts of phosphorus, a mineral that hogs need but it is very much bound up with other substances that hogs use poorly. Instead, hog feed is supplemented with the more easily accessible phosphorus. This results in an overall surplus. A surplus that moves with the hog manure out to the fields and adds to the phosphorous excess. The global store of phosphorus available to supplement animal feed cannot last beyond 50 years. Plant breeders that can ensure that hogs utilize the phosphorus value in feed would be able to kill two birds with one stone: Firstly, to reduce the flow of phosphorus to the Baltic Sea and, second, to delay an impending shortage of phosphorus.



The Rönne River, which runs through farmland, is thick with sludge.

But more needs to be done. Cereals represent the foundation for the global food supply. These were the plants that were most easily "tamed" but although they constitute nourishing food they don't offer everything we need. They include too little and too much. Take, for example, amino acids – the building bricks in proteins – that strengthen human muscles and those of hogs. Grain proteins have a slightly different combination of amino acids than what hogs and humans require. To get a sufficient amount of the least available amino acid, a hog gets far too much of that of which there is more. And where does the surplus go? Out with the pig manure, of course – in the best case to the fields and plants; in the worse case to add to the nutrient load in the Baltic Sea. In any event it is a completely unnecessary waste, which could be avoided if plant breeders could only ensure that the grain had a balanced mix of energy and the right amino acids. Needless to say, the dream is that they can also develop a perennial cereal grade.

In Denmark, 25 million hogs are raised each year, which produce 34 million tons of manure. Of course, the manure includes a good deal of water, but in terms of weight it is above eight times more than all other solid waste in Denmark, which only confirms the significant input that plant breeders could make if, for example, they could reduce the phosphorus and nitrogen content of waste in Denmark by just 10 or 20 percent. But this requires research and plant breeding. And Denmark suffers from the same problem as Sweden – funds are available for research that is closely consumer related and which offers definite market benefits. But for research with a long-term social interest, resources are far scarcer. Also in Denmark, jointly financed plant breeding has strengthened in areas in which R&D offers more definite commercial applications. In Preben Bach Holm's opinion, this is tragic, and also highlights another problem – distrust.

"We've started at the wrong end. Instead of discussing the problems that we must solve and then identifying the research and breeding techniques will best help us achieve our goal, we have focused totally on technology."

What he has in mind is, of course, genetic engineering. Nobody denies that new techniques can entail new risks that must be studied, made safe and managed. But because the debate has almost ignored the social benefits and the urgent problems that we must solve and can solve using new techniques, the debate on genetic engineering has focused solely on risks and ethical conflicts. Quite simply, it has proved impossible to offset them against the benefits, since the few people that talk about future potential have not been able to have their voice heard in the debate. The only thing that has proved possible to highlight is the practical application to date of genetic engineering – crops that can cope with weed pesticides and plants with built-in insect poisons. And in these cases, consumers, the public and NGOs have not been able to find any benefits that they feel offset the risks.

Perhaps change is on the way, as represented by new types of genetic engineering, which, as noted, do not move genes from one species to another. It is sufficient to use the plants' own genes or those of close relatives. In laboratories worldwide, genetically modified crops are emerging with characteristics that offer more obvious social and consumer value. Genetic engineering can offer solutions to a number of energy and environmental problems. And food shortages worldwide make it increasingly obvious that farming needs innovative plants with new characteristics. For example, plants which, with new growing methods, can be part of a farming approach that can solve one of the most serious problems in modern agriculture – decreasing biological diversity.

Recreation of Eden

The lark has been silenced. Well, if not completely, it has at least become increasingly rare across our farming flatlands. The same fate has befallen the yellow wagtail, starling and house sparrow. All these species are associated with farmland. Meanwhile, other species that are also dependent on a farmland landscape have increased – the barnacle goose, the grey goose and whooper swan, for example. How we grow our food influences everything else in the landscape. Certain species are favored and others suffer, but the common trend is for a change in biodiversity.

The number of larks in Sweden is now just one third compared with when estimates commenced 30 years ago. On average, the number of birds in species usually associated with the farming landscape is 40 to 50 percent less now than when estimates started in the early 1970s. As yet, no species has disappeared, although a few are living near the edge, which creeps ever closer in pace with changes in the farming landscape. The common denominator for large-scale flatland farming – which accounts for the dominant share of Sweden's farmland – is intensification, which has progressed since the major redistribution of land holdings at the end of the 19th century.

A mosaic landscape was predominant up until then. All farms had livestock and grazing land. Arable areas and grazing land were surrounded by stonewalls and thicket. The water and vegetation of the marl pits offered food and protection. However, with the land redistribution process, the boundaries on the flatland's largest grain fields disappeared towards the horizon. Open ditches were covered in and the marl pits filled in, grazing land disappeared and stonewalls removed. The impressions from Swedish and international contexts are similar: the greater the intensity of agriculture, the less the biodiversity. And how could it be otherwise?

Nature abhors a vacuum. Wherever the smallest little unutilized resource emerges, there is always some microorganism, animal or plant that spots its chance to survive and takes it. And the greater and more different the resources that occur in space and time, the greater number of varying, specialized microorganisms, plants and animals that find a niche in which to survive. In the old farming landscape there were numerous niches; modern farming offers fewer. The question then arises as to whether Man can pursue intensive agriculture that also offers diverse niches for diverse organisms. But the first question that requires an answer is: Why? What is biological diversity good for?

The meaning of diversity

One answer is that biodiversity is a form of insurance. We never know what type of organisms will prove to be crucial in the future – so it's best never to reduce diversity. And should it decline, make sure that there are areas from which rare organisms can spread out into the landscape that day when climate change, new crop plants or new cultivation techniques make it possible and necessary to be able to change the supply and structure of the landscape's biological diversity. We are dependent on the diversity that delivers all ecological services – ecosystem services – in order to be able to grow our food. For example, all the butterflies, bumble bees, and flies and bees we need for the rapeseed field to provide the maximum harvest and to ensure that various fruit and seed breeding can provide any harvest at all. Or the birds, insects, fungi and microorganisms that are required to maintain the balance against plant pests or secure land value in terms of growth potential.

Another answer is that we cannot live by bread alone. There are serious ethical and esthetic arguments for maintaining biodiversity and the multifaceted landscape: But which diversity and in what form? These are not given data. The concepts of ethics and esthetics tend to overlap. Also, we trend to classify them under "soft" values that we can take the time to deal with when we have satisfied our basic requirements for daily food, clothes and shelter for the night. To quote Bertold Brecht: "First food and then morals". This is pretty much how the old Maslow hierarchy of needs appears in most people's mental landscape. But modern researchers have shown that it provides a distorted image of the human hierarchy of needs.

If a small monkey who is separated from his mother is offered milk from a tin can and the "esthetics of love" from a soft toy, which will it select – the virtual embrace of the soft toy or the real food from the tin can? If the researcher conducting the test does not intervene, the baby monkey risks dying of hunger against the dry breasts of the soft toy. So much for the hierarchy of needs, which puts the body and food ahead of the esthetics of feeling and commonality. And why should we be any different from the baby monkey? People in hospitals with a view across green parks regain their health faster than those forced to stare at a concrete wall. Other studies show that human anxiety increases in dark uniform spruce forests or on the open sea where there is no break in the horizon for as far as the eye can see and, thus, cannot focus. In a varied landscape of about the complexity of a Japanese garden, the human heart finds peace. We feel best, stay healthiest, work hardest, relax most deeply and feel most assured in open landscape with about the level of order and diversity that reigned when we became people, that is, in boundary areas between, for example, the wild savanna and deep jungle or in a coastal landscape between water and forest.

