A GUIDE FOR FOREIGN VISITORS

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MTT

MTT Elonkierto
The Agricultural Exhibition Park

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I

Getting familiar with Finnish agriculture at Elonkierto Park

Elonkierto Park is an exhibition park featuring Finnish agriculture. Located in the Loimijoki River valley in Jokioinen, it is in an ancient agricultural landscape. The Park demonstrates agricultural practices and research in a natural environment, set in the fields of its founder, MTT Agrifood Research Finland. This brochure will introduce foreign visitors to Elonkierto Park.

The Elonkierto Tour follows a 2.5 km (1.5 miles) path. It starts with the history of agriculture in small fields surrounded by traditional rail fences, and ends with a view to the future of agriculture, complete with remote controlled tractors. There are rest stops along the way. It takes 1-3 hours to complete the Elonkierto Tour.

Elonkierto is open from the beginning of June to mid-September, and entry is free. Guided tours may be arranged through MTT, tel. + 358 29 5300 700. There is a charge for the guided tours.

Points of Interest:

1. Main gate
2. History of agriculture
3. Pastures
4. Soil
5. Plant nutrients
6. Plant production
7. Weeds
8. Cleaning runoff waters
9. Agriculture and Climate change
10. Goats
11. Finnish dining table
12. MTT's experimental fields
13. Meadows
14. Storehouse
15. Fallowing
16. Rural landscape
17. Milk production
18. Agriculture of the future
19. Route to Jokioinen Manor Park

Piirros: Kaarina Toivanen

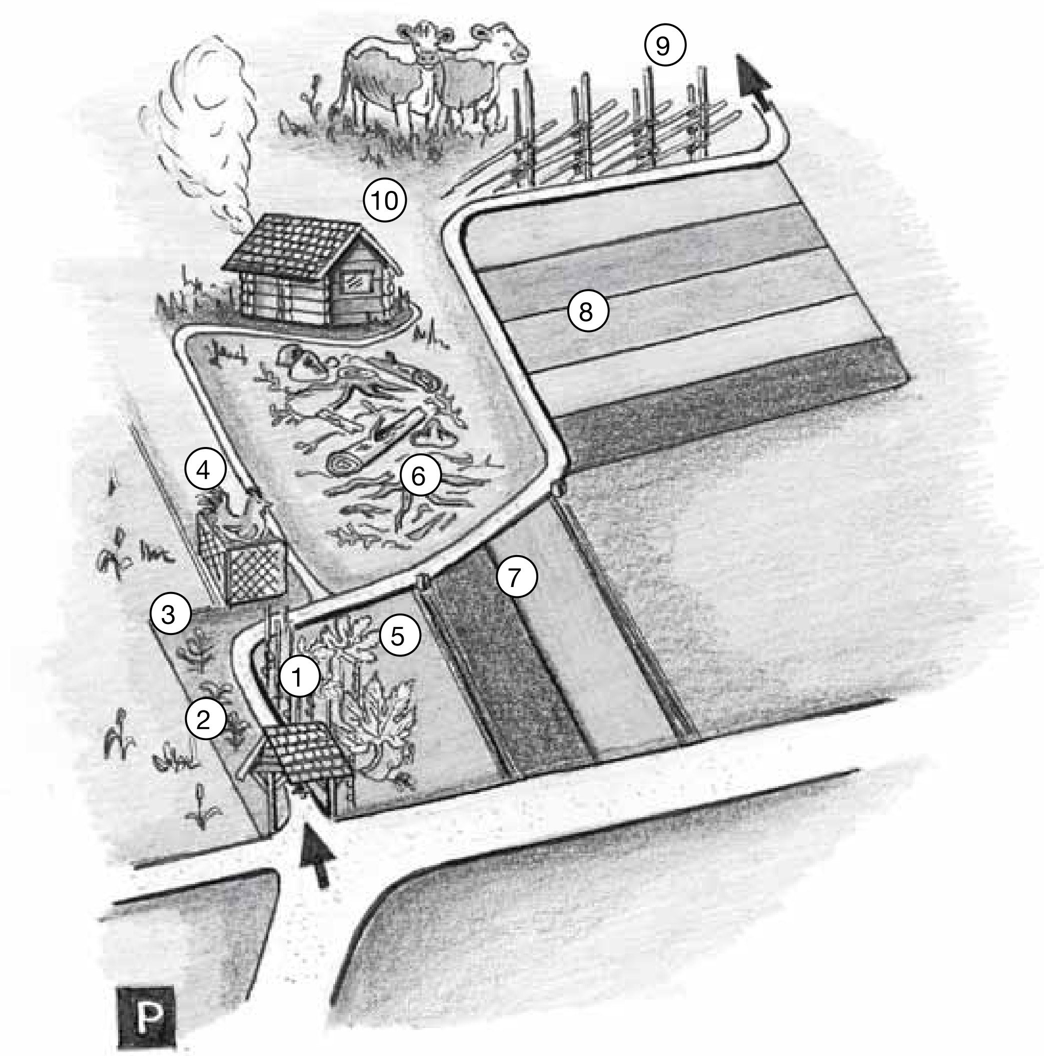
II History of agriculture

The forest pastures surrounding the Elonkierto parking lot and the fields beyond the main gate represent the rural landscape from the 17th to the 19th century. Some of the most commonly cultivated plants and crop rotations of the period are on view. Rail fences that helped keep livestock out of the fields were part of this period. Native breeds of chickens, sheep and cows were well adapted to northern conditions. Note the typical white back and underbelly color pattern of the “kyyttö” cows. A new cultivation system that came to Finland at the end of the 19th century and involved a more complex crop rotation, is shown at the end of the history section.

After entering the main gate, you will see old **herb and medicinal plants.**

On the right side of the path are hop poles (1). Hop *(Humulus lupulus)* was needed for brewing beer because the acids and essential oils in the hop cones enhance the clarification of beer, improve its shelf life and give it its typical bitterness. Hop cultivation was already mandated to be obligatory during the Middle Ages, so every house had to have its own hop garden.

In southern Finland during the 16th century, it was typical for part of the taxes imposed by a priest or judge to be paid with hops. However, the establishment of hop cultivation was hampered by the damage caused by the cold winters, and cultivation declined toward the end of the 18th century, and came to an end by the early 1900s.



On the left side of the path grow (2.) traditional medicinal herbs that were cultivated in monasteries as early as the Middle Ages. It wasn't until the end of the 18th century, and particularly during the 19th century, that herb cultivation started to spread; first to manor and parsonage gardens and from there slowly to the gardens of common folk, as well. Herbs were also used to medicate animals.

A practitioner using medicinal herbs for medication needed extensive experience, continual learning and a living knowledge of traditional folklore. According to modern knowledge, many of the medicinal herbs were ineffective in treating the ailments for which they were used. The use of medicinal herbs was usually based on the resemblance between the herb and the organ to be treated, or on the strong side effects that were caused by the plant, and were thought to be a sign of their effectiveness. Some of the most typical herbs of the 18th and 19th century grow in the Elonkierto herb garden, such as rough comfrey *(Symphytum asperum)*, sweet cicely *(Myrrhis odorata)*, wormwood *(Artemisia absinthium)*, old-man wormwood *(Artemisia abrotanum)*, tansy *(Tanacetum vulgare)*, lovage *(Levisticum officinalis)*, sage *(Salvia officinalis)*, hyssop *(Hyssopus officinalis)* and elecampane *(Inula helenium)*.

The first turn of the path is bordered by **a field of small tobacco (3.)** *(Nicotiana rustica)*. The cultivation of small tobacco had its heyday during the18th century. At that time, the government restricted tobacco imports and promoted Finnish tobacco growing. However, growing small tobacco wasn't easy because in the Finnish climate tobacco didn't develop the full aroma, and the cultivation required a heavily fertilized soil and a location protected from cold winds. For that reason, tobacco was usually grown only for household use to satisfy the craving for tobacco. When importing tobacco became easier during the 19th century, and at the same time the requirements for quality by the users increased, even the peasants started to smoke more and more commercial tobacco. Small tobacco cultivation experienced a comeback during the war years 1918 and 1941-1944 when there was a shortage of imported tobacco.

In the shade of the tobacco field, there's a **hennery (4.)** with Finnish native breed chickens. Their plumage varies from shiny black to dull carbon black, uniform gray, light brown, cream white and a spotted 'forestchicken'. The rooster is called Kordelin, after the last private owner of the Jokioinen Manor. With only about 2,500 of them remaining, the native Finnish breed of chicken is endangered. In 1998 MTT started a project to save and conserve them.

In the adjacent pasture, you can often see a Finnish horse. Finnish sheep use the same pasture as the horses.

After the turn, Finnish field cultivation from the 17th to the 19th century begins. **The first item on theright side of the path is a courtyard field (5).** Courtyard fields were small and heavily fertilized, and mainly used for plants that were needed only in smaller quantities. Cabbage, rutabaga, flax, hemp, bean, pea, as well as the new crop plants potato and tobacco, grew in courtyard fields.

On the left side of the path, you can see burn-beating cultivation (6). Burn-beating was the original form of agriculture every where in Finland. Rye and turnips, which were sown in late summer, were the most typical crops grown on burn-beaten land. Oat also grew well on burn-beaten land even though it was usually sown during the years following rye. Buckwheat and flax were also cultivated on burn-beaten land. In southwestern Finland, burn-beating for cultivation had already decreased in the Middle Ages, but in eastern Finland it continued to be popular until the middle of the 19th century. Successful burn-beaten cultivation gave a 12- to 15- fold crop compared to the seed rate.

On the right side of the path, opposite the burn-beaten cultivation, **a two-course rotation (7.) is used.** The two-course rotation, where soil was cultivated every other year and lay fallow every other year, was the predominant cultivation method from the Middle Ages. The unproductive fallow year was necessary because weed control was not possible without repeated tilling during the fallow summer and because there was not enough manure for an entire field area. In southern Finland, winter rye was the most commonly cultivated crop, while spring cereals were less popular. An average rye yield was 700 kg/ha in a two-year crop rotation. Two-year crop rotation maintained its dominance until the end of the 19th century.

Traditional cultivation methods and cold growing seasons were followed by years of crop failures and famine. Draft animals were needed for tillage and manure to sustain the fertility of the fields. Farms also had sheep, goats and pigs in addition to horses, bulls and cows. The amount of livestock was limited by the availability of feed, which was collected almost entirely from natural meadows.

It wasn't until the 1870's, after the great famine years, that cultivation methods rapidly began to develop. When hay cultivation started, iron plows, harrows and reapers appeared on fields and the number of dairy cattle increased. Before the 1850's, hay was not cultivated in fields but was collected from natural hayfields. When new cultivation methods began to spread to Finland from Europe during the 19th century, the most suitable one turned out to be **'koppeli' cultivation (8.)**, which originated from Germany. In this method, hay and cereal were cultivated alternately. Crop rotation enabled intensive animal husbandry and thus an ample source of manure became available. However, koppeli cultivation took hold slowly because the famine years were still fresh in people's minds and using fields for hay cultivation was considered to be an unheard of waste. Koppeli cultivation was modified in Finland with the following crop rotation:
fallow – fall rye – perennial sown hay (4 to 5 years) – spring cereal.

Hay
In the early 20th century, the hay crops of Jokioinen Manor were 2,000-2,500 kg/ha. A mixture of timothy *(Phleum pratense)*, red clover *(Trifolium pratense)*, meadow fescue *(Festuca pratensis)* and orchard grass *(Dactylis glomerata)* was most commonly cultivated. Often, alsike clover *(Trifolium hybridum)*, awnless brome *(Bromus inermis)* and false oat-grass *(Arrhenatherum elatius)* were also added to the mixture. False oat-grass can still be found on the field headlands, as a remnant of the cultivation.

Oat
Oat was cultivated in the 18th and 19th centuries mainly as a winter feed for horses. As the importance of animal husbandry grew, oat cultivation spread rapidly toward the end of the 19th century, and it was the most important cereal in Finland from the beginning of the 20th century to the end of the 1960's. In crop rotation oat was placed as the last crop after hay thus utilizing the minor amounts of nutrients left in the soil.

Rye
In the beginning of the 20th century, fall rye and 'midsummer' rye were cultivated at Jokioinen Manor. Fall rye was sown in August and summer rye in early summer. Oats, wild peas and peas were sown together with summer rye. In autumn, a green feed crop was harvested and the next autumn, a rye grain crop.

A traditional rail fence (9.) follows the leftside of the path. Already during the Middle Ages, the law mandated that cultivations be fenced. The purpose was to protect fields and meadows from cattle that roamed and grazed freely during the entire summer. The structure of the wooden fences varied depending on the locality and purpose. A typical fence in eastern Finland was made of shorter pieces with equal length rails extending from the ground and sloping to the ridge of the fence. A fence in western Finland was made of longer pieces with unequal length rails that were at a lower angle than in its eastern counterpart, and they did not extend from the ground all the way to the ridge of the fence. Spruce and aspen make the best fence materials. Slender spruce saplings and juniper are suitable as withes.

Behind the rail fence a native Finnish breed of cows is grazing. There are three original Finnish breeds of cows, and all three were in danger of extinction during the past decades. The cows grazing on the Elonkierto fields have reddish brown sides and a white back and underbelly. There are just barely over 400 purebred members of this Eastern Finnish breed left. Equally rare is the Lapland cow. The most common native breed is the uniformly reddish brown Western Finnish cow. The native cattle are usually hornless. MTT is studying genetic variation of the native breeds using DNA techniques. The Research Center is also in charge of the practical conservation program for the native breeds. The old breeds are maintained to secure biological diversity and to foster their cultural and economic historical value.

Smoke sauna (10.)