Thus, we have shifted the question of the landscape's esthetics from the "soft" value world to the "hard" value world on a par with the issue of the volume and nutritional value of food. If we can't live on bread alone, then ethics, esthetics and morals are also a form of sustenance that we find difficult to live without. In addi-

Is it possible for us to pursue intensive farming while simultaneously offering diverse niches to diverse organisms?

tion, an esthetically functioning landscape has a very concrete intrinsic value for the farmer himself in at least two dimensions: For his own well being, but perhaps especially for retaining consumer confidence. In the debate on locally grown, non-toxic and ecological food, esthetics probably plays a far greater role than technology. What we think is beautiful feels better than that which is ugly and feels wrong. The question for the future is how crucial esthetics can be combined with crucial diversity and the equally crucial farming intensity. To answer this question, you must know where in the landscape diversity emerges and where it disappears. Henrik Smith, Professor of Zooecology at Lund University, has studied the matter.

Far away, but very near

Henrik and his post-graduate students are interested in flowers and bees and other pollinators. They have calculated the number of species of pollinating butterflies in various landscape types. That is, how many butterfly species that can ensure a functioning sex life for nature. But they could just as well have estimated the number of species of insectivore insects.

Insects are specialist creatures of habit. Order and discipline is the rule, with each insect species in its place and niche. This means that the number of species of pollinators or predatory insects can act as a functioning gauge of how many other sorts of insects or blooming species a landscape supports. And thus how many different ecological niches the landscape can offer and the degree of diversity. In addition, they have studied where the rare species live, including those on the verge of extinction. Not very surprisingly, there is a special landscape that includes most pollinating butterfly species and most rare species – the open or semi-open natural grassland. This is not the slightest bit surprising really. Natural grassland is actually one of the most diverse "cultivated" landscapes that we have in relation to what "uncultivated" nature consists of.

Nature itself is most varying and diverse only when viewed from a helicopter above large areas. Of course, both the vast forests and grasslands each have many species. But the real diversity arises when these two converge. The edge zones between these two ecosystems contain the most evolutionary creativity and diversity, and that is precisely what natural grasslands achieve: Many edge zones in a small area. All created, as they are, by Man's cultivation, our culture – surely what we now refer to as natural pastures should be called what they really are, namely, cultivated pastures. There is no such thing as natural farming. Nature itself creates neither arable land nor enclosed pastures. The entire biological diversity that we associate with the farming landscape is a product of human culture. It is we who must decide what is to be protected, conserved and developed... and why. If we wish to retain the diversity and esthetics that (natu-

Nature itself creates neither arable land nor enclosed pastures. The biological diversity we find in the farming landscape is a product of human culture.

Grazed nature areas close to each other can function as a "local species bank" but do not provide sufficiently diversity throughout the landscape.

ral) cultivated pasture and small-scale farming landscapes offers, then we must retain diversity and esthetic values. But – and this sounds completely paradoxical – it does not mean that the landscape must look like it did at about the time of the Swedish land redistribution in the last century, or by local farmsteads like Katthult in the 1940s (the epitome of the Swedish small farm as described in the works of the Swedish author Astrid Lindgren) or as portrayed by the Swedish writer/singer Ulf Lundell during the 1970s. Henrik Smith's research assists in identifying the landscape factors that provides its diversity and helps us to envisage how the mechanisms of diversity could be incorporated into the modern farming landscape.

You find the greatest diversity and also the rarest species in landscapes well endowed with grasslands that lie close to each other. The greater the distance between the grasslands and the fewer they are, the greater the decline in rare insects and the insect diversity. But there is a difference: The number of rarest insects falls considerably faster than overall diversity. What does that indicate in terms of various conceivable diversity strategies for the future?

"We must decide what we are going to do," says Henrik Smith. "If we want to retain red-listed species, then we should make sure to have many natural grasslands in the landscape, close to each other. If we are looking for ecosystem services, then perhaps it is sufficient to protect diversity and be satisfied with fewer and less dense natural grassland features in the landscape."

Many grazed nature areas close to each other probably represent the strategy that best matches the insurance argument. Many such areas alongside each other can be viewed as a dedicated species bank from which we can extract the species we need when required. However, that strategy does not meet the need for sufficient diversity throughout the entire landscape to guarantee the ecosystem services we require today. Farming's natural desert in the form of the deeply plowed, large-scale flatland cannot itself maintain the diversity required to provide, for example, pollinators that rapeseed growing can benefit from and on which vegetable and fruit growing are directly dependent. In view of this, we should focus our tax money for environmental-support on creating many natural types of grassland well spread throughout the landscape.

"I expect environmental-support funds for the farming sector to decline in the future," says Henrik. "The funds won't suffice for having many grasslands in concentrated clusters as well as having them across the entire landscape."

As he sees it, we just have to choose. Either we decide that it is most important to save red-listed species or, alternatively, ecosystem services and diversity become our core goal. If these are the only alternatives, then the choice seems obvious. Hard facts rather than soft values, and ecosystem services rather than red-listed species. However, as we concluded above, the soft world actually includes just as much hard currency such as the production landscape – although it maybe a little more difficult to identify in terms of time and space. Perhaps we should try a third path that offers the potential to eat our cake and yet have it. Maybe it's time to start discussing seriously the concept of cultivated diversity and conscious agro- and eco-design.

Eco-design

Basically, it is not semi-natural/cultivated pastures per se that offer biodiversity and favor red-listed species. It is the opportunities for sex, food and protection that they offer. When we identify the features of pastures that offer the entire package for all – including the red-listed species – will it then be possible to design a production landscape to ensure a complete delivery? Meaning the delivery of products and ecosystem services and the survival potential for threatened species? Maybe, but if this is the case, researchers face a difficult task in solving the puzzle and then attempting to emulate it in a new context. The features offered by semi-natural/cultivated pastures have been developed over hundreds of years of interaction between uncultivated land, soil microbes, worms, fungi, herbs, bushes, insects and birds. A single example indicates the complexity of the task. The Large Blue is a red-listed butterfly. Its various life phases are played out along with the Myrmica Sabuleti ant and the Wild Thyme (or Creeping Thyme) in a refined interplay that includes specialized microorganisms. Identifying what in this interaction is a prerequisite for whom and copying it as cultivated diversity and conscious eco-design can appear like a superhuman task. And perhaps we find ourselves having to divide up our goals of maintaining and developing biodiversity into a "parlor" and a "living room". A parlor that may be costly – with no glances at anything other than pleasure and the value per se of conservation – to conserve certain natural types in their present state, in sufficient quantities and in sufficiently large reserves to really maintain a certain set diversity and rare species. And a living room in which we consciously design our agricultural landscape as far as science gives us the potential to favor diversity and rare species.

But we know little about where the boundary will run between the parlor and the living room. The more our knowledge deepens as regards how nature functions, the more the border can be shifted in any direction. What we currently think we can only keep in the parlor may prove necessary and possible to move to the living room. And vice versa. The crucial ecosystem services that we can currently maintain only through biological diversity perhaps can be arranged in a less costly and superior manner.

Where the borders run can only be known via research and practical experiments, as at the holding called Högestad Gods AB just north of Ystad in the province of Skåne, Sweden.