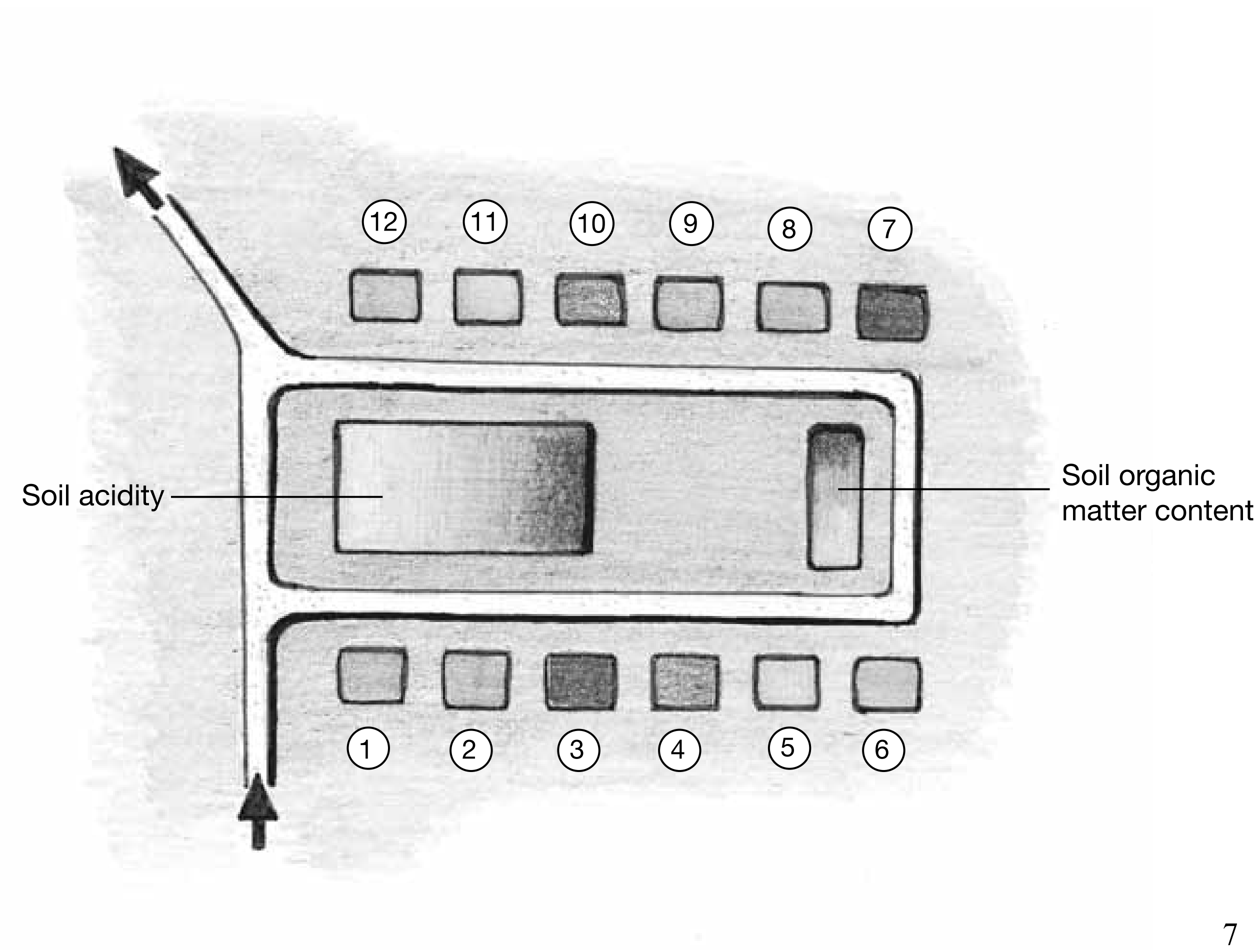
III Soil

After the wooden bridge, Finnish soil types are demonstrated. Soil is not just 'mud' but is a complex ecosystem consisting of minerals, organic matter, water, air, roots, microbes and other soil organisms. After the middle of the 19th century the yield levels started to increase, when researchers began to better understand the importance of soil to plant growth.

A plant gets necessary water from soil because soil can store rain water in its pores and make it available to roots for weeks or even months. Also, soil mineral particle surfaces and organic matter (humus) functionas storage, from which nutrients, such as nitrogen, phosphorus and potassium, are released to soil solution. Soil functions are regulated by microbes.They break down organic matter releasing nutrients, forming new humus and improving soil structure.

Pores are an integral part of the soil. The largest pores are necessary for roots to obtain oxygen. Large pores are made by worms, plant roots and desiccation cracking of soil. Tillage also affects soil surface and pore structure.

MTT has a strong tradition in soil research. For example, MTT has developed a soil fertility analysis for Finnish conditions. In modern research, essential topics include the effects of cultivation methods on soil structure and biology, and environmental questions regarding soil. Elonkierto demonstrates soil chemistry, physics and biology. The park includes points of interest for soil types, soil acidity and organic matter content, and the nitrogen cycle from fertilizer to food.



The soil type demonstration blocks are located on the right after the bridge. Finnish soil is usually naturally acid and very young (approximately 10 000 years), because the last ice age erased the older layers and formed new soil. The soil type classification for mineral soils is based on particle size and its sorting, and for organic soils on the quantity and quality of organic matter. If the organic matter content by weight is less than 20 %, soil is classified as mineral soil. Mud soils are an exception; they are classified as organic soils if their organic matter content is over 6 %. Mineral soils are divided into two main groups: till-derived soils and well-sorted soils. A soil type is named based on its main fraction(s).

Soil type classification for mineral soils

Particle diameter, mm lower limit-higher limit	Soil fraction
0.002	clay
0.002 - 0.02	fine silt
0.02 - 0.06	coarse silt
0.06 - 0.2	fine sand
0.2 - 0.6	medium coarse sand
0.6 - 2	coarse sand
2 - 20	gravelly soil

1. Heavy clay (AS)
The stiffest clay is heavy clay, containing at least 60% clay. Heavy clay holds water very well but most of the water is bound to it so tightly that plants can't utilize it. Dry heavy clay is hard and very heavy to plow. Jokioinen is one of the most clay rich areas in Finland; the plow layer of 30 %, and the subsoil layer of 60 %, of the fields in this area are of heavy clay soils. About 1 % of Finnish fields have heavy clay topsoil.

2. Silty clay (HsS)
Silty clays are the most difficult clay soils to cultivate. They harden easily after rain because of their tendency to silt up.

3. Sandy clay loam (HtS)
Sandy clays are very good soils to cultivate because of their water and nutrient resources. Sandy clay has the good water and nutrient retention capacity of clay and the good water-carrying capacity and workability of sand.

4. Gyttja clay (Muddy clay) (LjS)
Muddy clays were formed when mineral and organic matter settled on the bottom of sea and clear inland lakes. In many coastal areas muddy clay is the most common soil type.

5. Silt loam (Hs)
Silty soils tend to become too wet and silt up because water permeates them slowly. The granular structure of a silted-up surface breaks, and as it dries it becomes so hard that plant seedlings have a difficult time penetrating the surface. Silty soils with little organic matter are difficult to cultivate and are best suited for growing grass. Silty soils comprise about 5% of Finnish cultivated area.

6. Sandy loam (HHt)
The majority of Finnish fields are coarse silt soils. The water retention capacity of coarse silt is good, and the capillary rise of water from the moister bottom soil is so fast that drought is rarely a problem for plants. The soil is usually sufficiently airy and the nutrients are adsorbed relatively well. Because of its good moisture properties, coarse silt is considered to be one of our best soil types. It is well suited for the cultivation of almost any plant species.

7. Fine sand (KHt)
The structure of fine sand is loose and light. Its particles are visible to the naked eye. Tilling is easy and heavy machinery is easy to use, even during wet periods. Fine sand doesn't adsorb nutrients well, and because of that, soluble nutrients leach easily. However, fine sand is one of the best soil types due to it's suitability for the most demanding plant species.

8. Sand (HHk)
There are not many sandy soils used for cultivation because of their low water holding capacity making them very susceptible to dry periods.

9. Glasial till (Mr)
Moraines are poorly graded mineral soils. They are the most common soil type in Finland – most of the forest soils are moraine. Moraine is a mixture of several soil fractions from stones to clay. The suitability of moraine soils for cultivation depends on their stoniness. A fine sandy till with few stones is an excellent soil for cultivation, but the stone rich moraines have been left for the forests.

10. Mud (Lj)

Mud is a mixture of fine mineral matter and organic matter formed as layers in sweet water. The organic matter content is over 6 %. Mud soils are relatively rarely used for cultivation, mostly along the coastal areas of the Gulf of Bothnia (the Finnish west coast).

11. Mull (Mm)

Mull soil can be found in the top layers of fields. It has been formed when the peat layer on the surface has worn down as a result of cultivation and has finally mixed with the mineral soil below. Mull soil has 20-40 % of organic matter left. Mull soils are excellent soils to cultivate because they hold water and nutrients well and are porous enough for air exchange.

12. Carex peat (Sedge peat) (Ct)

The organic matter content of peat soils is over 40% by weight. Peat is either sedge peat or sphagnum peat depending on the predominant plant residue. Sedge peat is formed mainly from the roots of sedges. Compared to inorganic soils, peat soils are able to hold much more water, and they warm up slowly in the spring. Peat soils comprise about 10% of Finnish cultivated area.

Soil acidity

The area inside the path, which circles the soil sample blocks, demonstrates how different plant species and cultivars react to soil acidity. At the other end of the area, the importance of soil organic matter is demonstrated.

Acidity regulates chemical and biological reactions in soil. Soil acidity means the amount of positive hydrogen ions in soil, and it is expressed by a pH value. The smaller the pH value, the more H^+ ions are present and the more acid the soil is. In Finland, soil pH value is usually 4-8, and most commonly 5.5-6.5. The most beneficial pH range for most plants is 6.5-7.5.

Soil organic matter content

In addition to the soil type, soil properties are essentially affected by its organic matter content. For soil structure and supply of water and nutrients, the best organic matter content would be 10-12 %. In that case, there would be 350 000 kg of humus on a hectare of field. In clay soils, physical properties of the soil worsen when organic matter content falls below 6 %. Organic matter changes slowly in soil, and it’s impossible to increase the content quickly without adding organic matter from outside the field.

The organic matter content of Finnish mineral soils is relatively high, about 2-4 %. This is partially due to the young age of Finnish farmland and partially to the cold Finnish climate, where organic matter decomposes slowly. The Elonkierto demonstration blocks include heavy clay with various organic matter contents.

The following classification for organic matter contentis used in Finland:

	Organic matter, % of soil mass
Poor organic matter content	1-2.9
Moderate organic matter content	3-5.9
Rich organic matter content	6-11.9
Very rich organic matter content	12-19.9
Mull soil	20-39.9
Peat	40-100

IV

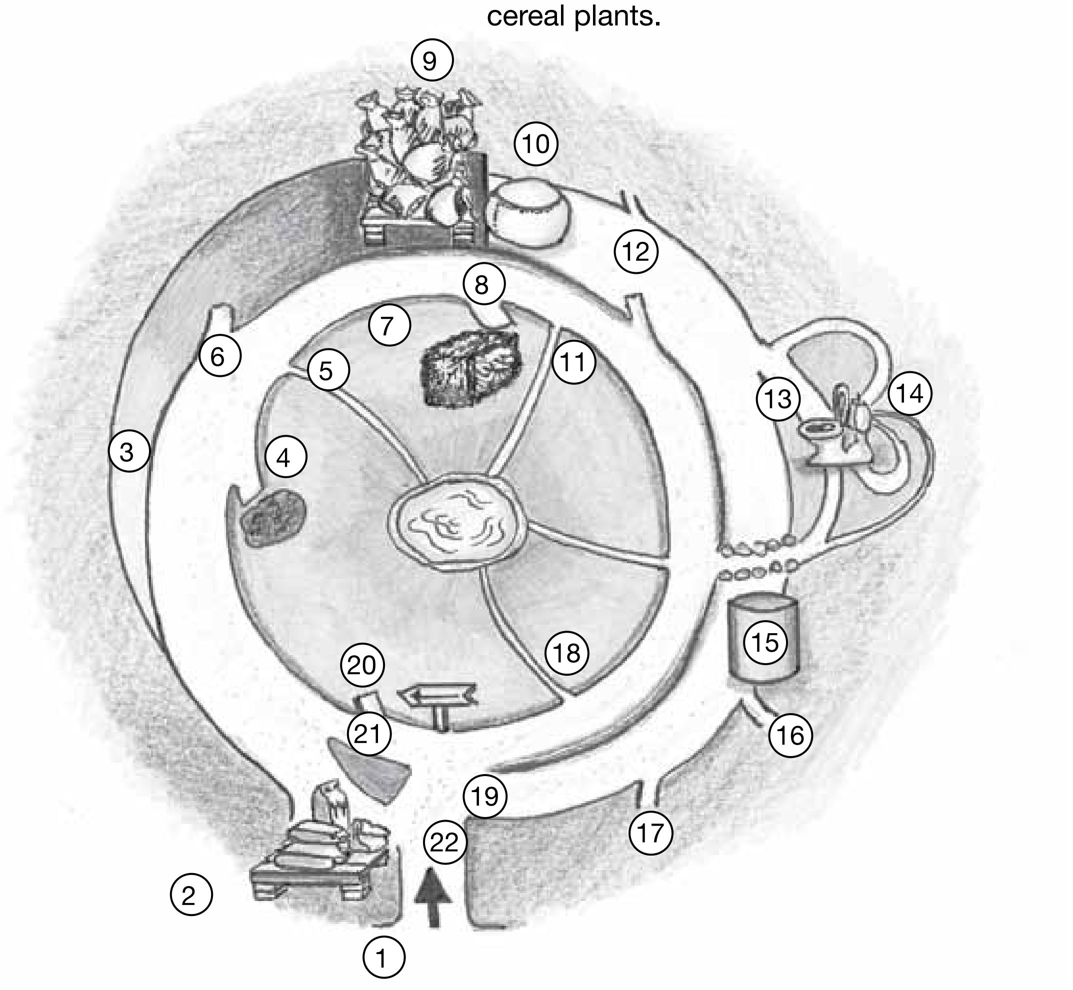
Plant nutrition is accurate "team work"

Plants need about 20 different chemical elements to grow and maintain their functions. Plant material consists mainly of carbon, oxygen and hydrogen, all of which plants take from air and water. There are 12-16 essential nutrients, which are available from soil. Nutrients are divided to macro and micro nutrients, based on the required amounts.

Plants take approximately 10-200 kg/ha of macro nutrients and less than 1 kg/ha of micro nutrients per year. The different nutrients can not take the place for one another for their specific plant physiological functions. This means that plant development is disturbed even if only one nutrient is missing, and also if the ratios of individual nutrients differ significantly from the plants' nutrient requirements.

Nutrient uptake from soil is a result of teamwork by plant roots, soil microbes and the nutrient-holding capacity of the soil. Under natural soil conditions, plant coverage efficiently utilizes nutrients that become available from the soil, and losses to air and water are minimal. The periodic lack of plant coverage on fields exposes nutrients to leaching. Because of nutrient losses and high yield expectations, plant nutrients must be added to cultivated land in fertilizers.

MTT is studying the supply of the most important plant nutrients, nitrogen and phosphorus. The focus of the research is on more accurate nitrogen fertilization, and on the leaks from the nitrogen cycle, where soil microbes play an important part. A more efficient utilization of nitrogen and phosphorus from manure is an important research subject. MTT also studies how the soil phosphorus status affects the amount of phosphorus that runs off into waterways, and how plants' phosphorus needs can be secured without burdening the waterways. Elonkierto demonstrates the soil nitrogen cycle, biological nitrogen fixation and nitrogen use by different cereal plants.



Nitrogen cycle

1. How nitrogen finds its way to our table and the environment

Nitrogen is often the most growth limiting factor. The amount of available nitrogen in soil varies during the growing season as a result of fertilization, soil microbe activity, nitrogen uptake by plants and various losses.

Along the stone edged path, it is demonstrated what happens to the available nitrogen that is present in soil and given in fertilizers during a year. The demonstration is calculated for a field of 3,000 m^2 (0.3 ha) which is the same size needed to produce domestic food for one Finn.

The path starts in May when nitrogen fertilizers are applied to fields, and ends in April of the following year. One meter width along the path and in the field equals 10 kg of nitrogen. The incoming tracks joining the path represent additional nitrogen input that is available to plants, and correspondingly the outgoing tracks represent nitrogen losses. The width of the cereal growth around the path indicates the amount of nitrogen taken up by the plants and the yield. What happens to the nitrogen used by the plants, after harvesting, is shown at the end of the tour.

2. Nitrogen fertilization
The natural nitrogen reserves of a Finnish mineral soil are sufficient only for cereal yields of less than 1,000 kg/ha. With the help of artificial fertilizers it has been possible to increase cereal yields to the current level of about 4,000 kg/ha. Cereals and other annual plants comprise two thirds, and hay one third, of the field area that is used for food production. The"average consumer" field (0.3 ha) gets an average of 28 kg of nitrogen. For that, 3.5 fertilizer bags of 40 kg are needed when the nitrogen content is 20%.