Högestad

Högestad is the largest landed estate in province of Skåne in southern Sweden, covering a total of 1.5 percent of the province or 13,000 hectares of forest and farmland. This is the site of a project involving cultivated diversity on part of the to-

On part of the farmland on the Högestad holding, wide edge zones are left untouched as part of a research project for cultivated diversity. The plants sown include cocksfoot, chicory and lacy phacelia (Phacelia tanacetifolia) on a total of 15 kilometers around the fields.

tal farm acreage of 6,000 hectares. The project, which is being supervised by Lund University and financed by the Wallenberg Foundation, involves leaving three to six-meter wide edge zones, totaling 15 kilometers, around the fields in a pilot area totaling 400 hectares. The plants sown in these edge zones include cocksfoot (a perennial grass that forms protective tussocks), chicory and the self-sowing, profusely flowering and nectar-rich lacy phacelia (Phacelia Tanacetifolia).

The immediately visible answer as to whether or not the number of insects increases in the landscape is indicated by the partridge. The partridge is a very attractive prey for raptors, crows, magpies, foxes and wild cats. Initially, their chicks live completely on an animal diet and are dependent on finding many and varied insects within a reasonable distance from the place where the partridge mother can find cover for herself and her chicks. The more partridges you find in an area, the better the access to cover and insects. How the increase in diversity, quantity and any red-listed species is affected in detail will be reported in the research and doctoral thesis project based at the Högestad holding. But the most visible and the directly attractive financial result of the success of the project will be shown by an increase in the number of partridges in the landscape.

For various reasons, the edge zones[2] of a farming landscape are frequently of marginal financial value in actual crop growing. But when used as areas of eco-design and cultivated diversity, they can offer a direct financial profit. Rich edge zones can function as reserves for living pesticides. Perhaps in the future, edge zones will fight the pests that we currently combat with chemicals. Certain research done at the Swedish University of Agricultural Sciences shows that we have perhaps underestimated predatory insects and the ability of our enemy's enemy to neutralize the organisms that infest our crops. Thus, edge zones could save the farmer substantial costs for pesticides and provide bigger harvests. A greater number of partridges and other field game that could be favored by conscious eco-design can also offer substantial income through renting out for hunting purposes. Naturally, rapeseed growers, fruit, seed and vegetable growers also benefit from the farmland landscape gaining a more varied insect fauna. Without insects that fly from flower to flower, there will be less rapeseed oil, no clover seed and no apples and cucumbers.

Högestad's domains encompass almost all

2) Edge zones are frequently turnaround spaces for farm machinery, resulting in the soil being heavily compacted and unsuitable for cultivation. They are often in the shade and mature later than other sections of the field. Moreover, they frequently adjoin ditches and watercourses and should be left uncultivated to protect watercourses from nutrient and pesticide leaching.

features of the discussion on sustainable natural resources management and nature conservation. This holding pursues forestry, farming and water management, as well as real estate management and eco-tourism. Highly varied hunting activities and associated game management are also key features of the company's operations. Natural resources management is pursued by the company itself and in cooperation with tenant farmers. The company manages considerable nature and culture values. And all of this is done in one of Sweden's most urban rural areas right under the eye of thousands of local city commuters who also use the area daily and for recreational purposes. Moreover, this is a landscape that that is invaded each summer and holiday weekends by holiday-home owners from Sweden's various metropolitan areas, notably Stockholm. This is the destination for artists, writers, corporate executives, journalists and politicians who frequently have very definite, well-formulated values and demands in terms of the landscape in which they have their holiday cottages. In addition, many of them exert considerable influence in politics, business development and opinion formation. The manner in which Högesta Gods AB manages, balances and compensates all the possible social, economic an ecological interests that arise in such multifaceted activities in a region like this – and how it communicates its solutions – can reasonably be expected to be of major social interest and offer potential applicability in a larger context. Thus, the Environmental Committee plans to propose that Royal Swedish Academy of Agriculture and Forestry takes the initiative in undertaking a future-oriented and current status study of Högestad Gods AB's strategic and long-term planning in terms of sustainable development.

Eden's forests

What is a forest? If you pose that question to forest owners, one possible answer is that it is their workplace, a means of living, or a capital investment and pension insurance, but occasionally also their abode, and hunting place, as well as a source of berries and fungi. Combined, these features provide daily work, a meaning to life, and money in the bank. However, surveys confirm that money in the bank is frequently subordinate to other interests.

If you ask representatives of the forest products industry, they will most likely reply that the forest is their raw materials base, the foundation for Sweden's largest export industry – and an indispensable employer. For naturalists, the forest is home to a substantial portion of Sweden's biological diversity – from wolves to white-backed woodpeckers and moose, to larvae, mosses and invisible microorganisms. For recreational and holidaying city dwellers, it is an excursion goal, or a place for riding and strolling. And in the Swedish soul the forest assumes almost mythical and religious dimensions as the abode of fairies, elves, and goblins.

In the wake of the climate-change and oil crises, ever-greater demands are imposed on the forest to deliver second-generation biofuel and raw materials that can replace oil in the petrochemical industry. Will the forest be able to meet everybody's demands in the future?

"Certainly!" respond both Esben Möller Madsen and Martin Werner during a seminar at the Högestad estate.

They qualify this by adding that forests can't satisfy all needs simultaneously. But they both think that the forest's potential to assume a larger share of all roles is far greater than what we would be led to believe from the current debate on the role of forests. And their opinion has a solid base. Martin Werner is a forest manager and was long-time researcher at the Forestry Research Institute of Sweden (SSF). Esben Möller Madsen is CEO at Trolleholms Gods AB and manages the company's forests, in addition to forests on the Knutstorp and Maltesholm estates, totaling 8,500 hectares of southern Swedish forestland.

But to attain their target, you have to accept a fairly wide-ranging slaughter of "holy cows" and basically change the current mind map of many in the forestry profession in terms of their perception of forestry and forest products. The mind map's basic orientation was set when Sweden progressed from an agricultural to an industrial nation, and – as Martin Werner and Esben Möller Madsen see it – remains in many respects the primary direction and mindset of those involved in forestry.

The majority of those who derive their living from the forest are associated with interests that continue to have the strongest market position, namely, the forest industrial complex. Historically, it has also been equivalent to being allied to a highly positive social interest. Just like similar professions in agriculture and the food products industry, occupational groups such as forest managers, forest rangers, forest wardens, forest researchers and forest products industry personnel and management were given a leading and acclaimed social status, since it seemed obvious that it was the industry's need for raw materials and society's interests in products, work and welfare that also determined how the forest should be used.

That meant that forestry focused on large volumes of uniform, high quality forest raw materials, transported to the industry in the most rational manner. This involved bulk production of spruce and pine, pulpwood and sawn timber.

Being part of a profession representing dominant social and industrial interests and which also provides social status, work and income facilitates the development of strong conceptual traditions and a shared culture – especially so since the profession's members are educated via the profession's schools, colleges and, ultimately, its own university. A school network and a university with the explicit objective of serving overall social interests – not any particular industrial sector or any special version of any industrial sector.

However, during the emergence of industrial society, social and industry interests overlapped and gave the profession a cultural and conceptual tradition that has acted as an effective lever in giving us better managed and more high-yielding forests than at any time in Swedish history. Forests and the forest products industry are two cornerstones of the Swedish economy.