3. Nitrogen uptake by plants
Plants need nitrogen for their essential physiological functions and protein production. Nitrogen uptake is at its greatest at the end of May and in early June for hay, and at the end of June and in early July for cereals. Nitrogen uptake by cereals ends during August, when ripening starts to take place, but grasses use nitrogen until the end of the growing season.
A yield from 0.30 ha contains 26 kg of nitrogen.

4. Nitrogen mobilization
The plow layer of Finnish clay soil contains about 5,000 kg/ha of nitrogen. The amount of nitrogen can be calculated based on the amount of organic matter; 1 % of organic matter equals about 1,000 kg of nitrogen per ha. The majority of the nitrogen is in organic form and thus is not directly available to plants. During the growing season, soil microbes mobilize an average of 8 kg (25-30 kg/ha) of nitrogen to ammonium and nitrate nitrogen, which are available forms for plants. Mobilization is heaviest in humid and warm growing seasons.

5. Leaching during the growing season
Nitrogen in nitrate form leaches easily from soil by water. According to studies done by MTT in Jokioinen, about 5-20 kg/ha of nitrogen leaches annually, which equals on average about 4.5 kg from an area of 0.3 ha. Even though there is plenty of nitrate nitrogen in soil early in the summer, leaching during the growing season is restricted by the small amount of runoff. There's substantially less nitrate leaching from grass since its nitrogen uptake continues until late autumn. Leaching during a growing season is about 1 kg per 0.3 ha.

6. Denitrification
Part of the nitrogen in the soil escapes into the atmosphere. The gaseous losses caused by denitrification are largest during wet summers when soil air is depleted of oxygen. Under an aerobic conditions, microbes start to convert nitrate to dinitrogen oxide and nitrogen gas. Estimated denitrification is about 5 kg (15-20 kg/ha).

7. Nitrogen mobilization after harvest
Nitrogen mobilization continues during autumn after the harvest. Estimated mobilization is 5 kg/ha or 1.5kg per 0.30 ha.

8. Nitrogen in plant residue
An average of 6 kg (20 kg/ha) of nitrogen returns to the soil in straw, tops, pressed liquids and other plant residue.

9. Plant products
Cereals and other plant products meant for direct human consumption take up about 20 % of the cultivated area. The nitrogen in yields ending up in plant products amounts to 1.4 kg. Cereals represent over 70 % of this amount.

10. Livestock products
About 80 % of the cultivated area is used for livestock feed production, and altogether 90 % of the total nitrogen taken up by plants ends up in feed. This means that out of the 20 kg of nitrogen taken up by plants 18 kg is used for feeding livestock. Livestock products contain 3.8 kg (21 %) of this amount, and the majority of the nitrogen (14 kg) ends up in manure.

11. Leaching during autumn
The uptake of nitrogen by cereals ends in August, but the nitrogen mobilization caused by microbes continues until late autumn. Nitrogen starts to leach with autumn rains since there is no nitrogen uptake by plants. Autumn leaching can be decreased by undersowing a grass crop among the cereal in spring. Leaching during the autumn season is about 1.7 kg per 0.3 ha.

12. Nitrogen in rain water
On average 2.4 kg (8 kg/ha) of nitrogen falls to the soil with rain water.

13. Nitrogen in food
Twenty kg of nitrogen is recovered with the harvested crop. Imported feed brings an additional 2 kg of nitrogen to the cycle. Eight kg of the amount goes to the raw materials for human food, from which about 5.2 kg finally end up in the food of an average consumer. The remaining 14 kg end up in manure and feed leftovers.

Of the nitrogen in food, 4.5 kg is excreted in feces and 0.7 kg goes out with the garbage. About 2.7 kg of the wastewater nitrogen finds its way into waterways, because only about 40 % of the nitrogen is removed from wastewater. In addition, a total of 0.3 kg of nitrogen per consumer ends up in waterways as a result of leaching from the food industry and food processing waste.

14. Nitrogen losses in the food industry
Remaining in the food industry's waste is 2.8 kg of the nitrogen in food raw materials. Of this amount, 2.0 kg returns to livestock feed, 0.5 kg evaporates into the air or is transported to landfills, and 0.3 kg ends up in waterways.

15. Nitrogen in manure
Two thirds of the nitrogen in a yield (14 kg) ends up in manure. The annual amount of new manure per consumer is about 2,500 kg. How much of this nitrogen in manure can be transferred for use by plants, is crucial for the degree of utilization of agricultural nitrogen and for the amounts of released nitrogen. Improving manure management and decreasing nitrogen releases form an important part of research at MTT.

16. Nitrogen evaporation during manure storage
About one fifth (2.5 kg) of the nitrogen in manure and urine evaporates into the air in cowsheds and manure storages.

17. Nitrogen evaporation during manure spreading
About one fifth (2.5 kg) of the nitrogen in manure also evaporates during manure spreading.

18. Leaching during spring
In spring, nitrogen is leached by melting snow. Nitrate nitrogen can contaminate groundwater; however, for the most part Finnish ground water is very clean. In surface waters, nitrogen causes eutrophication, especially in the Baltic sea. However, phosphorus usually has a bigger role in algal growth in lakes and coastal waters. Leaching during the spring season is about 1.5 kg (5 kg/ha).

19. Manure nitrogen available to plants
About 45 % or 9 kg of the nitrogen in the original yield is returned to the field in manure. Of this amount, approximately 4 kg is in a form that is directly available to plants.

20. Manure nitrogen unavailable to plants
Over half of the nitrogen in manure is in organic form, which is not available to plants and accumulates in soil. Soil microbes mobilize this nitrogen slowly, making it available to plants.

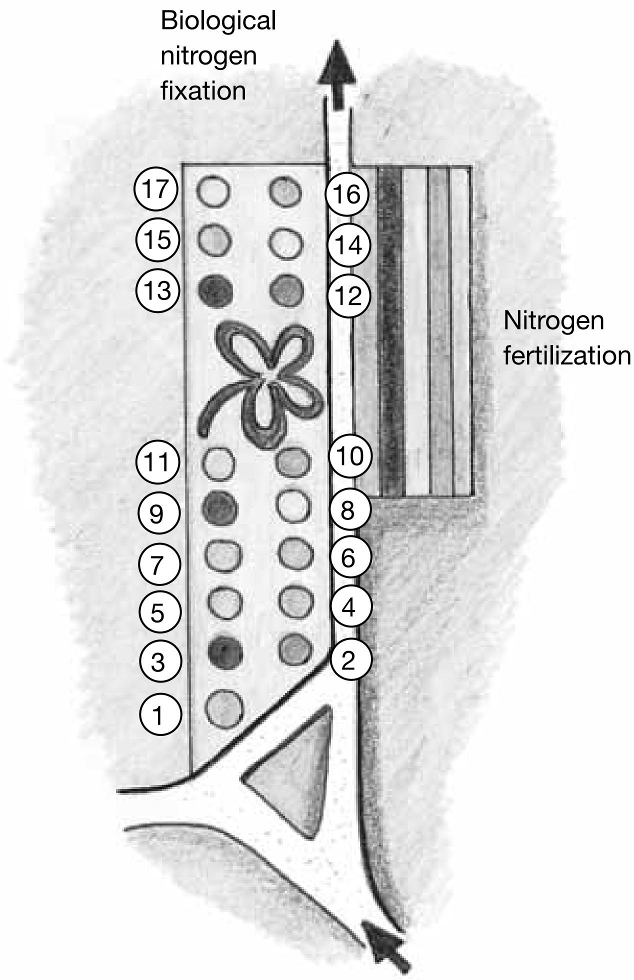
21. Nitrogen in soil
Before spring sowing and fertilizing there are about 12 kg (40 kg/ha) of nitrogen left in the soil, which is available to plants.

22. So where did all the nitrogen in the fertilizer bag finally end up?
Returns back to the cycle in the field:
32 % is returned to the field in manure
Ends up in the environment:
27 % evaporates during waste management or ends up in landfills
16 % is leached from the fields to waterways
13 % evaporates from the fields (denitrification)
12 % finds its way in wastewaters to waterways

V Biological nitrogen fixation

The utilization of atmospheric nitrogen is based on the cooperation of leguminous plants and nitrogen fixing bacteria. Rhizobium bacteria enter the plant roots in soil, forming nodules in the roots. The bacteria in the nodules fix nitrogen from the atmosphere and excrete it in ammonium form to plants. The following legumes can be found in Elonkierto:

1. Bird's foot trefoil *(Lotus corniculatus)*
2. Goat's-rue *(Galega orientalis)*
3. Black medick *(Medicago lupulina)*
4. Yellow-flowering alfalfa *(Medicago sativa ssp.falcata)*
5. Alfalfa *(Medicago sativa ssp. sativa)*
6. Red clover *(Trifolium pratense)*
7. European yellow lupine *(Lupinus luteus)*
8. Alsike clover *(Trifolium hybridum)*
9. Yellow sweet clover *(Melilotus officinalis)*
10. White clover *(Trifolium repens)*
11. Caucasian clover *(Trifolium ambiguum)*
12. Common serradella *(Ornithopus sativus)*
13. Burrowing clover *(Trifolium subterraneum)*
14. Crimson clover (Trifolium incarnatum)
15. Sulla *(Hedysarum coronarium)*
16. Sainfoin (Onobrychis vicifolia)
17. Berseem clover *(Trifolium alexandrium)*



Nitrogen fertilization
The natural nitrogen reserves of Finnish mineral soil are sufficient only for cereal yields of less than 1,000kg/ha. The availability of nitrogen is usually the most important factor limiting yields, and with the help of artificial fertilizers it has been possible to increase cereal yields to the current level (about 4,000 kg/ha).

The nitrogen fertilization used in Elonkierto demonstration blocks is 0-250 kg/ha. The nitrogen amounts of 75-100 kg/ha found in the center part of the area represent the average nitrogen fertilization levels used for cereals in Finland.

VI From deficiency to overuse - the short history of phosphorus fertilization

The short history of phosphorus (P) fertilization and the related research from the 1940's up to to 2010 are briefly reviewed. The first experiments were started as early as 1927, and the 1940's saw organized campaigns to promote the use of chemical P fertilizers for improving crop growth. At present, however, farmers are advised to fertilize less as a consequence of high levels of plant-available P in the soil. The different recommendations reflect both the change that has occurred in the society in terms of agronomic/environmental goals and the change in cultivated soils themselves as a consequence of the high P inputs in the past. In the demonstration area of Elonkierto, the superphosphate (9% P) sacks placed in front of the different decades show the annual amount of chemical P applied in Finland to produce the average diet per person.

1940's

The total use of P was about 10 kg/ha, most of it coming from animal manure circulated back to the fields (chemical fertilizers 1 kg, animal manure 8 kg). Obviously the P deficiency severely limited plant growth in the whole country. The year 1947 was the breakthrough year in the use of chemical P fertilizers as the restrictions on their import were lifted. To enhance the use of chemical fertilizers even more, the total cost for the whole Finnish agriculture was reduced by one billion Finnish marks with additional subsidies of another billion marks. To increase the use of P, in particular, the campaign was supported by commercial advertizing and the government funded agricultural advisory system.

1950's

Farmers quickly learned to exploit fertilization and about 22 kg/ha P was applied (chemical fertilizers 12 kg, animal manure 10 kg). A special company, Viljavuuspalvelu Oy, was established in 1952 to analyze soil samples for many nutrients, including the plant-available P. The Finnish soil test for nutrient availability had been developed in the previous decade with the first official analyses being done in 1949 at the Soil Department of the Agricultural Research Centre (later called MTT Agrifood Research Finland). The average level in the soil test P (STP) for the samples taken from private farms was 5.4 mg/l. Over the next fifty years, STP raised 2.5-fold due to the accumulation of P in the top soil.

1960's

The use of P increased to 33 kg/ha (chemical fertilizers 22 kg, animal manure 11 kg). In small farms, the earlier system of subsidizing the fertilizer purchases was replaced by a new system based on the area under cultivation. In 1966, MTT recommended the following use of P: In normal cultivation, the best way to fertilize with P is to give at least 2-3 times the amount that the yield will contain, i.e. for cereals and grass crops 30-45 kg/ha. A new topic in research was the development of technology to apply fertilizers in rows or with narrow and precise placement close to the seeds. The latter increased the cereal yields by 13-17%. Consequently, very quickly before the end of the decade the method had become popular. On the other side of coin, in the 1960's there were the first observations of eutrophication in surface waters that was assumed to be due to P fertilization.

1970's

In the 1970's, the P use was still increasing, reaching 43 kg/ha (chemical fertilizers 31 kg, animal manure 12 kg). In this decade, the most popular NPK-fertilizer was called "Normal-Y" that contained N-P-K with 15, 9 and 13 percent, respectively, being as rich in P as superphosphate. The peak in the P use was recorded in 1975 (chemical P 35 kg/ha). The farmers thus obeyed faithfully the recommendations which advised P fertilization of 30-60 kg/ha for cereals. The STP in the top soil increased sharply over the whole decade. These years triggered the first debates between environmentalists and agronomists on possible links between the P fertilization and the eutrophication of lakes and coastal waters. MTT established the first wide scale experimental field plots to study P and nitrogen leaching in cultivated soils.

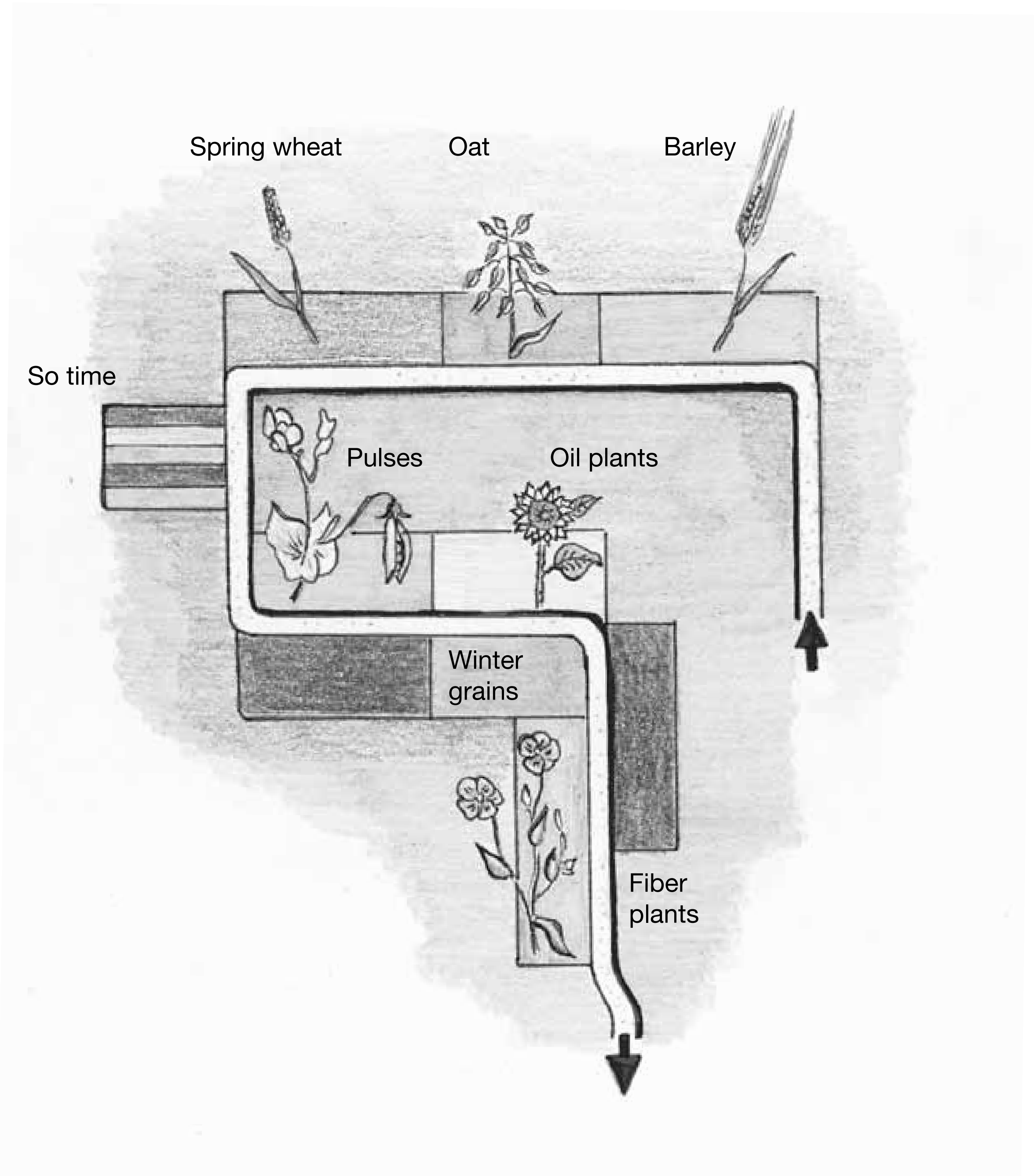
1980's
The phosphorus input to the soil was about 43 kg/ha (chemical fertilizers 30 kg, animal manure 13 kg) which was more than 4 times the P output as crop yield. In 1980 the apatite mine at Siilinjärvi (eastern Finland) was opened, and Finland became self-sufficient in chemical P fertilizers. The fertilizer recommendation for cereals was still as high as 30 kg/ha for soils belonging to STP class "satisfactory". At the end of the decade (1989), however, the farmers' union (MTK) acknowledged the contribution of agriculture to nutrient leaching and eutrophication of waters.