Nowadays – having progressed a long way into another age in which social interests are more complex and multifaceted – established cultural and conceptual traditions paradoxically share the common weakness of being strong.

The weak aspect of power

Distinctly drawn mind maps with clear main routes suffer from the fact that alternative paths to goals are difficult to identify and access. It is also easy to miss new goals and opportunities and difficult to understand criticism from others than those favored by the main routes.

"Forests do not only produce raw materials for industry. They also produce the life conditions and landscape for animals and people. And no other occupational group affects the life conditions and landscape over such a vast surface and protracted period as the forestry profession," notes Martin Werner.

This also means that what people see and experience of forestry management means more for their understanding of the forest than the actual forest itself. Thus, how the forest is managed becomes the most effective – and most revealing – tool to communicate to others what

Forests do not only produce raw materials for industry. They also produce the life conditions and landscape for animals and people.

Landscape esthetics is attracting an ever-greater social interest . Will landscape architects gain greater influence in forest management?

owners, forest managers and the forest products industry actually do, wish to do and plan to do with the forest.

"In hindsight, we note a number of catastrophic mistakes," says Martin Werner.

The early sawmill "squires" and their dubious business methods are the first. Then came the expanding pulp and sawmill industry's felling, which stretched far beyond what the eye could see. With this followed also phenoxy-acid herbicides to kill broadleaf plants, while the macho, forestry jargon inferred it was preferable to see a space in the forest than a thriving birch tree.

When the forestry industry eventually abandoned clear felling and herbicide spraying, it was not those with a forestry-based education that were given the task of providing the narrative, and commencing a dialogue with forestry critics in an attempt to restore respect for forestry among the public. The forest products companies shifted the task to professional public relations people. When nature conservation and the preservation of biological diversity emerged as a key social interest, it was university-educated ecologists who were given the task of attempting to merge forestry with considerations for nature – despite the fact that nature conservation was a component part of the forester's education program

"Will landscape architects be the next profession to instruct forestry as to how we should look after future forests, now that landscape esthetics is beginning to attract an ever-greater social interest?" ponders Martin Werner.

Knowledge in the marrow

It may appear obvious that as new requirements and tasks arise, new professions also emerge to solve them, since existing disciplines have neither the credibility nor the expertise to solve them. But – to reverse the perspective – perhaps neither have the new groups either.

Trustworthy communication does not only involve the superficial, it must also have depth. Either because the underlying basis must be changed or because what lies at the base is okay, but can only be discussed in an understandable manner if there is a sufficiently deep understanding of how things work in practice.

In both roles, the communicator's trustworthiness and potential to perform his/her job is highly dependent on the depth of their insight into the practical aspects. And perhaps the conditions underlying reality are similar for the professional ecologist. Will anybody in forestry listen to an ecologist who is unfamiliar with clear-felled areas or the state of the roads to the sawmill or pulp mill? And what about the future landscape architect? How does knowledge of the actual industry affect his/her ability to influence the practical workings of forestry and ability to identify solutions that meet long-term sustainable goals and short-term production requirements?

For Esben Möller Madsen, the answer seems clear – but not simple:

"If the forestry profession is to regain its former social status, it must fix its entire internal culture," he explains.

As he sees it, it is only when you come to grips with the old way of reaching production targets that you can turn to and use the know-how of the communicator, ecologist and landscape architect. You can then integrate their expertise with your in-depth knowledge of forests and forestry and chart new courses to reach a goal that must never be abandoned, namely, to use the forest so that it creates considerable commercial and non-commercial added value for industry and society. And conversely – it is only when other parties interested in the forest's future respect, listen to and understand the skills of the forestry industry and the underlying conditions that they can add to their expertise in a new, intelligent, nature-friendly, ecologically sustainable and ecologically profitable approach to managing forests.

Martin Werner is convinced that one of the key reassessments that should – and must – accompany such an internal cultural revolution is the assessment of deciduous forests.

"It is only when it rains that people who find themselves in a forest take shelter under a spruce. In all other situations, when you take a break in the forest – whether you're operating forest machinery or hunting, picking mushrooms, berries or walking or riding – you will look for a leafy glade," he notes.

Is it time to reassess the deciduous forest? Does our approach to it reveal our plans for forestry?

"How we in the profession view and manage deciduous trees is the most effective way of communicating what we plan to achieve with forest management," he adds.

Certainly there are studies that show that spruce is the most profitable type of tree in Swedish forests, despite major destructive storms about every five years. But these studies apply only to average cases and across very large areas. For individual forest owners, the calculation can look very different, depending on the risks they wish to take, and their attitude to the forest that they share with and wish to create among the public. In such cases, a few cubic meters more per hectare are far less significant in long-term forestry operations.

The relationship between wood volumes for industrial applications and how intensively forests are managed is shaped like an extended, slanted "S". If you're looking for a lot of commercially viable timber – the type that pays directly when you cut it – you need to be near the top where the curve begins to flatten out.

However, that dos not infer that the forest's overall ability to capture solar energy and transform it into biomass or other attractive products follows the same curve. The opposite may be case. The greater the diversity, the larger the biomass per solar hour?

Nature abhors a vacuum and has developed refined mechanisms to use every trickle of resources; irrespective of whether what's involved is solar energy, atmospheric gases, or soil water/salts. All these vary with time and place. Perhaps nature knows best – or almost best – as to how to utilize resources most efficiently in each place, in each habitat. Is there a habitat-adapted forestry that relies more on and supports nature's own capacity to put the right tree in the right place? A multi-cultural mosaic forestry with numerous tree types that vary with natural conditions in a totally different way than in modern monoculture forestry? A multifaceted forestry in which economies of scale in our current monoculture forestry are attained with intelligent sorting when the timber emerges from the forest? Virtual monocultures in the digital world?

All these features could perhaps provide the basis for a more diversified view of what forestry is, and which commercial interests – other than just the traditional sawmill and pulp industry – could use forests and forest products.

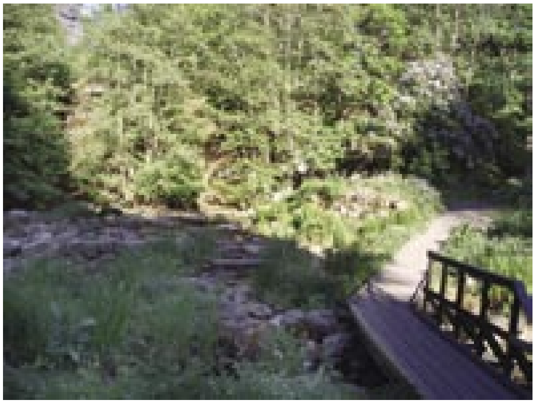
The new social contract

A new mind map that views multicultural forestry in this dimension is also likely to offer considerably larger industrial value to recreational forests, too. Forests near urban areas must primarily be managed to facilitate recreational interests to ensure the city dweller's quality of life and forestry's credibility. For the sake of long-term development and public status, the local councils and the forestry industry should sit down at the negotiating table and attempt to identify these forests. This is Martin Weber's opinion, who adds that he really isn't an admirer of the Swedish nature conservation model, which unfortunately is beyond all discussion today.

The Swedish model comprises the classifications NO (nature conservation, untouched), NS (nature conservation, maintenance provided) PF (production forest, supplementary nature conservation) and PG (production forest, general nature conservation). But an important class for the future is missing, namely, PU (production without nature conservation, or tree growing using intensive production), meaning the equivalent of the NO classification in production operations. Apart from the NO classification, which may amount to maximum of ten percent of forest acreage, the real aim is to permit forest owners to conduct intensive forestry with a minimum of nature conservation in all the other hectares.