1990's
At the beginning of the decade it became obvious from the long-term P fertilizer trials that the P recommendations need to be changed. The recommendation for spring cereals was reduced to 20 kg/ha (clayey soils, STP "satisfactory"). At the same time a special tax was passed for the chemical P (1990: 1 Finnish mark/kg; 1992: 1.7 mark/kg). As a consequence, the P use started to come down reaching 28 kg/ha (chemical fertilizers 16 kg, animal manure 12 kg). When Finland joined the EU in 1995, the system of Agri-Environmental support was established, including the maximum P use of 15 kg/ha for spring cereals (with the exceptions of allowing substantially higher use of P in animal manure). Thus, over just ten years, the recommendation for cereals had decreased by 10-25 kg/ha, and the use of chemical P fertilizes was reduced by 60 %. The Agri-Environmental support system included also other actions aimed to mitigate the P load to surface waters. The research at MTT showed that high STP of soil is linked to increased losses of P in surface runoff from fields.

The first decade of the current millenium
The P use was about 20 kg/ha (chemical fertilizers 9 kg, animal manure 12 kg). At farms with plant production only, the P input was often near the output, while at farms with animal production the overuse of P prevailed due to spreading of animal manure. Animal production tended to be geographically concentrated and there was inadequate technology to deliver manure further outside such areas. In the soil samples taken from fields, representing 95% of the cultivated area, the average STP was 13.9 mg/l, and the increase of STP seemed to be leveling off. The research findings at MTT were meta-analyzed to produce models for optimized P application both in plant production and animal nutrition. There were not yet any clear signs of recovery in the agriculturally loaded surface waters.

VII Plant production in harsh environments

Finland is the northernmost agricultural country in the world. Plant production is limited by low temperatures, a short growing season and, in some parts, by summer frosts. In southern Finland, lack of water is also often a growth-limiting factor. The natural conditions for plant production get worse towards the north, and the country is divided into cultivation zones based on the climate. Bread grain production is possible in the two southernmost zones (zones I and II), zones III and IV are suitable for feed grain production, but in the northernmost zone (zone V) only grass production is successful. Seven percent (2.3 million hectares) of the Finnish surface area is agricultural land. The cultivated field area, 2.2 million hectares, is divided between different plants as follows; grains 44 %, grass 29 %, oil plants 8 %, potato 1.5 %, sugar beet 1 %, other plants 3.5 %, and fallow 13 %. Elonkierto begins its introduction to Finnish cultivated plants with cereals, followed by the oil plants, pulses, fiber plants and buckwheat.



Cereals

Barley

Barley is the most important grain in Finland. Its cultivation area has been 500,000 ha and its yield 1,600 - 1,900 million kilograms, of which 75 % is used for animal feed. The rest of the yield is used by the food industry mainly for pilsner malt used for brewing beer, and enzymatic malt used for whisky. Barley is also needed for production of ethanol, starch and enzymes, among other uses. First cultivars in the demonstration are old ones that are not cultivated anymore. These are followed by currently cultivated cultivars, which have been bred for specific purposes. The last cultivars are cultivars of future years.

Oat

The second most important grain in Finland is oat, with a cultivation area of 370,000 ha. Only two percent of the total oat yield is used for food production, but the food use is growing because of oat's good nutritional value. In export markets, the thin-husked Finnish oat is well known for its good quality. On the demonstration blocks, you can see old and currently cultivated oat cultivars.

Spring wheat

The cultivation area for spring wheat is about 200,000 ha. In Finland, about half of the yield is used as a bread grain. The suitability of wheat to be used as bread grain is dictated by its baking quality. Bread wheat needs to have a falling number of at least 180 and a protein content of 12.0 %. Wheat cultivation is concentrated in southern Finland because wheat needs a long growing season. The demonstration blocks include results of spring wheat breeding from various decades. The oldest cultivars are from the 1920's and the newest ones from the 21st century. In the second last block grows spelt, and in the last one spring rye.

Do you know your cereals?

Can you distinguish the main cereals? What about emmer, durum and spelt?

After the cereal blocks, on the right side of the path, **the significance of sowing time** to the growth of cereal plants become obvious.

Pulses

The main ingredient of Finnish pea soup is grown annually on 5,000 hectares. Cultivating peas for animal feed has not become common in Finland. Traditional Finnish pea varieties grow in the first pea block. They are long and thus unsuitable for the modern harvesting technique. In the following blocks are current semi-leafless and short pea varieties. After peas come broad beans, vetch and lupines.

Oil plants

The total cultivation area for oil plants is about 50,000 ha. Of this, the area for annual turnip rape is 36,000 ha, annual rape 16,000 ha, and seed flax 1,000 ha. In addition, small quantities of German sesame, mustard and sunflower are also grown. On the demonstration block, annual turnip rape, annual rape, white mustard, sunflower, seed flax and German sesame are grown.

Fiber plants

The cultivation and processing of fiber plants have been revived during the last few years. The fiber flax cultivation area has already increased to 1,000 hectares, and even fiber hemp was cultivated on several hundred hectares in 1998. However, the cultivation area dropped after this to just a few hectares. Hemp and flax give stem yields of 5,000-8,000 kg/ha, from which 25 % is usable long fibers. Common flax has traditionally been used as a textile fiber but its use in technical applications, such as an insulation material, is growing. Further processing of hemp is still open. Hemp fiber can be used for paper manufacturing and as a plastic substitute, for example, in the auto industry. Hemp seed oil is used for health products.

Buckwheat
Buckwheat is an old cultivated plant from eastern Finland, and it was cultivated on burn-beaten land after rye. As an undemanding plant it grew well even in nutritionally poorer soils. Buckwheat cultivation was revived in the early 1990's, and Finnish buckwheat flour is available now. The buckwheat cultivation area is less than 1,000 ha and the yield level is 200-2,000 kg/ha.

Winter grains
Winter grains cultivated in Finland are rye, wheat and triticale. While in Middle Europe most grains are sown in autumn, winter grain cultivation in Finland is often limited by rainy autumns, which make sowing difficult. Common winter damages also diminish the farmers' willingness to cultivate them. Cultivation of winter wheat is concentrated in the southwest, and the annual cultivation area is 20,000-45,000 ha. Finnish consumption requires about 40,000 hectares of cultivation.

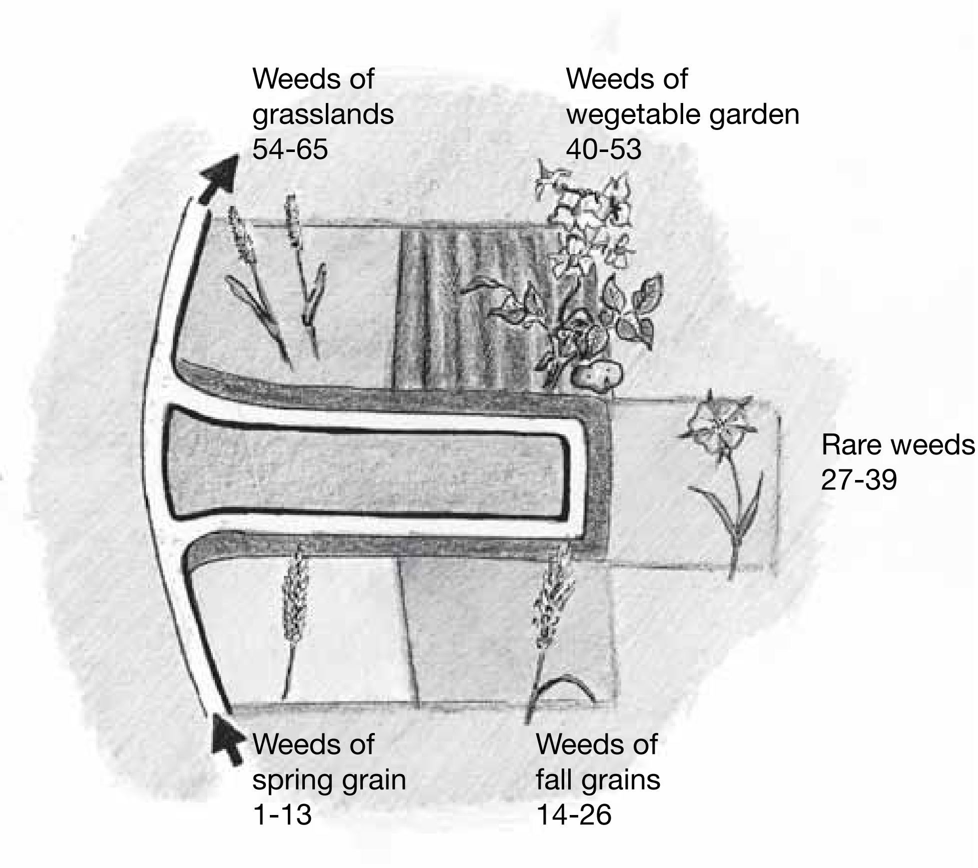
Triticale is a man-made cultivation plant, which was developed by crossing rye and wheat. It is a high yielding feed grain that is cultivated on a few hundred hectares. Various cultivars of rye, winter wheat and triticale grow on the demonstration block.

VIII Weeds - the stubborn gatecrashers of fields

In addition to the cultivated plants, several weeds do well in fields and gardens. From the human point of view, a weed grows in the wrong place causing economical damage or other harm. In Finnish fields, forests and waterways there are about 600 species of weeds; 60 species of them are classified as very damaging and about 100 as fairly damaging. Rapid changes in weed abundances are possible. Corn cockle *(Agrostemma githago)*, cornflower *(Centaurea cyanus)* and marguerite *(Leucanthemum vulgare)* are not important anymore. They have been replaced by creeping yellowcress *(Rorippa sylvestris)*, goatweed *(Aegopodium podagraria)* and wild oat *(Avena fatua)*, among others. However, most of the harmful weeds have been abundant for a long time, for example, chickweed *(Stellaria media)*, fat hen *(Chenopodium album)*, creeping thistle *(Cirsium arvense)*, scentless mayweed *(Tripleurospermum inodorum)* and quackgrass *(Elymus repens)*.

Weeds usually produce a large number of seeds. For example, one shepherd's-purse *(Capsella bursa-pastoris)* plant produces 2,000-40,000 seeds and one scentless mayweed 10,000-200,000 seeds. Weed seeds usually have a long dormant period during which they don't germinate, and they can maintain their germination capacity in soil even for decades. There are about 30,000-40,000 weed seeds per square meter in a Finnish field. Of these, about 60 % are dead, 30 % dormant and less than 10 % germinating. This means that there are enough germinating weed seeds for decades to come even without new seeds. In addition to seeds, weeds have other means of reproduction, such as rhizomes, runners, runner tubers, sprouts and bulbils. MTT studies weed ecology and control, and inspects the suitability of new pesticides for Finnish conditions.

The weed section of Elonkierto demonstrates weed species from the most common to the threatened ones.



Weeds of spring grains (1-13)

Fat hen *(Chenopodium album)* is the second most common weed in Finnish spring grain fields, after chickweed. It grows best in nutrient-rich mineral soils. Fat hen spreads with seeds, of which there can be up to 20,000 in a lush plant. The seeds maintain their viability for a long time; seeds that have been buried in soil and later uncovered have germinated relatively well even after 80 years. (2)

Corn spurrey *(Spergula arvensis)* thrives best on acid, moist and nutrient-poor soils. In spring cereal fields, it has been the sixth most productive weed. It produces plenty of seeds. (3)

Common fumitory *(Fumaria officinalis)* is a weed primarily found in vegetable, potato, beet and spring cereal fields. It is a seed-propagated species, and its seeds can survive in soil for at least 20 years without loosing their germinative capacity. (4)

Treacle mustard *(Erysimum cheiranthoides)* came to Finland in imported hay seed. It is quite susceptible to all herbicides. In spring cereal fields, it is the tenth most common weed. (5)

Wild radish *(Raphanus raphanistrum)* grows particularly on poor quality acid mineral soils. Typical to the species are its siliques, which break easily into pieces and spread with seed grain. Wild radish has rapidly become increasingly rare during recent decades due to liming of fields and efficient weed control. (6)

Charlock *(Sinapis arvensis)* is part of the weed flora of the most southwesterly part of Finland. It has become less common during recent decades. (7)

Pale persicaria *(Polygonum lapathifolium)* thrives particularly in moist humus-rich spring cereal fields where the cereal stand is thin. It became more common in the 1950's when the use of MCPA increased, but became less common in the 1980's, when more efficient herbicides became more widely used. (8)

Black bindweed *(Fallopia convolvulus)* thrives on dry mineral soils, especially in cereal, vegetable, potato and beet fields. Black blindweed has spread with seed grain around the world. (9)

Red dead-nettle *(Lamium purpureum)* favors well-tilled vegetable and garden cultivations. It is most common on dry clay soils, and it is very common even in Elonkierto fields. Cut-leaved dead-nettle and henbit are very similar to red dead-nettle. All dead-nettles are quite resistant to most commonly used herbicides. (10)

Field horsetail *(Equisetum arvense)*
Field horsetail grows light brown spore-producing shoots early in spring. Green sterile shoots grow later in early summer. Field horsetail spreads to fields mainly through vegetative reproduction using horizontal rhizomes that grow under the plow layer. It is common in all cultivations. (11)

Creeping thistle *(Cirsium arvense)* spreads by seeds and rhizomes. It forms patches using its rhizomes, which grow in various depths. Tilling cuts the rhizomes to pieces, and a piece less than a centimeter long can grow into a new plant. (12)

Wild oat *(Avena fatua)* is the most dreaded of the Finnish weeds. It is native to the dry steppes of Middle Asia, and it has been able to colonize almost the entire world. It arrived in Finland in the 16th century but became a serious problem only after the crop failure year 1962, when large amounts of seed grain containing wild oat seeds were imported to Finland. Now the law requires that each farmer controls wild oat in his land. Seed grain for sale is not allowed to contain any wild oat seeds. Wild oat grows best in spring grain fields that are rich in organic matter, and it has become a nuisance to farms specializing in grain production. (13)

Weeds of fall grains (14-26)

Scentless mayweed *(Tripleurospermum inodorum)* spread to Finland hundreds of years ago, but didn't reach its current distribution until the end of the 19th century. It became common with hay cultivation as a seed weed because its caryopsis is the same size as timothy's. One big scentless mayweed plant produces over 30,000 seeds. The seeds maintain their germination capacity in soil for years, and the plant is also relatively resistant to most herbicides. It thrives best in clay soils. It is especially abundant in young grasses, fall wheat fields and fallow areas. In the Jokioinen area, scentless mayweed and quackgrass are the most noxious weeds. (14)

Nipplewort *(Lapsana communis)* is often a winter annual, i.e. the small rosettes of leaves that develop from seeds germinating in autumn overwinter under the snow. It is especially a weed of fall grains, open fields and first-year grass cultivations. Nipplewort has become more common during recent decades. (15)

Rye-brome *(Bromus secalinus)* has become like rye in many ways; it is a grass of the same length, its seeds are the same size and even the growth rhythm is the same. It is not found in the wild. According to the Maanviljelijän tietokirja (Farmer's Information Book) published in 1963, rye-brome was one of the most common weeds of fall cereals. Since then, commercial seeds, rye cultivars with large seeds and more efficient seed cleaning proved to be detrimental to rye-brome. The cycle from a rye field to a new field by way of the grain bin was broken, and the story of this weed, which had been common and abundant for centuries, came to an end. (16)

Common scorpion-grass *(Myosotis arvensis)* thrives on dry mineral soils where fall or spring grain or vegetables are grown. It is also very common in first-year grass cultivations. Common scorpion-grass is quite resistant to most commonly used herbicides. (17)

Cornflower *(Centaurea cyanus)* came to Finland from the southern steppe region with cereal cultivation. However, it has become much less common in the 20th century. Reasons for this include decreased cultivation of fall cereals, improved seed cleaning, increased competition caused by denser vegetation, and increased herbicide use that inhibits flowering of cornflowers. The cornflower can bloom after germinating either in autumn or spring because it doesn't require a cold treatment period. (18)

Field pansy *(Viola arvensis)* is an annual weed, the seeds of which germinate in autumn or spring. Field pansy is found most commonly in fall grain fields and first-year grass cultivations. (19)

Wild chamomile *(Matricaria recutita)* is a commonly used medicinal herb that grows as a weed in southern and southwestern Finland. (20)

Quackgrass *(Elymus repens)* is a harmful weed in all cultivations. It spreads by seeds, and particularly by its huge runner-like rhizome system. Quackgrass grows best on coarse soils rich with organic matter but also on clay soils. It has become more widespread during recent decades. Previously, quackgrass was controlled using repeatedly-tilled open fallow. Now, it is controlled mainly with glyphosate products. (21)

Marsh foxtail *(Alopecurus geniculatus)* thrives in moist and open cultivations. It appears particularly in water-logged depressions in grass and fall cereal fields. (23)

Mousetail *(Myosurus minimus)* has three different types of habitats; bird roosting sites on skerries, rocky pasture meadows, and clay-based cereal fields. Mousetail had declined, but in recent years it has become more common in fields that had been left unplowed in the autumn. (24)

Norwegian cinquefoil *(Potentilla norvegica)* Norwegian cinquefoil is a common but unimportant weed. (25)

Field speedwell *(Veronica agrestis)* is an annual weed that can be found for example in gardens. In Central Europe it is a serious garden weed, but in Finland its importance as a weed has been small, at least for the time being. (26)

Rare weeds or weeds found only occasionally (27-39)

Yellow marigold *(Chrysanthemum segetum)* found its way to Finland with grain, flax and grass seeds. Originally it was a Central and South European weed. (27)

Corn cockle *(Agrostemma githago)* is one of the most beautiful of the Finnish weeds. Its occurrence in Finland is tied to seed grain imports. Corn cockle was most common in the early 20th century when large amounts of seed grain were imported from Russia after a year of crop failure, and with the seed, corn cockle spread through the entire country. During the 1930's it became less common and in the 1960's it finally disappeared from the permanent flora of Finland. (28)

Forking larkspur *(Consolida regalis)* is one of the most beautiful Finnish weeds. It came to Finland mainly with Russian grain seeds. Today, forking larkspur can only be found occasionally in Finnish fields. (29)

Long-headed poppy *(Papaver dubium)* is a threatened annual companion plant of many field plants. It came from the south to southwestern Finland with seed grain. Long-headed poppy has become less common in Finland, but in Sweden it is still quite a common weed in grain fields. It is most common in Finland in the Åland islands. (30)

Gold of pleasure *(Camelina sativa)* is an old weed of rye which is now cultivated as a fiber plant. (31)

Fodder vetch *(Vicia villosa)*
Fodder vetch came to Finland mostly with rye from Middle Europe, particularly from Germany. It was a permanent weed in the rye fields of the Åland islands and in the Finnish archipelago. Its decline already began in the 1930's, and the last observations were made in the 1960's. (32)

Cornflower *(Centaurea cyanus)* came to Finland from the southern steppe region with cereal cultivation. However, it has become much less common in the 20th century. Reasons for this include decreased cultivation of fall cereals, improved seed cleaning, increased competition caused by denser vegetation, and increased herbicide use that inhibits flowering of cornflowers. The cornflower can bloom after germinating either in autumn or spring because it doesn't require a cold treatment period. (33)

Rye-brome *(Bromus secalinus)* has become like rye in many ways; it is a grass of the same length, its seeds are the same size and even the growth rhythm is the same. It is not found in the wild. According to the Maanviljelijän tietokirja (Farmer's Information Book) published in 1963, rye-brome was one of the most common weeds of fall cereals. Since then, commercial seeds, rye cultivars with large seeds and more efficient seed cleaning proved to be detrimental to rye-brome. The cycle from a rye field to a new field by way of the grain bin was broken, and the story of this weed, which had been common and abundant for centuries, came to an end. (34)

Yellow chamomile *(Anthemis tinctoria)* used to grow well on burn-beaten clearings, and its first period of decline came with the end of burn-beating. Yellow chamomile became more common again in the early 20th century when cultivation of seeded hay increased. However, improved cultivation methods already decimated it in hay fields decades ago. Today, the species has permanent habitats in meadows and on rocky slopes. (35)

Marguerite *(Leucanthemum vulgare)* is a characteristic plant for clearings and meadows. When the importance of meadows finally plummeted after the last war, marguerite lost its previous reign and prevalence. It was still common in hay fields in the 1960's. However, earlier hay making, efficient seed cleaning and fertilization of fields have finished marguerite as a weed. Nowadays, marguerite is mostly a weed of shoulder areas and hillside meadows. In fields, it can be found in old grass pastures. (36)

Common orache *(Atriplex patula)* is a member of the goosefoot family. This annual weed follows old cultural landscapes. (37)

Warted bunias *(Bunias orientalis)* is a perennial weed that spread to western Europe with Russian seed grain and cavalry. It is considered to be a very noxious weed, but it has not thrived very well in Finnish fields. (38)

Common Poppy *(Papaver rhoeas)* (39)

Weeds of potato fields (40-44)

False cleavers *(Galium spurium)* thrives in fields that are tilled annually. It attaches itself tightly to surrounding vegetation with its hook-tipped hairs. False cleavers is quite resistant to many herbicides, so it has become more common in cereal fields during recent decades, replacing some more herbicide-susceptible species. (40)

Marsh woundwort *(Stachys palustris)* is a very bothersome species in gardens and in potato and sugar beet fields. It spreads efficiently by seeds and thin runners. The runners get stronger as the growing season progresses until their tips swell to small tubers in autumn. When winter arrives, the roots die and only the tubers overwinter. (41)

Spiny sowthistle *(Sonchus asper)* is an annual seed-propagated weed that thrives around human settlements in gardens, in compost heaps, around cowhouses and in fields. It is rare outside its southwestern main area. (42)

Field sow-thistle *(Sonchus arvensis)* is a perennial weed, which spreads to fields forming wide stands with the help of its roots, which form plenty of adventitious buds. It also spreads efficiently by tufted seeds that are able to float in the air. It is particularly noxious in open fields. Field sow-thistle became more common during the 20th century. (42)

Chickweed *(Stellaria media)* has followed man everywhere, and in Finland it grows widely wherever people live or move about. It adapts easily to new conditions and tolerates shading well. It thrives best on well fertilized and moist soils, which are rich in organic matter. Chickweed is one of the most common and noxious weeds in cultivated land in Finland. (43)

Sun euphorbia (Euphorbia helioscopia)
Sun euphorbia is an annual local weed of beet fields and gardens. (44)

Weeds of vegetable gardens (45-53)

Knotgrass *(Polygonum aviculare)* is found in yards, fields and fallows. In fields, it is most commonly found in fall grain cultivations. Knotgrass tolerates trampling well because it is able to grow new tissue to replace the damaged. (45)

Cow parsley *(Anthriscus sylvestris)* is spreading with an accelerating speed to waste lands, road shoulders and other man-made habitats all around Finland. (46)

Hairy tare *(Vicia hirsuta)*
Hairy tare is an annual leguminous plant that has spread to Finland with cereal cultivation. It is found particularly in spring and fall grain fields. It has become less common during recent decades. (47)

Groundsel *(Senecio vulgaris)* is an annual weed, which spreads by seeds dispersing in wind. It prefers open places with sunlight where soil is tilled. (48)

Hedge bindweed or bell-bind *(Calystegia sepium)* is a perennial creeper that has been commonly used as an ornamental plant. After getting into a garden, it becomes a troublesome weed that is difficult to control. (49)

Bishop's weed *(Aegopodium podagraria)* is a garden weed, which is rarely a problem in fields. It spreads to new locations mainly by broken-up pieces of rhizomes in nursery products and soil. It can spread to wide areas by its long rhizomes. Controlling bishop's weed in a garden is difficult because it tolerates tilling and most commonly used herbicides well. (50)

Creeping yellow-cress *(Rorippa sylvestris)* was found in Finland for the first time n 1854. Today, it is one of the most aggressively spreading garden weeds. It finds its way from place to place as pieces of rhizomes mainly in soil or root balls. (51)

Common wintercress *(Barbarea vulgaris)* is a biennial or perennial plant that didn't spread to Finland until the 1840's together with seeded grassland cultivation. Nowadays, it is one of the most visible cultural plants, particularly in southern Finland. (54)

Weeds of grasslands (54-65)

Scentless mayweed *(Tripleurospermum inodorum)* spread to Finland hundreds of years ago, but didn't reach its current distribution until the end of the 19th century. It became common with hay cultivation as a seed weed because its caryopsis is the same size as timothy's. One big scentless mayweed plant produces over 30,000 seeds. The seeds maintain their germination capacity in soil for years, and the plant is also relatively resistant to most herbicides. It thrives best in clay soils. It is especially abundant in young grasses, fall wheat fields and fallow areas. In the Jokioinen area, scentless mayweed and quackgrass are the most noxious weeds. (55)

Dandelions (Taraxacum) are most common in old grasslands. They are suitable feed for animals but require a lot of growing space replacing much more productive hay species. Over 400 species of dandelion grow in Finland and tens of these species are common in grasslands. (56)

Sheep's sorrel *(Rumex acetosella)* grows in dry and acid fields. Wide reddish sorrel patches are a sign of a general lack of plant nutrients. (57)

Creeping buttercup *(Ranunculus repens)* is a noxious weed of grasses particularly common in the humus-rich fields of northern Finland. It becomes more abundant as the grass gets older. It is toxic to animals, as are many other Ranunculus species, and animals leave them untouched. (58)

Longleaf dock *(Rumex longifolius)* grows primarily in old pasture grasslands. It doesn't thrive well in fields that are tilled annually. It spreads easily with clover and grass seeds. (59)

Marsh horsetail *(Equisetum palustre)* grows particularly on wet peat soils. It is very harmful to cows; just 2 grams of marsh horsetail is enough to decrease milk production. Cows can get this amount if there is an average of one plant per two square meters of grass. (60)

Nettle *(Urtica dioica)* thrives particularly well on nitrogen-rich light soils. In pastures, it spreads using its runner-like shoots, which grow in the plow layer. Nettles have been used as a food plant, a medicinal herb and a fiber plant. (61)

The leaves, stem and inflorescence of **common thistle** *(Cirsium vulgare)* are completely protected by stout yellow thorns, and, because of this, it can grow alone in sheep and horse pastures, which are otherwise gnawed. (62)

Coltsfoot *(Tussilago farfara)* spreads from shoulder areas to fields with the help of its rhizomes. In fields, it is quite a difficult weed to control due to its deep and strong root system. Coltsfoot is also quite resistant to most commonly used herbicides. (63)

Tufted hair-grass *(Deschampsia cespitosa)* is a permanent weed, particularly in moist old pastures. It is very abundant, particularly in old grasslands in northern Finland where, year after year, it forms growing tussocks that complicate cutting and take space from more valuable grasses. A tufted hair-grass tussock can live for up to 30 years. (64)

Common yarrow *(Achillea millefolium)* has been used as a medicine and for tea and beer brewing in Finland. It spreads with seeds and rhizomes. Common yarrow is most common in old grasslands. (65)

IX Nutrient disharges from agriculture have to be controlled

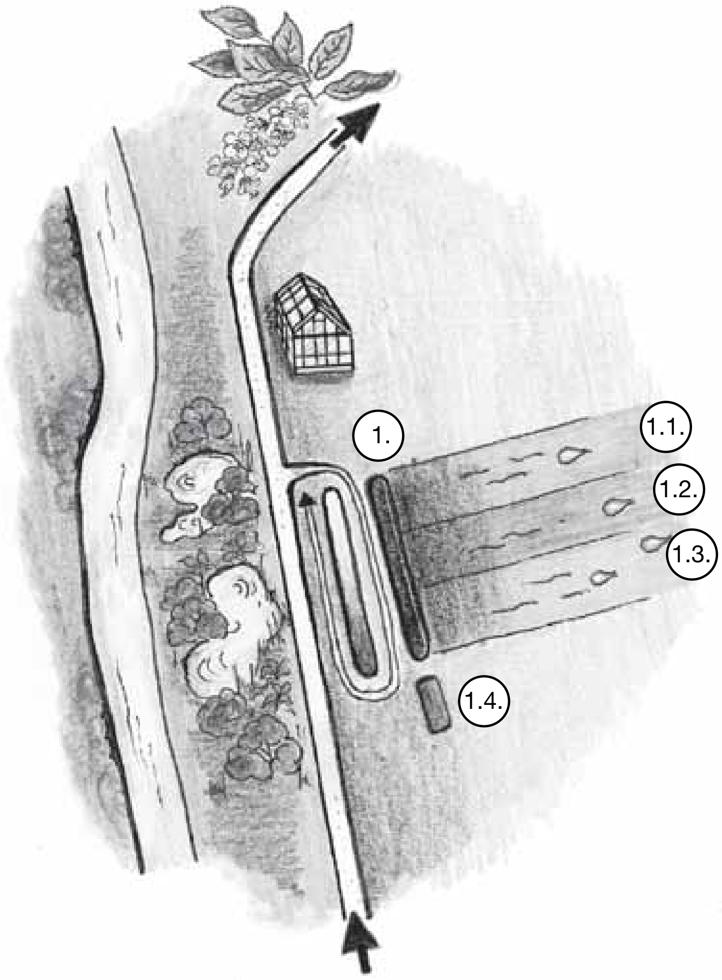
Decreasing the nutrient discharges caused by field husbandry is one of the most important research topics at MTT. Nutrient discharges have been decreased with the help of research during the past years particularly by decreasing the use of fertilizers and adjusting manure use. The load coming from fields can also be decreased by establishing buffer zones, settling ponds and wetlands, which decrease the nutrient runoff to waterways, if properly located.