"The map has led us and will continue to lead us into trench warfare against nature conservation," notes Martin Werner.

Instead, he believes we should set aside sufficiently large areas that are required for sensible



Multicultural forestry would provide maintenance for forests close to urban centers, favoring the recreational interests of city dwellers.

A sustainable and consciously designed forest landscape can be attained without any adverse environmental results, while also complying with current nature values and creating new values.

and effective nature conservation. In this case, we would refrain from all aims of maximizing timber extraction. In return for such really effective nature conservation, forestry would be permitted to achieve maximum efficient production in certain PU-classified areas. For example, hybrid aspen and poplar produce 25 cubic meters per hectare annually on good soil and can be felled after 20 years and rejuvenate themselves via root/stump shoots. Sitka spruce is a conifer that can produce a lot more than just spruce, but is viewed as an alien tree species and thus must grow in specially designated land so as not to conflict with the nature conservation approach.

And Esben Möller Madsen mentions a few more tree species that he would very much like to see in Swedish forestry, such as sycamore maple and Douglas fir, they form a key feature in his vision of diversified forest management in southern Sweden. A sustainable and consciously designed forest landscape – which is not compelled to comply with current nature values but which would, of course, be pursued without any adverse environmental consequences – featuring forests that are planted and managed so that they provide new esthetically attractive values and completely new nature values.

He is also convinced that we would gain highly diverse and multifaceted forestry, even without a conscious focus on different tree species in various habitats. Nature is itself multifaceted and he believes that, already, second-generation forestland on decommissioned arable land, for example, would offer a rather multi-varied forest. The new mind map involves thinking outside the box in terms of esthetics, ecology and economy – perhaps even featuring trees cultivated with the help of innovative gene technology. But that requires that the forest can be given a reliable and socially useful narrative in terms of the benefits offered by innovative forestry. A narrative that shows that everybody can benefit from the "new" Swedish forest.

Forests and animals – a round trip

Having spent an entire generation treating the forest as an industrial raw material, and considering that during the past century we converted almost two million hectares of agriculture land into forestland (albeit coniferous), it can prove difficult to think differently, namely, that the forest could be felled to make way for farmland. Nevertheless, that's the approach of Karl-Ivar Kumm. His research and proposals go hand in hand with the ideas of Martin Werner and Esben Möller Madsen as regards changeable and dynamic land use, which over time produces a long series of other attractive products in addition to just wood and food – such as rising property values, thanks to a beautiful landscape.

His ideas took root with an individual landowner who wanted to take over a small forest holding that had too few livestock to pursue rational and somewhat profitable meat production – but which had a lot of forest. However, the landholder's interest was more in livestock than in forestry, so why not take a contrary rather than conventional approach? Instead of allowing the forest to take over what was left of the open land, he made open land of some of the forest. After felling, he let the livestock loose on the clearing. Surprisingly fast, grass and herbs grew up that provided ample summer forage for a herd of beef cattle and calves, which provided the basis for keeping a sufficiently large herd of beef cattle to ensure some profitability.

Karl-Ivar Kumm has continued his research along this beaten path. His studies confirm that it is possible to attain profitability in meat production with grazing cattle on a forest clearing. Land cost is low. Fencing costs can be reduced if the acreage is sufficiently large and rationally designed. There are no building costs for housing if you save enough dense forest to provide wind protection.

This opens up an interesting perspective of rotation between farming and forestry – animals and nature. Especially, if you think in terms of new tree species with rapid turnaround. Why not sparsely planted hybrid aspen or poplar over a 25-year period during which grazing livestock keep the land open between the stands? After felling you protect the root shoots that will form new trucks and let the grazing livestock handle thicket control.

Designed properly in relation to semi-urban development and tourist flows, this construed "cut-over pasture" will also produce rising property values. Karl-Ivar Kumm got a number of independent real estate agents to price similar residential properties in various landscapes. Hardly surprisingly, they attached the lowest value to residences that were surrounded by purely coniferous forests. These were followed by those located in open farmland. The highest value was attributed to properties surrounded by land with self-rejuvenating deciduous forest (in this case birch), where the grazing landscape keeps the land bright and open, with a clear view between the stands. The difference in va-

We feel most at home in a varying landscape with wide-open vistas that nevertheless allow our gaze to focus.

The dark spruce forest plantation – perhaps a thing of the past in tomorrow's ecological forestry?

luation was a full 25 percent between residences in the shadow of spruce forests compared with residences facing bright meadows. Spruce forests also grew on the "cut pasture land", but only as one of a number of features in a varying landscape.

We feel most at home in a varying landscape and not in the wide-open landscape with its featureless horizon. And neither in the dense spruce forest, where our focus gets lost in the dark brushwood.

A varied landscape is what we like best – as expressed by Sweden's unofficial national anthem as penned by writer and singer Ulf Lundell. How many of the two million hectares of forestland, which just a century ago were farmland, could be switched to Karl Ivar Kumm's modern rotation between farm and forest, and animals and nature? We don't really know. But what we can do is to identify the legislation, regulations and financial conditions that would attract more people to give it a try. And eventually to cooperate with neighbors in creating large continual grazing land on current and former forestland and dedicated forestland. Under these conditions, the combined economy might even permit the production of meat at a price that could compete with imported meat from Brazil. As Karl-Ivar Kumm sees it, this point will have a particular importance when Brazilian meat producers are compelled to bear the entire cost of the environmental impact of their current meat production methods.

The timber loss sustained during the transition from forest to farmland would be offset by the wood derived from the transformation of marginal farmland into forestland.

But irrespective of the potential, the ideas and examples of Martin Werner, Esben Möller Madsen and Karl-Ivar Kumm offer an entirely new multi-colored palette with many tones. A palette with whose help we can paint a forest vision that offers an enormous amount of opportunities – the challenge is simply to be able to tell the difference between long and short needles.

Energy for eternity

Six noses inhale deeply from a red bucket containing dark brown slurry. The odor is earthy; perhaps not exactly pleasant, but certainly not unpleasant either. The owners of noses (the Environmental Committee of the Royal Swedish Academy of Agriculture and Forestry) – who are aware of the origin of the slurry – regard it as a virtual miracle.

A large share of the slurry derives from the liquid manure of 6,000 slaughter hogs, which produce one the most pungent hydrogen sulfide-saturated by-products from agriculture. Less odorous slurry is also pumped to the site in a pipeline from the food giant Findus a few kilometers away. We are at the Wrams Gunnarstorp estate located between the towns of Åstorp and Bjuv in the northwest of Skåne province in southern Sweden. Here, some 45,000 cubic meters of "worthless" waste is converted into biogas equivalent to 2,000,000 liters of gasoline, with a pre-tax value of about SEK 8 million. The only components eliminated from the sludge are the energy and – to the delight of all rural dwellers and tourists – the stench. The fermentation plant itself is virtually odorless. All nutrients in the manure and waste remain in a more refined form more accessible for crops.

The 45,000 cubic meters of energy and odorless sludge also hold about 200,000 kilos of nitrogen worth about SEK 3 million and some 30,000 tons of phosphorus valued at about SEK 1 million, according to facility's approximate estimates. The final profitability depends eventually on all ancillary costs in the form of transport and treatment stages, but these are a company secret.