The buffer zones control surface runoff on sloping fields. Research conducted by MTT has shown that, depending on the slope and length of the field, the buffer zones may decrease the surface runoff nitrogen load by 50 %, phosphorus load by 30 %, and erosion by 60 %. Coarse soil and adsorbed phosphorus are effectively stopped by exclusion areas, but they are not effective in retaining dissolved phosphorus.

The settling ponds function by slowing the water flow and thus allowing soil particles in the water to settle on the bottom of the pond. Soil particles and nutrients (phosphorus in particular), which are adsorbed by the soil particles, are also removed from the water.

In the MTT studies, on average, 200 kg of solid matter per hectare of drainage area was collected in settling pools annually. Wetlands hold solid matter in runoff water and adsorbed nutrients similar to settling pools. The wetland vegetation also removes nitrogen and phosphorus. Nitrogen is also removed by microbes, which convert it to gaseous form. Sufficient size is essential for the function of settling ponds and wetlands.

In the Elonkierto area you can find a buffer zone, two wetland areas, a chemical treatment plant for runoff water (1.4.), a settling pond and a set of artificial cascades that decrease the erodibility of running water in a steep ditch.



1. Nutrient leaching

Soil can naturally retain nutrients and protect them from leaching, and the strong structure of soil particles prevents material from loosening by water. In spite of this, a small amount of nutrients and soil finds its way to waterways even from natural soils. Cultivation and many modern cultivation techniques accelerate leaching. Soil tilling, cultivation of annual plants, and fertilization change the activity of soil, which in turn causes larger nutrient discharges and emissions into waterways and the atmosphere. Grass, grain cultivation and open fallow, which are demonstrated next, differ from one another in terms of their cultivation methods and thus by their environmental emissions.

1.1 Grass is closest to a natural soil

Grass protects soil most efficiently against erosion and nitrogen leaching because during grass years the soil surface is not broken by tilling and the vegetation uses soil nutrients during the entire growing season. However, fertilizing the grass and regenerating it every few years increase the loads into waterways compared to those of natural areas. The loads can grow especially large if phosphate fertilizers are applied to the surface of grass because surface runoff is often common on grass-covered soils.

Grass is cultivated in particular on cattle farms, and manure spreading is an integral part of the crop rotation. The geographical concentration of animal husbandry and the large production units create new challenges for utilizing the nutrients in manure in an environmentally sustainable way.

1.2 Emissions from grain cultivation are decreasing

In spring grain cultivations, plants take up nutrients for only a few months and the soil can be without protective vegetation most of the year. Under normal cultivation practices, 10-15 kg/ha of nitrogen is leached annually from spring grain fields. The longer growing season of fall grains decreases nutrient (particularly nitrogen) losses. Lighter tilling also decreases nitrogen washout in grain cultivation, and thus most likely does the transition to direct sowing.

The amount of easily soluble phosphorus in soil directly affects the amount of phosphorus carried by water in a soil surface layer. Currently the phosphorus state of soils, and thus the loads into waterways, are decreasing because phosphorus fertilizing has decreased since the early 1990's, especially in farms where animal husbandry is not practiced.

1.3 Open fallow has the highest loads

Open fallow is tilled in the summer to control weeds. Tilling breaks the soil surface and exposes it to erosion and deteriorates soil structure by compacting it. At the same time, nitrogen is released from soil, and it leaches away easily because there are no cultivated plants taking up nutrients. Nitrogen leaching is often twice as much as in grain cultivation. Because open fallow stays moister than other arable land, nitrogen losses caused by denitrification can also be significant.

The best way to decrease the loads caused by open fallow is to try to stay away from it. There are other methods for weed control, such as crop rotation and chemical control.

1.4 Phosphorus is recovered from runoff water

Eutrophication of water is the most significant environmental damage in Finland. The eutrophication of inland waters, in particular, can be prevented by decreasing the agricultural phosphorus load. Phosphorus binds to soil particles and a significant portion of it is carried to water in erosion silt.

The load coming from fields can be decreased by using exclusion areas, settling pools and wetlands. They effectively stop the phosphorus, which has been adsorbed in coarse soil, but only a little of the dissolved phosphorus is retained. Therefore, chemical cleaning is needed.

In Elonkierto you can learn about a cleaning method developed at MTT, which can be used to clean solid matter and water-soluble phosphorus from field runoff water. In this method, soil matter in water is crumbled by using positively charged and slightly acid low-molecular-weight aluminum hydroxide polymers. Water-soluble phosphorus binds to oxides that are inside the formed soil crumbs, and it changes into a form that is unusable to algae.

In practical cleaning, aluminum hydroxide polymer solution is measured into the dammed pool to which the main ditch drains. There phosphorus binds to oxides inside clay particles and settles down on the bottom of the pool with the solid matter. To clean all runoff waters from Finnish fields with this method would cost about 70-100 million euros.

1.5 Nutrient leaching in food production
Domestic food production requires 3,200 m^2 of cultivated land per person in Finland. The amount of runoff water from this area is 960 m^3 per year, 2.6 m^3 per day and 1.8 l per minute. However, the largest part of the runoff is formed in the spring when snow melts and in the fall in October and November. For waterways, the most damaging factor is the leaching of nitrogen and phosphorus.

Materials that are carried from fields to waterways, per person, in Finland (from the area of 0.32 ha):

Material	Amount per year	Effects in waterways
water	960 m^3	
erosion material	300 kg	clouding of water, especially in clay areas
nitrogen (N)	6 kg	eutrophication of the Baltic Sea, ground water pollution
phosphorus (P)	0.3 kg	eutrophication of inland and seashore waters
potassium (K)	5 kg	no effects on waters
magnesium (Mg)	6 kg	no effects on waters
calcium (Ca)	9 kg	no effects on waters
chloride (Cl)	9 kg	no effects on waters
sulfur (S)	5 kg	no effects on waters

X Climate change

1. Greenhouse effect

In the greenhouse effect, the gases in the Earth's atmosphere restrict the exit of solar radiation energy into space. Without the greenhouse effect the Earth's surface temperature would be on average –18 ^{o}C and the Earth would be inhabitable.

The greenhouse effect strengthens when, as a result of human activities, more greenhouse gasses are released than would naturally be released. The greenhouse effect is caused by the use of fossil fuels, changes in land use and agriculture, among others. The most important greenhouse gases are methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2).

It is estimated that the Earth's surface temperature will increase by 1.4-5.8 ^{o}C by the year 2100. It's difficult to reliably estimate the effects of climate change, but the changing climate effects natural ecosystems, water resources, food production and human health. Low-lying areas will suffer from rising sea levels. Extreme climate conditions, such as drought, floods and storms, may become more common.

Greenhouse gases dissipate slowly in the atmosphere, which complicates climate change prevention.

Elonkierto provides information about the effects of climate change in Finnish agriculture.

1.1 Global warming changes the composition of plant and animal species

It is estimated that the annual average temperature in the Nordic countries will increase by no less than 4 ^{o}C if the warming effect of the Gulf Stream does not decrease in an unexpected way.

In that case the temperature conditions in Southern Finland would correspond to those of Denmark today. The warming climate would substantially improve the production capacity of Finnish agriculture. The summers would be warmer and the winters more humid.

The growing season would be longer in the fall and spring, but this would benefit plants only in spring when there's plenty of solar radiation energy. A hundred years from now, the climate change will have advanced the arrival of spring on average by a month. Later varieties will be cultivated; the cultivation area for winter grains and winter oil crops will be increased; and the grazing season will be longer. Even corn will give a seed crop in Finland in 2100. The increased carbon dioxide content in the atmosphere will also improve the yield capacity of grains.

At the same time the risks of cultivation will increase. Spring and summer frosts brought by northern air currents will damage plants that started their growth early in the spring. Many plant diseases and pests will become more common. The increased autumn rains will also cause quality-based crop losses. A longer growing season, increased autumn rains and decreased ground frosts would increase leaching of plant nutrients and make it more difficult to maintain a good soil structure.

2. Agricultural greenhouse gas emissions and how to decrease them

Agriculture contributes about 20 % of the global greenhouse gas emissions. Forest clearing for agricultural use increases carbon dioxide emissions, whereas animal husbandry and rice cultivation cause methane emissions. Nitrogen fertilization increases the amount of nitrous oxide in the atmosphere. In Finland, agriculture contributes about 11 % of the total greenhouse gas emissions.

2.1/1 Agricultural land nitrous oxide emissions

The nitrous oxide emissions of agricultural land are caused by microbes living in the soil. Warm and moist conditions and the freezing and thawing of soil are favorable conditions for the formation of nitrous oxide. The nitrous oxide emissions of agricultural land are estimated to be about 35 % of agricultural greenhouse gas emissions.

The sources of agricultural land nitrous oxide emissions:

- artificial fertilizers spread in fields 32 %
- manure spread in fields 10 %
- plant waste tilled into fields 6 %
- cultivation of organic soils 37 %
- nitrogen leached from fields into waterways 15 %

2.1/2 Decreasing agricultural land nitrous oxide emissions

Soil nitrous oxide emissions can be decreased by improving the nitrogen use efficiency of plants. Soil compaction should be avoided, the water balance of the field should be good and the amount of nitrogen fertilizers and manure used should be properly adjusted.

2.2/1 Agricultural land carbon dioxide emissions

The decomposition of soil organic matter is the largest source of carbon dioxide in agriculture. After a field has been cleared, mineral soils release large quantities of carbon for about 10 years, but peat and rich organic soils continue to release large quantities. Annually about 15,000 kg/ha of carbon dioxide is released from peat soils in grain cultivation, which equals the burning of 5,000 liters of heating oil. About 15 % of the agricultural greenhouse emissions comes from the carbon dioxide emissions of organic soils and about 3 % of the mineral soils.

2.2/2 Decreasing agricultural land carbon dioxide emissions

It's possible to favor soil cultivation methods that decrease the degradation of the soil's organic carbon reserves and promote carbon binding. Possible measures include decreasing soil tilling, avoiding open fallow, and using crop rotations that include grass and green fallow. On peat and rich organic soils, organic soil carbon dioxide emissions can be halved by cultivating grains instead of grass.

2.3/1 Carbon dioxide emissions of liming

Liming of agricultural soils causes 450 kg of carbon dioxide emissions per one metric ton of lime. Liming contributes about 4 % of the total greenhouse gas emissions.

2.3/2 Liming and greenhouse gas emissions

Even though liming causes carbon dioxide emissions, it improves crop productivity. A larger crop binds more carbon and utilizes the soil's nitrogen resources more efficiently and, as a result, liming might actually decrease greenhouse gas emissions.

2.4/1 Domestic animal methane emissions

When a plant dies, its organic matter decomposes in the soil and the carbon burns into the air as carbon dioxide if the decomposition takes place in the presence of oxygen. If the decomposition takes place in an oxygen-free environment methane is formed as a decomposition product. This is common, for example, in marshes and wetlands that are in their natural state. In Asia, rice fields release large quantities of methane into the atmosphere.

Methane is also formed in the digestive track of herbivores when microbes decompose plant material. Ruminants produce the largest amount of methane. Cows contribute over 90 % of the domestic animal methane emissions but non-ruminants, such as pigs and horses, also produce methane. One milk cow produces about 114 kg of methane annually, which equals the amount of greenhouse gases formed when 750 liters of heating oil are burned. Ruminants contribute about 16 % of the total agricultural greenhouse gas emissions.

2.4/2 Decreasing domestic animal digestion methane emissions

Domestic animal digestion emissions can be decreased by adjusting feeding and using good animal stock. However, the critical factor is the number of cows.

2.5/1 Methane and nitrous oxide emissions of manure

Methane and nitrous oxide are released from manure in animal sheds, manure storage areas and during manure spreading. Methane emissions from liquid manure are larger than from dry manure, whereas for nitrous oxide emissions the situation is the opposite. For cow manure, the greenhouse gas emissions from the liquid manure fertilization method are half of that of the dry manure fertilization method. It is estimated that manure handling and storage contribute 8 % of the agricultural greenhouse gas emissions.

2.5/2 Decreasing of methane and nitrous oxide emissions of manure

Methane and nitrous oxide emissions of manure can be decreased by avoiding overfeeding of proteins, by covering liquid manure storages and by avoiding unnecessary mixing of liquid manure, as well as by covering the manure as soon as possible after spreading.

2.6/1 Energy consumption in agriculture

Agriculture uses about 2 % of the total energy consumption in Finland. The largest energy consumers in agriculture are greenhouse production (40 %), agricultural equipment (30 %) and grain drying (15 %). Energy contributes about 19 % of agricultural greenhouse gas emissions.

A large amount of energy is also needed for manufacturing inputs required for cultivation and for transportation. The largest energy glutton is nitrogen fertilizer production, which accounts for one third of the agricultural energy demand.

Cultivating one hectare of grain takes as much energy as in 200 liters of heating oil. The energy use is divided as follows:

	energy demand (liters of heating oil)
- chemical fertilizers	92
- drying of crops	40
- spring tilling and sowing	30
- autumn tilling (plowing)	20
- threshing	10
- pesticides and lime	6
- transportation	2

2.6/2 Decreasing energy consumption in agriculture

As agriculture becomes more efficient, the energy need for each produced unit becomes smaller. New methods, such as direct sowing, decrease oil consumption. Greenhouse cultivation area is very important for energy consumption. Climate change also affects the weather during the grain harvesting period and therefore influences the need for grain drying.

2.7 Production of bioenergy in the field

Energy plants, such as reed canary-grass, oil crops, energy willow and parts of grain plants (straw, seeds), can be cultivated in the field as substitutes for fossil fuels either for direct use or for processing into fuels. Agricultural biomass production is still experimental in Finland and the production area is only a few thousand hectares.

2.8 Consumer carbon dioxide emissions on a plate

Greenhouse gas emissions caused by the production of domestic foodstuff raw materials in Finland (carbon dioxide equivalent per person):

field nitrous oxide emissions	440 kg
emissions caused by the energy used in agriculture	290 kg
ruminant methane emissions	280 kg
field carbon dioxide emissions	180 kg
manure methane and nitrous oxide emissions	150 kg
carbon dioxide emissions of liming	60 kg

A total of 1,400 kg of carbon dioxide is generated, which is as much as is produced by burning 440 liters of heating oil or driving a car 8,500 km.

The greenhouse gas emissions in carbon dioxide equivalents are divided for various foodstuff raw materials as follows:

milk	630 kg
meat	500 kg
eggs	40 kg
plant products (grains, vegetables, etc.)	160 kg
greenhouse vegetables	70 kg

XI Finnish dining table

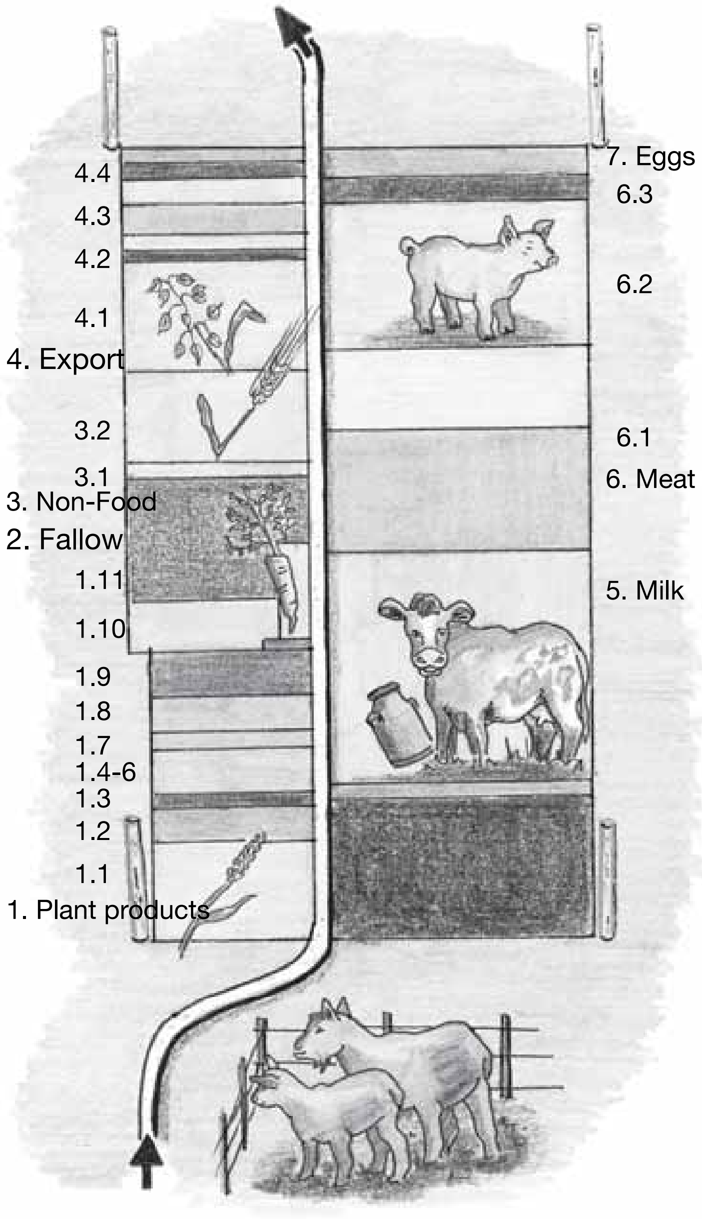
During the hunting, fishing and fallowing period, one Finn needed tens of hectares of forests and waters for food gathering. Even burn-beating still required large areas. To satisfy the annual needs of one person for grain, about 5 ha of land, which was suitable for burn-beating, was needed when the land was burned every 40 years. Field cultivation and the two-year crop rotation made it possible to produce a similar diet on 5 ha for 12 people. With modern cultivation methods, a 5 ha field gives the same amount of cereal to 80 people.

The development and intensification of agriculture to its current form has contributed to the huge population growth. The cultivated field area in Finland is about 2,200,000 hectares which means that there are 0.42 ha of fields per inhabitant. Globally, there are 0.2 ha of fields per person.

Nowadays, an ever larger part of Finnish food consists of animal products, which increases the need for field area. No less that 80 % of the field area is used for animal feed production and only 20 % for directly edible plant products. Almost half of the Finnish field area is needed just to feed the cattle.

Finland is primarily self-sufficient in the most important food products. The self-sufficiency level for vegetables is 65 - 70 % and for sugar about 40 %. Eggs are produced in excess for domestic consumption but more meat products are imported than exported. Protein-rich animal feed needs to be imported to Finland, and, at the same time, feed grain is exported.

Elonkierto demonstrates what is grown in Finnish fields and what size field areas are needed to produce raw materials for various food products per one average Finnish consumer. You will also learn about other uses for the field areas.



The area bordered by the white wooden posts is 0.42 ha, which equals the Finnish field area per inhabitant.

1. Plant products

The growing of plant products such as cereals, potatoes, sugarbeet, oil crops and vegetables occupies 15 % of cultivated area in Finland.

1.1 Wheat

Wheat is the most important cereal in terms of baking quality and, globally, 20 % of energy in food is derived from wheat. In Finland, wheat cultivation became common in the 1920's. Wheat is used for baking, as breakfast cereal and other food industry products.

1.2 Rye

Rye cultivation, concentrated in eastern Europe, became more common in Finland along with burn-beating cultivation, and rye was the most commonly cultivated grain in Finland from the late 18th century until the early 20th century. Traditional Finnish sourdough rye bread is healthy and stays fresh for a long time.

Whole rye flour contains plenty of vitamins, minerals and fibers, which have beneficial health effects. Rye is also needed for some traditional Finnish dishes, such as mämmi (baked rye meal and malt pudding for Easter), sahti (home-brewed beer) and talkkuna (a powdered smoked mixture of various grains [and peas]).

1.3 Oat

In Finland, oat has traditionally been cultivated for horses. The nutrient content is very good, but its value as a food source for humans is limited by its poor baking properties. Oat protein is of a high quality and its fat contains plenty of unsaturated fatty acids. Oats contain beta-glucan and phytic acid, which have positive health effects.

1.4 Barley

Barley and turnips were an important part of the Finnish diet up until the 19th century. Today, about one fourth of the barley crop is used as food grain, 13 % as malting barley, 10 % for alcohol and starch production and 2 % for other food products. Barley's suitability for baking is poor because the grain lacks gluten.

1.5 Malting barley

Finns drink about 81 liters of beer per person annually. For this amount, 12 kg of malt is needed, which equals 15 kg of malting barley. One square meter of barley provides 6 bottles of beer, which means that one average consumer needs 40 m^2 for malting barley cultivation.

1.6 Barley for alcohol production

The annual consumption of hard liquor is 2.1 liters of 100 % alcohol, which requires 14 kg of barley from an area of 41 m^2.

1.7 Turnip rape

The average consumption of vegetable oils is 5 kg. In Finland, the most popular vegetable oil by far is turnip rape seed oil. It is also the third most common vegetable oil in the world after soy and palm oil. The popularity of turnip rape cultivation increased in Finland beginning in the 1970's, when new cultivars were successfully bred giving healthier and better quality oil.

1.8 Potatoes

Potatoes give twice the amount of starch per surface area compared to cereals. The increase in potato cultivation was followed by a rapid population growth in Europe after the middle of the 18th century. Today, annual potato consumption has decreased to about 60 kg per person. On the other hand, the consumption of French fries and potato chips has increased. For an edible crop, and to provide potato seeds for the following year, an average of 250 seed potatoes is needed. These seed potatoes are planted on a 40 m^2 area.

1.9 Sugar beet

Sugar beets give 4,000-6,000 kg/ha of sugar, which is the biggest energy yield of any crop plant per hectare in Finland. The sugar content of sugar beets is usually 16-17 %. Cultivation is concentrated in southern Finland, around sugar mills. Sugar consumption is 30 kg per year and about 40 % of this is domestic production. Globally, 25 % of sugar comes from sugar beets.

1.10 Edible peas

The main ingredient of Finnish pea soup is grown annually on about 4,000 hectares. Pea consumption is 1.5 kg, which amounts to about 9 liters of pea soup. Today, the semi-leafless yellow- and greenseeded cultivars are cultivated.

1.11 Vegetables

Total annual consumption of vegetables is about 70 kg per person and 65-70 % of this is domestic production. For the domestic vegetable production, 21 m^2 of fields and 0.5 m^2 of greenhouse space is needed.

2. Fallowing

When cereal overproduction became a problem in the 1980's, production was cut by set-aside fallowing. Already in the early 1990's, a fourth of the Finnish cultivated area was out of production as fallow. Joining the European Union in 1995 decreased the fallow area again to less than 10 % of the cultivated area in Finland. About half of the fallow fields grow perennial grass as a green fallow. The current fallow area would be enough to produce food raw materials for 500,000 people.

3. Non-food

The yield of non-food production is not used for food products or for animal feed. Non-food plants include starch potatoes, fiber plants, ornamental plants, energy plants and plants cultivated as raw material for animal feed for horses, fur animals or pets. Their total cultivation area is about 85,000 ha, 4 % of the cultivated area.

3.2 Horse feed

The majority of non-food production is horse feed cultivation. For one horse, less than a hectare of cultivated area is needed, and two thirds of this area is grass and one third is oats. For the total of 66,000 horses, 2.7 % of the cultivated area is needed.

3.1 Starch potato

About one third of the potato area is used for starch potato cultivation. The starch is used in the paper industry.

4. Export production

The value of Finnish agricultural export is about 1,500 million euros. The most important export products are cheeses, chocolate, alcohol and feed grain. The top export countries are Russia, Estonia, Sweden and Germany. About 15 % of the Finnish cultivated area is used for export production.

The value of Finnish agricultural import products is almost 4,300 million euros. The most valuable import products are coffee, fruits, alcoholic beverages, vegetables and grain products. The top import countries are Germany, The Netherlands, Sweden, France and Denmark.

4.1 Cereal exports

Each year, Finland exports 500-800 million kilograms of oats, wheat and barley. The export portion in barley is 10-20 %, in wheat 10-20 % and in oats 20-35 % of the total yield. Food industry products, such as alcohol, beer and enzymes, form a significant part of the barley exports. Oat is exported as feed grain.

4.2 Pork export

Finland produces pork less than it is needed for the domestic consumption.

4.3 Egg exports

Finnish egg production is 11 % larger than the domestic consumption.

4.4 Milk product exports

The degree of self-sufficiency for milk products is nowadays less than 100 %. The most important milk export products are cheeses, butter, milk powder, ice creams and yogurt.

5. Milk production

The annual consumption of liquid milk products is 180 liters, cheeses 21 kg, butter 4 kg and ice-cream 12 liters, per person. To produce all this, 420 liters of cow milk is needed, which means that one cow yields the annual milk products for 20 people. A cow needs about 0.8 feed units to produce one liter of milk. This amount of energy can be obtained from one kilogram of oat grain or from five kilograms of grass pasture. During a higher production phase, a cow also needs additional proteins in its feed. The main source of protein-rich feed in Finland is coarse turnip rape meal. For the milk consumption of an average Finn, 0,13 ha of field is needed. This area consists of 760 m^2 of grassland, 420 m^2 of grain and 130 m^2 of turnip rape. Altogether, 30 % of the Finnish field area is used for milk production.

Grass seed production

The area for grass and legume seed production is 10,000 ha. The most common species are timothy, meadow fescue, red clover and perennial rye-grass. Grass seeds used for green areas and parks are imported.

6. Meat production
Annual meat consumption is 78 kg per person. Nearly half, 36 kg of the production is pork. The consumption of beef as well as poultry is 19 kg and that of game is 2 kg, mutton/lamb and reindeer 1,2 kg. Imported meat makes up 22 % of the total consumption.

Poultry husbandry is the most efficient type of meat production. The production of one kilogram of meat requires 2.6 feed units (one feed unit equals roughly the amount of energy in a kilogram of oats). The respective feed unit amount for pork is 4, for beef 11, and for mutton/lamb 16. Altogether 28 % of the field area is used for feed production for animals to be slaughtered.

6.1 Beef
Beef consumption is 19 kg per person. In Finland, one third of the beef comes from slaughtered cows and two thirds from bulls and heifers, which were raised for meat production. Approximately 5 % of beef production is the result of self-renewable production using mother cows.

Mutton and lamb
Only 700 g per person of mutton and lamb is eaten in Finland. Less than half of this is domestic production. Domestic production takes 6 m^2 of cultivated land per person.

6.2 Pork
Pork consumption has doubled during the past 30 years. Current consumption is 36 kg per person. A pig’s carcass weight is about 88 kg (live weight 118 kg), which means that there is enough meat for more than two people per year in one slaughter pig. A sow gives birth to 20 piglets a year, and these offspring will produce enough meat for 48 consumers. Pork production takes 11 % of the cultivated area.

Feed for slaughter pigs is 80 % grain and 20 % protein feed. Protein feed sources include soy, side products from barley starch production, and turnip rape

6.3 Poultry
Poultry consumption has doubled during the last decade and is still increasing. In 2012 poultry consumption per person was 19 kg. About 86 % of this consumption is chickens, 12 % turkeys and 2 % other poultry.

7. Eggs
The average Finn annually eats 10 kg of eggs (172 eggs of average size 60 g). This egg production amount requires 0.65 chickens and 30 kg of feed for egg laying. The feed contains 80 % grain and 20 % protein feed (mainly soy). Egg production takes 2 % of the cultivated area.

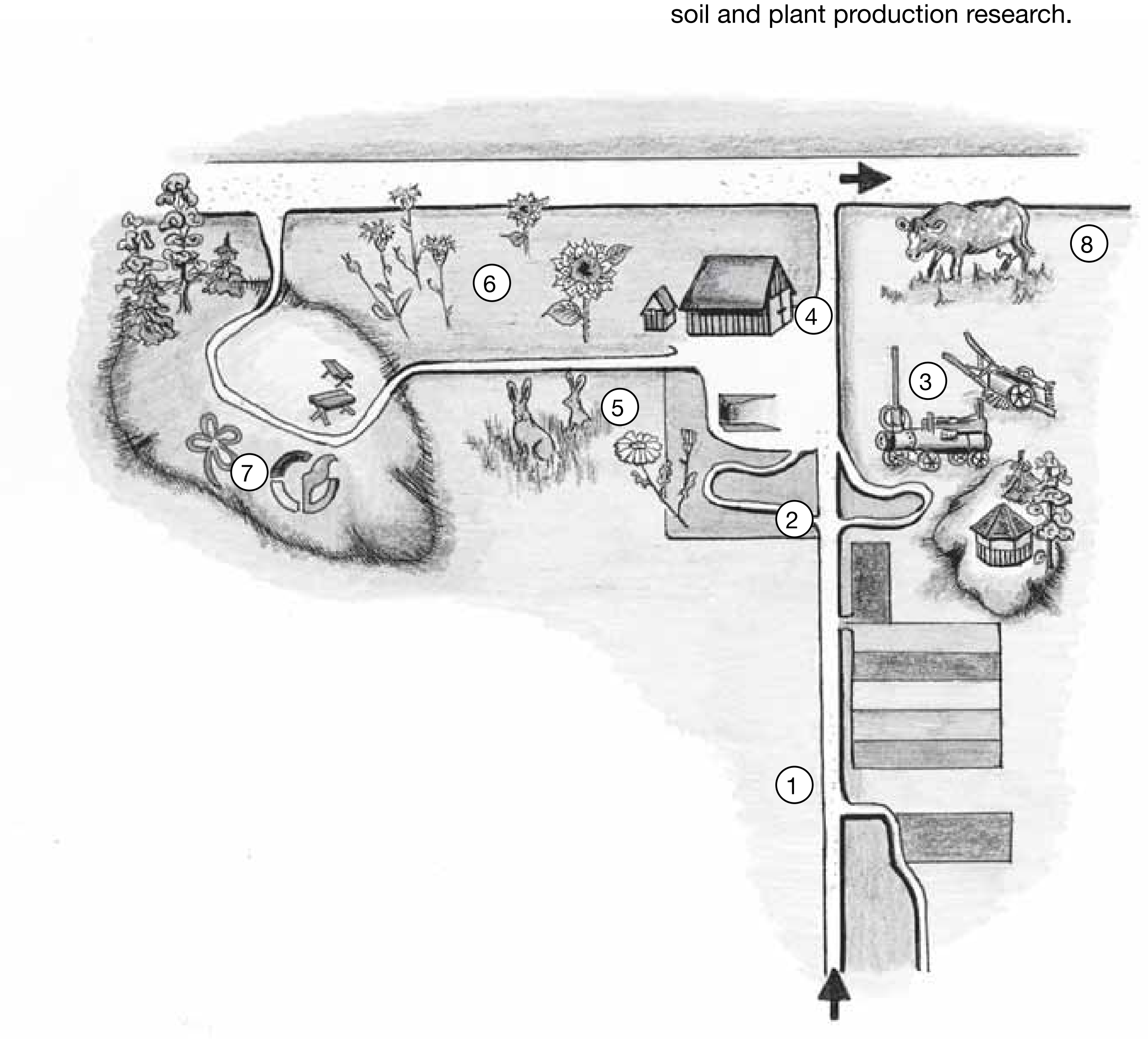
XII Experimental fields, older farm machines, etc.