But what is nowadays more interesting is

The Wrams Gunnarstorp estate may be viewed as a model on the path to a sustainable agriculture and food-processing industry in Sweden. The facility processes waste from hog farming using an almost odorless process. Biogas is extracted from the waste, and this can be used to replace energy and thus reduce carbon dioxide emissions, in addition to nitrogen and phosphorus, which are returned to the soil in the form of fertilizer.

that the carbon dioxide balance of the biogas is very negative – which makes it extremely positive. Methane gas that previously leaked out to the atmosphere – where it is much more destructive than carbon dioxide – has now replaced fossil fuel and its resulting carbon dioxide emissions. And the nitrogen fertilizer that the bio-fertilizer contains replaces all the fossil energy that the industry would require to make the same amount of fertilizer.

At Wrams Gunnarstorp the fertilizer will be sprinkled on the fields. This saves the soil from compaction by heavy machinery and also saves fuel. Wastewater is pipelined from Findus and replaces a considerable amount of road transport. Needless to say, the Gunnarstorp estate earns money from this process – so much so that investments of SEK 40 million can be undertaken without any government subsidies. And the figures will be even more favorable when regulations permit that biogas plants and fields sown with perennial bio-energy crops are included in the emission rights trading system.

The plant at Wrams Gunnarstorp also benefits from being located in a part of Sweden where there is already a natural gas grid. Here, there is a readymade infrastructure to connect up the town with the countryside, which could also be made available in the rest of Sweden. In southern and western Sweden, fossil-based natural gas has paid for the construction of an infrastructure that will be an effective catalyst for and carrier of the next generation of sustainable energy, namely, biogas. This should offer a lesson for all of Sweden.

Using the Wrams Gunnarstorp model and the expertise of Preben Bach Holm and Christer Nilsson, it is possible to draw up a credible vision of Sweden's future sustainable agriculture and food industry. A vision in which biogas and plant nutrient from manure, waste and energy crops make the sector self-sufficient in energy and fertilizer and also supply the surrounding community with both energy and industrial raw materials that can partly replace fossil raw materials. Currently, agriculture's overall use of oil and diesel corresponds to almost four terawatt hours.

Data from the Swedish Biogas Association indicate that manure from Swedish cattle, poultry, horses and hogs could be fermented to produce biogas corresponding to 2.6 terawatt hours. Moreover, if you grow energy crops on 10 percent of the land and ferment biogas from waste from industry, households and sewage sludge, the potential rises to a total of 14 terawatt hours – or about a similar percentage of the transport sector's overall fuel requirement of almost 100 terawatt hours. On top of this there are savings in energy volumes from industrial nitrogen fixing.

Just like the sludge from metropolitan water treatment works, the fermented sludge contains quantities of phosphorus, a crucial but scarce element. The Earth's stored and extractable phosphorus deposits are limited and this shortage is one of the most serious threats to our future food supply. Finding a positive way to close the phosphorus cycle between the soil and the table is essential in every sense. Returning the phosphorus in the sludge from the Wrams Gunnarstorp estate should not pose any problems. That sludge derives from hog manure and the food processing industry, which can be expected to have tight control of infectious substances and heavy metals. Neither should there be any major problems if the sludge derives from household waste. However, conditions are not so positive in the case of digested sludge, which may contain quite a few components that we do not wish to put on food-producing fields. But thanks to research at the Swedish University of Agricultural Sciences there is now a functional laboratory method for producing pure phosphorus fertilizer from sludge derived from biogas fermentation.

However, no matter which way you count, it doesn't add up. Energy from land and forests will play a crucial role in the Swedish energy balance in our progress towards a sustainable Sweden. But we must also find new energy sources if we wish to move away from dependence on fossil raw materials. In a global perspective it is quite obvious that bio-energy – as we define it today – will never be anything other than a marginal energy source.

On a global scale, each year we use about 125,000 terawatt hours. Bio-energy currently accounts for a modest 10,000-terawatt hours. Compare that with the some 15,000-terawatt hours of energy contained in all the food grown worldwide. Even if we were to burn up all the food we grow, it would only double the available energy. Thankfully, there is a completely different alternative in which nature and biology can play a decisive role in giving us a sustainable energy system, without having to resort to hair shirts and changing lifestyles for the sake of sustainable energy – namely, the Sun and the mechanism of the green life processes when viewed in a completely different context.

Light in the tunnel?

The solution to the energy problems of Sweden – and of our planet as a whole – rises above the horizon every morning. It glows all day and it goes down every evening. The Sun radiates the Earth every moment with an almost incredible 174,000 terawatts. This corresponds to the output of 21,000 nuclear plants like that of the decommissioned Barsebäck plant in Sweden. Total solar radiation worldwide is about 10,000 times greater that the total energy supplied to communities in the form of oil, coal, gas, hydropower, nuclear power and biofuel. In locations in which it is practically conceivable to capture solar energy, the radiation during a few hours corresponds to the entire global energy requirement. A surface area of about 80 by 80 kilometers covered by solar cells on our latitudes – using the best-known efficiency ratio of 12 percent – can capture energy equivalent to Sweden's overall energy requirement. That is almost four times the area of the Municipality of Stockholm. Furthermore, as yet, nobody knows the ultimate efficiency of a solar cell.

But what we do know is that nature has a particularly efficient way of transforming sunlight to energy. In the initial photosynthesis stages of green plants, almost 50 percent of the captured sunlight is transformed into chemically bound energy. However, what ultimately remains in the form of the actual plant (such

The Sun rises every morning and goes down each evening. In this process, it provides 10,000 times more energy to the Earth than the energy we humans have access to in the form of oil, coal, gas, hydropower, nuclear power and biofuel.

as a carbohydrates that we ferment in making ethanol) is only about one percent. This is why energy from farming and forestry offers so little potential to replace energy from oil, coal and natural gas.

However, replacing oil and coal as industrial raw materials in the petrochemical industry with raw materials from farming and forestry is much more realistic on a global scale. Of all the oil extracted worldwide, only about one percent is used as an industrial raw material and, thus, nationwide in Sweden, bio-raw materials can provide a significant contribution in our progress towards an oil-free society.

The high efficiency ratios in the initial stages of photosynthesis (40–50 percent) indicate that nature itself has a "solar cell" that is considerably more efficient than the most efficient solar cell that we have produced to date. The dream is to emulate the feat that spurs researchers such as Stenbjörn Styring, Professor and supervisor of the Photosynthesis Group at Uppsala University.

Stenbjörn Styring dreams of pure hydrogen – the gas that is the perfect carrier of tomorrow's energy. In reality, hydrogen is the secret behind all the energy produced in the combustion of natural gas, oil and coal. All fossil fuels derive originally from air and water. Nature uses an ingenious mechanism that takes carbon from the air's carbon dioxide and hydrogen from water in the soil and combines them to form hydrocarbon – loaded with the solar energy that drives the actual miracle. All coal, oil and natural gas that exist on planet Earth were once part of the atmosphere. We are now reversing the miracle. Burning hydrocarbons releases the solar energy that shone on the Earth a billion years ago, with the carbon and hydrogen returning to the air and water.

Stenbjörn Styring's dream is to understand and emulate the entire process in so much detail that he can copy part of it in a totally artificial industrial system. A system that can separate hydrogen from water – but does not combine it with carbon but instead forms pure hydrogen gas. When it burns hydrogen combines with oxygen in the air and simply leaves pure energy and water. That could prove to be very sustainable; but the scientific challenge is daunting. But not so challenging as to prevent a Swedish consortium from making a substantial investment that has already shown considerable progress along another path – the use of bacteria in large fermentation tanks to produce pure hydrogen in this context, too. This project is a little closer to hand. Although research in many parts of the world has confirmed that this approach functions, hydrogen-producing bacteria on a large scale is something for the distant future. However, a few figures indicate the potential offered by hydrogen.

An ordinary single-family house uses about 150 kilowatt-hours per square meter annually. Solar radiation at our northern latitudes is 1,000-kilowatt hours per square meter. If only 15 percent of the sunlight that shines on a house roof could be converted to storable and useable energy, the fuel equivalent would be sufficient to meet household requirements for a full year.

Using the same conversion ratio, solar energy that falls on a house garage would suffice to run the family's cars – assuming they use a half-liter for every 10 kilometers and are not driven more than 20,000 kilometers annually.

Thus, it is not the lack of nature's energy resources that sets the limits for how sustainable our lifestyle is in a modern, comfortable and consumer-friendly community on Earth. It is the lack of knowledge. Knowledge of how we can convert solar energy to usable energy and how we allow that energy to drive processes in society – in the form of an eternal cycle in which everything is reused again and again.

Animal Eden

Can you slaughter hogs without slaying them? Of course, you can. You don't need to slay hogs to slaughter them. You can just as easily put them to sleep with a gas that doesn't suffocate or scare them. And neither do you need to stress them with a tortuous journey to a gigantic slaughter plant along with completely strange hogs. It is just as easy to put hogs to sleep in peace and quiet on the farm, near all their friends and siblings that they've grown up with. And only after anesthesia and bleeding out should the carcasses be taken in chilled trucks to the meat processing plant.

Is this costly? Of course it is if you have to rebuild your existing facilities and if the meat industry is to change its logistics patterns overnight. But any calculation should include the costs of not rebuilding. And if you estimate what it costs to adopt a new approach from the very beginning, the extra cost is likely to be negligible and probably also a prerequisite in being able to produce pork that consumers wish to buy.

Needless to say, modern slaughterhouses do not slay hogs. The modern slaughter process in the best slaughter facilities is a rather calm procedure. Especially if you compare it with the on-farm slaughtering method used in the past or the methods used in slaughterhouses a few decades ago. But when the trend towards more animal-friendly slaughter and transport methods gained pace in the 1980s, similar discussions emerged. Ethics has a cost that consumers must sooner or later pay in the form of higher prices. But why?

The farm along the E5

Gun Ragnarsson's farm – Kärragärde – is near the town of Tvååker on the E6 highway in the Swedish province of Halland. But Gun has come a long way on the E5 in terms of raising piglets. In close cooperation with researchers from the Swedish University of Agricultural Sciences, she has developed a system for raising piglets that satisfies all conceivable requirements in terms of empathy, ethics, esthetics, ecology and economy. When the Environmental

Adopting innovative thinking is perhaps a prerequisite for being able to produce pork that consumers want to buy. But do consumers really need to pay more for an esthetic approach?

Gun Ragnarsson demonstrates how a sow lies down and rises up.

Committee of the Royal Swedish Academy of Agriculture and Forestry visits her, she starts the guided tour of the farm by lying prostrate on the concrete floor in a temporarily vacant pig house.

"This is what a sow does when she lies down," she demonstrates.

Her point is that you must have detailed knowledge of how a sow behaves in order to be able to build pig houses in which sows can move freely, rise up and lie down without injuring their piglets. This requires science and Gun Ragnarsson adopted a very scientific approach when she designed her facility. She checked everything to find out what sows think is important in this life, what piglets appreciate most in their mother and how they would like to have their surroundings. She then started building, and built big. Spacious, open housing with places for a total of 140 sows, divided into sections that are each designed to accommodate eight sows. Hogs are like people. Eight is the number of individuals that hogs and humans can cope with on a daily basis. Between eight and twelve individuals is the optimum number in a functioning stable social order in which each individual is aware of his/her position.

There's lots of straw on the floor. In addition, each sow has her own "one-room apartment" – a farrowing pen that she herself selects among those in the large enclosure. When it's time to give birth, the sow herself builds her nest in her pen, where she then gives birth to her piglets.

It's quiet and calm here. No noisy fans and so on, which is a key feature. The piglets and sow converse almost constantly with each other. They chat all the time about where they are, when it is time to suckle, when it is time to massage the udders, that the milk will soon come – and then its flows. The entire process is a finely tuned symphony of coordinated instruments, tones and scores. One movement follows the other and cannot be played until the first has finished. If anyone interrupts the concert, it degrades into chaos. There is even an intimate relationship between how many piglets a sow has, how much they massage the udder and how much milk she produces and releases. It's a matter of managing resources and distributing them correctly. Not too much and not too little. Each according to his needs. Each piglet has its own udder and seems to be able to determine the amount of milk required. Bo Algers from the Swedish University of Agricultural Sciences, who has studied the interplay between piglets and sows, refers to this process as the "restaurant hypothesis" (meaning that the piglet essentially "orders" the size of its future meals).

On the threshold of each farrowing pen is a large roller. The sow can cross over it with ease, but all the piglets trying to follow her fall back into the nest. Thus, the sow can personally de-

Piglets almost constantly converse with their mother, so it's essential that the family has a calm and quiet environment.

cide when she needs to be alone, and when she can socialize with other sows without the company of grumpy piglets, and when she wants to be with her brood. It is also an effective way of making piglets aware of whom their mother is when they come out into the "big" world in the form of the large enclosure. There they will meet seven other sows and their piglets. It's a matter of knowing who is who.

But it's also a matter of breeding. The sows in the large pens with many other sows must be able to stand their ground and protect their brood – just as they would do in the forest. The sows are varyingly good at this. Good or bad material characteristics are also an issue in breeding. Such as how the sow views the handler who must always do a few rounds among the sows. It isn't much fun being a swineherd if a sow has an excessively territorial and defensive instinct. Everything the sows do and how they look after their piglets is entered into Gun Ragnarsson's journals and used when it is time for the next brood. Sows that do not behave properly may not be among those released to meet the boar.

Gun Ragnarsson inseminates the sows artificially, but she nevertheless has a boar on the farm. This is a matter of passion and scents. The boar attracts. When the sows are released from the piglet enclosure, they rush to the 'dry period' enclosure where they all run freely and together during the period they don't produce milk – the dry period – and are not pregnant. Gun Ragnarsson describes their enthusiasm to get there as the dual effect of being tired of piglets and a longing to meet the boar.

"Any woman who has suckled knows how pleasant it is to escape it all," she comments.

With all the sows rutting and covered at about the same time, they all farrow around the same time, too. The whole system rolls on in a generally restricted natural, labor-saving cycle with two litters annually, most of which is controlled as much as possible by the hogs themselves.

And the results?

The piglets produced by Gun Ragnarsson's sows have a better survival rate than those of even the record-breaking Danish hog-breeders. And all of this is achieved without her using such tricks as segregated early weaning or keeping the sow tethered, keeping piglets on slatted floors, along with teeth clipping and tail docking, or adding antibiotics to feed.

She works fewer hours with sows and piglets than other breeders. The buildings are simpler and cost half that of conventional facilities. Heating costs are lower and she has almost no costs for veterinary visits or medicines. The end result: lower costs, reduced inputs, high output, same revenue but substantially higher profitability. And nobody can complain about ethics, esthetics or ecology it terms of recycling. Manure from the hogs is returned directly to the fields.

Although Gun Ragnarsson's hog operations meet all reasonable requirements for ecological sustainability, she is not permitted to refer to herself as an organic farmer, at least not in line with EU definitions or those of KRAV (Swedish organic certification organization).

According to prevailing rules, an organic hog must be reared outdoors. But Gun Ragnarsson does not wish to let her hogs out. Outdoor hogs root in the earth and mud, thereby risking infections and sunburn. But now, however, her hogs are out anyway. Not on farmland but on a concrete slab, in line with EU requirements for certification as an organic farmer. The sows and piglets seem to enjoy the arrangement. They already have their comfort and can now walk out into the fresh air with no great risk of infections. Gun Ragnarsson and her husband are also happy with the arrangement. If the hogs appear happy, they are happy. And the situation is certainly not made worse by the fact that they get a higher price for their piglets. Customers decide what they are willing to pay and organic produce commands a higher price, even though the requirements set by KRAV or the EU do not stipulate directly measurable ecological effects or animal welfare. Instead, they proceed on the basis that certain methods are forbidden or permitted. Higher prices pay for the investment in the concrete slab and offer superior profitability. The Kärragärde farm now also grows organic hog feed in line with EU organic regulations.

Cows on the path

A little further south on the E6 highway is another farm that has made substantial progress on the "E5", namely the Wapnö holding, just north of the city of Halmstad in southern Sweden. This is the location of Sweden's largest dairy herd, with more than 1,000 cattle.

Hot-tempered motorists driving between Gothenburg and Malmö who wish to take a break from the highway stress could do themselves a favor by slowing down as they approach the holding's billboard with a giant milk package and brand on the roadside. Here you can eat lunch and learn more about the marvelous power of nature to convert inedible grass into tasty milk products. The farm has its own dairy and a consistent policy of openness. This is part of the E5's ideal of ethics and esthetics in order to be able to know and show the way forward without any other restrictions than those set by considerations for animal welfare.

The release of the cattle from the loose housing barns to outdoor grazing is a virtual folk festival for Halmstad people with a bovine interest. Cattle are a high-profile feature of the landscape at Wapnö farm. But not for grazing purposes, since the cattle get only a minor share of their feed requirement from the grassland. Most of it derives from carefully composed feed blends throughout the year. The cattle are released primarily for exercise and also because cattle in the landscape indicates to consumers that the farm is concerned – about cattle and consumers alike. And the green landscape looks so beautiful with its black-and-white cows. Moreover, the calves are let to graze on land that would otherwise become overgrown.

The milking plant and the various milking berths are open for viewing via large windows or directly from the visitors' galleries. The Wapnö farm satisfies the ever-greater desire of consumers for proximity and product freshness. The milk package billboard also shows the time when the milk left the cows – and chilled just a few hours later, before being packaged and loaded on trucks on its way to the stores. The company controls the entire chain, such as the excess heat from the milk from some 1,000 cows daily, which must be chilled from 37°C to about 3°C. This means that they can manage and utilize a great deal of energy that provides hot water throughout the farm as well as heat to pens that need extra heat, such as the calve pens.

The excess heat that cannot be used directly in heat and hot water production is pumped down into a rock cavern, where it is stored and then recovered via a geothermal heat exchanger to provide heat and hot water for many of the farm's other buildings during winter. These include the old manor, dairy, conference, exhibition and restaurant facilities and the forthcoming conference hotel with its 40 rooms. Wapnö's hot cattle save us a great deal of carbon dioxide that would otherwise be blown into the atmosphere, contributing to the greenhouse effect.

In the loose housing facilities, the straw material in the pens was recently changed from sawdust to peat. In addition to fixing more nitrogen, peat is better for soil when it is spread on the fields. A better barn environment, fewer greenhouse gases, and more nutrient all add to more sustainability. The manure is transported across 2.5 kilometer-long pipelines to collection ponds for all fields. From there it is spread – not with heavy, soil-compacting tanker trucks – but with hoses to lightweight spreaders on the fields. Later, it is planned to build a biogas plant to capitalize on the energy in the manure.

The feed philosophy at Wapnö does not differ from the core approach applied in Swedish dairy production. As much as possible, the coarse feed and cereals derive from on-farm crops, supplemented by purchased feed concentrate. This means that the protein content derives partly from Swedish rapeseed and partly from Brazilian soy crops. The ultimate goal is to replace the long-distance, transported feed with forage from the farm or neighboring protein crops.

But this is the Achilles heel of dairy pro-

Openness is a core concept at the Wapnö farm. Among other features, visitors are welcome to view the stalls and milking facility via large windows or from the visitors' galleries.

duction in the sustainability chain. A weak link that research and plant breeding can be expected to correct. When will we develop protein crops that can be grown in line with Christer Nilsson's receipt for "lean and green"?

Sustainable development

Wapnö is a limited liability company with definite profitability requirements. The company's ethical, esthetic and ecological goals of moving towards sustainable development are driven by the need to be financially profitable, just like hog breeding at the Kärragärde farm. A few years ago, most people would have viewed the development of these companies as being quite impossible.

But development in a number of social areas indicates that we do not view potential profitability, necessity and opportunities offered by change when we are in the midst of it – at least not until such change is complete. In the infancy of the environmental debate, it was felt that it was far too costly to put filters on factory chimneys, put catalytic exhausts on cars or stop using hazardous pesticides. Nowadays, however, nobody can sell products or pursue operations that we know undermine the environment. Environmental requirements are fundamental – just like hygiene requirements in food production. There was a time when hygiene requirements also gave rise to fears of more costly production. The same applies to the in-house work environment. There was a time when it was said that these improvements would incur costs that jeopardized profitability, work and output. But now we know better. In pace with the higher demands – and meeting them at ever higher levels – production costs have declined, profitability has risen, pay has increased, and earnings and stock prices have risen while consumer prices have declined.

It appears that we continually underestimate the dynamics of technological progress and human innovation and our propensity to adapt.

What we now demand of ethics, esthetics and ecology in livestock production will most likely progress in a similar manner. What we currently feel costs money and reduces profitability and competitiveness will prove to constitute some of the fundamental conditions in ensuring a market presence in the first place. And will also prove to be the path that leads to reduced production costs – in contrast to current preconceptions.

However, a prerequisite for this vision is that research is given the potential to offer new insight into animal behavior, physiology and genetics and that this know-how can be applied in new methods – all the way from calving and farrowing to feeding, production, slaughter and transport.

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The path to sustainable natural resources management lies along the “E5”. This virtual path to the future meets all our wishes in respect of farmers and businesspeople who view animals and nature – and consumers – with considerable Empathy and who cultivate the soil or raise livestock using Ecologically sound and Ethically defensible methods that offer major Esthetic values and provide favorable Economic results.

To test accessibility on the E5 in practice and theory, the Environmental Committee of the Royal Swedish Academy of Agriculture and Forestry set off on a combined study trip and scientific workshop in autumn 2007. The most urgent and challenging issue involved the original Fall of Man and whether there was a potential path back to Eden.

“Return to Eden” offers considerable hope of the real existence of the E5 – at least in a few years time – if we focus on and can use the increasingly advanced biological expertise and technology of our age.

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