1. Experimental fields are the foundation of research

Experimental fields have been part of the rural landscape in Jokioinen Manor since the 1930's. The majority of the experimental fields was used by the Jokioinen Plant Breeding Department until the 1980's. MTT's move to Jokioinen in the early 1980's increased the number of experimental fields. Today, their total area is about 100 ha.

There are approximately 100,000 individual experimental plots. Measurements done on the plots form the basis of plant production research. The experimental plots give material for research on soil properties, cultivation techniques, growth factors, plant protection, plant breeding, animal nutrition, and food quality. Most of the experimental plots are 5-10 m long and 1.5-2.5 m wide. In one experiment, from one to hundreds of plots are used. There are usually four replicates, i.e. plots that receive the same treatment. In long-term studies, treatments are repeated in certain plots every year, and in some cases, even for dozens of years.

Currently MTT is primarily studying oat, rye, malting barley, potato, and grass production. A new wide research program studies the use of plant-derived biomolecules in food production. The latest research programs in environmental protection and management focus on the effects of climate change on plant production, and on the indicators of sustainable development of agriculture. Elonkierto is located in the Ojainen area, where most of the experimental plots belong to the soil and plant production research.



2. Flowering fields and lush meadows

The majority of Finnish meadows was formed through forest clearing and burn-beating or by drying alluvial areas or marshes. In addition, there are natural meadows, which were formed without human intervention on shores, rocks, and fell areas above the timber line. The traditional agriculture was based on wide meadow areas where winter feed was harvested for the cattle and where the cattle grazed after the harvest.

As a result of centuries of grazing and harvesting, meadows developed into diverse and species-rich communities. The traditional methods – grazing and cutting – promoted small sized plant species, which needed sunlight and were poorer competitors, and insects that used these species as food sources.

Dry, sandy or rocky soils have their own type of meadows. In these dry meadows, long-continued grazing has formed typical plant communities that thrive in a nutrient poor soil. Various colorful flowers can be found in these meadows, such as sticky catchfly (Lychnis viscaria), lady's-bedstraw (Galium verum), maiden pink (Dianthus deltoides) and harebell (Campanula rotundifolia).

A meadow that formed in a burn-beaten field, after cultivation, was called a glade. Many plants, which are rare today, thrived in glades, such as bristled bellflower (Campanula cervicaria), large hop-trefoil (Trifolium aureum) and fragrant orchid (Gymnadenia conopsea). Lush meadows that used to be the best hay fields, formed on fertile, waterholding soils.

The flora of lush meadows varies depending on soil humidity, fertility and lime content. The main part of the growing space is used by various grasses. Among these grasses, grow flowers, such as spreading bellflower (Campanula patula), Dane's-blood bellflower (Campanula glomerata), red clover (Trifolium pratense), zigzag clover (Trifolium medium), tufted vetch (Vicia cracca), meadow vetchling (Lathyrus pratensis), northern bedstraw (Galium boreale), yellow bedstraw (Galium verum), marguerite (Leucanthemum vulgare), golden-rod (Solidago virgaurea), brown-rayed knapweed (Centaurea jacea) and greater knapweed (Centaurea scabiosa). In moister locations, meadowsweet (Filipendula ulmaria), melancholy thistle (Cirsium helenioides), purple avens (Geum rivale) and wild angelica (Angelica sylvestris), among others, thrive.

There are lush meadows in the pasture area between the Elonkierto trail and the Loimijoki River. For the most part they are very lush because of nutrients and water from the upper fields. A flower meadow has been sown next to the parking lot and on the hill near the storehouse, including typical plants of dry and lush meadows. There is also a landscape area on the hillside of the forest patch behind the storehouse, where wild flower seeds have been sown.

Hay was harvested from the low-lying flood meadows of the Loimijoki River for centuries. However, in the 1940's these meadows were taken for cultivation. During the last few years, grazing has been started in part of the flood meadow area, while part of it has been left as a nature reserve area. It is already possible to hear the creaking of several corn crakes on early summer nights.

3. Older farm machines

Some old farm machines from the Jokioinen Manor are displayed around the storehouse.

4. Storehouse

The Elonkierto storehouse has a coffee shop, which is open on weekends. Modulare, the remote controlled tractor also has its base in the storehouse.

5. Fallow – the pawn in agricultural politics

In a traditional fallow, the soil was left unsown in spring, and the soil was tilled during summer for weed control. Other soil improvements were also made. In fall, winter grain was sown in the fallowed soil. Almost half of the cultivated land was fallowed fields as recently as the 19th century. As hay cultivation became more common, fallowed area decreased, and in the 1970's and 1980's it was only about 2 % of the cultivated area. When grain overproduction became a problem in the 1980's, fallowing was used to cut production, and in the early 1990's, one fourth of the Finnish field area was already out of production as set-aside fallow. Joining the European Union in 1995 decreased the fallow area again to less than 10 % of the cultivated area in Finland. In year 2013 the area was 11 %.

There has been a shift from the traditional open fallow to a green fallow where plants prevent nutrients from leaching from fields to waterways. Green fallow also benefits the fauna and the soil structure. The green fallow fields can be used to sow plant mixtures suitable for game and other natural animals who then feed on these fields during the following autumn and winter. Sowing plants that beautify the landscape is also permitted. Fallowed fields may also be used to grow so called non-food plants for fiber production or as fuel.

MTT has studied the potential of non-food plants as part of an economically sensible utilization of surplus fields. The goal is to conserve the traditional agricultural landscape and to protect the environment. Most advances have been made in studies targeting the use of field biomass as a paper raw material, and new uses for flax fiber. Reed canary-grass has proved to be the most promising agro-fiber plant. In the Elonkierto area, you can become familiar with reed canary-grass production, several landscape plants, and how green fallow is used to improve soil. The benefits of green fallow for animals of the field ecosystem are demonstrated in the nature management area.

6. Flower garden

Later in the summer, you can pick a bouquet of your choice of flowers, from the field behind the storehouse.

7. Landscape's many faces

Elonkierto is located in the Loimijoki River valley, which forms the backbone of the Jokioinen landscape. The Loimijoki River valley was permanently inhabited during the 13th century. The first inhabitants came along the river, and the first fields were cleared in the fertile valley when the settlement became permanent. Jokioinen Manor was founded in the 16th century along the river near the Alakoski rapids.

The people living and working in the countryside have created the time-reflecting layers of the Finnish cultural landscape. The various phases of rural history have been visible in the environment in the form of slow and gradual development, but also as fast and dramatic change. The cultural landscapes created by the farm economy are usually beautiful and diverse. When the structure of agriculture changes, the rural cultural landscape also faces change; the need for more efficient production decreases the diversity of nature and landscape and eliminates small details. The landscape changes discretely, little by little, so that in the end only a memory is left. The disappearance of meadows and forest grazing land is one of the most significant changes in Finnish nature.

From an idyll to a livelihood

The rural cultural landscape consists of an open landscape of fields, farm and other buildings, and nature affected by cultural impact. Landscape protection requires simultaneous actions to protect and care for all of these elements. Caring for the cultural landscape requires vitality of agriculture and diversity in production. Scenery and pristine nature won't be strengths of the countryside until they are converted into a source of livelihood. MTT's landscape research is working on the social values and the ecological changes of landscape.

8. Forage grass is the basic food for Finnish cows

Ensilage made from fresh grass is the number one item on the menu of Finnish cows. The high-quality Finnish milk production is based on the good quality of the grass grown in the northern climate. About 30 % of the cultivated land in Finland is used for grass cultivation, and the crop value is about 330 million euros.

Finnish farmers know how to preserve forage grass and optimize supplements of concentrated feed. Internationally, the production level of Finnish cows is very high. Unlike in many other countries, this has been achieved without large inputs of concentrated feed that can be harmful to cows. Concentrated feed can contain feed grain, industrial whole feeds and concentrates, protein feeds and food industry side products.

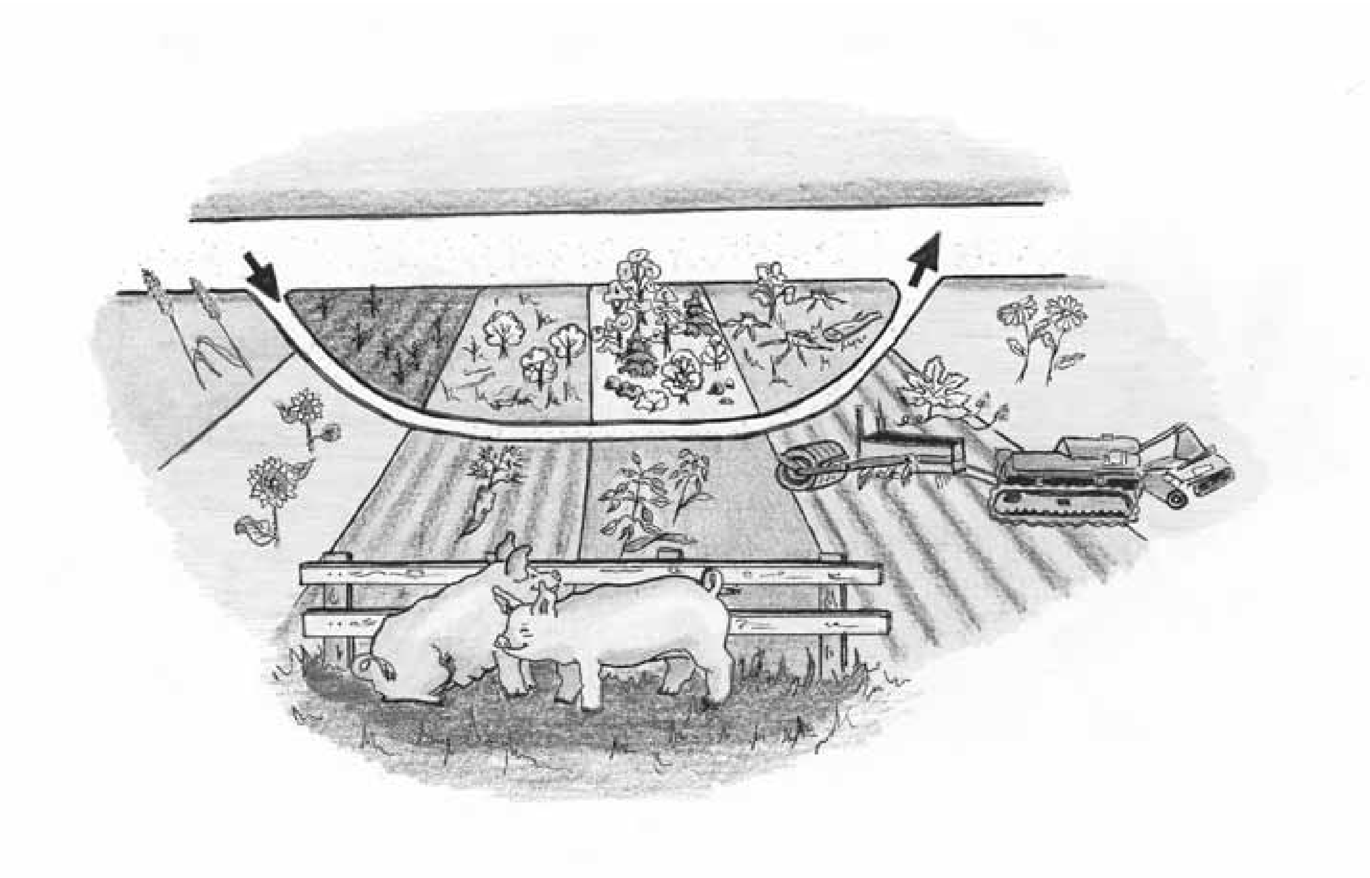
Grass feed is a natural food for ruminants and their digestion needs it for trouble-free functioning. A highproducing cow can eat about 70 kg of good quality grass feed daily. During the indoor feeding period, cows get grass silage, and in summer they graze in pastures eating at the grass-root level. Pasture season lasts for about four months in Finland.

Grass is the most natural feed alternative in Finland because it grows quickly under the favorable northern conditions. Animal nutritionists and plant breeders are working together to improve the nutritional value of grass at MTT. Research goals include increasing the yield and quality of grass crops around the country, making feed production techniques more efficient, and conducting official variety tests.

XIII Agriculture of the future

What will Finnish agriculture, and the rural landscape look like in the future? Researchers, policymakers and farmers will affect the direction of development, but the future of the countryside and the food industry will ultimately be decided by consumers through their purchasing decisions.

Two different trends are demonstrated on the path to the future. On the left side, news headlines describe development where the conditions for Finnish agriculture have further weakened. In turn, the right side describes events in agriculture where Finnish agriculture is given a sufficiently positive chance.



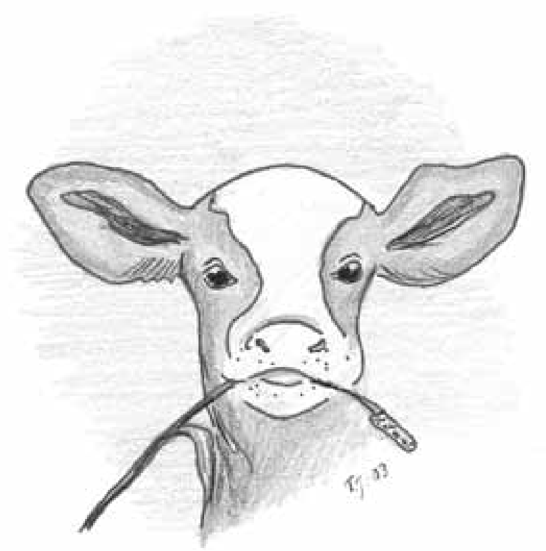
Future farming with a remote controlled tractor

Computers and satellite-based positioning systems are coming to basic agriculture. The cultivation tasks for the following year are planned during winter taking into account the cultivar, yield level, nutrients in the soil, soil vitality, and environmental factors. Spring tasks are carried out and fertilizing adjusted according to the plan. The combine harvester can be fitted with equipment that tells the operator the yield capacity of different parts of the field. Yield results will be used when planning cultivation for coming years.

After further technological improvements, machines can even be remotely controlled from a farmer's living room. The tractor works and moves in the field according to the adjustments and instructions given by the farmer on a computer. When the farmer works at home, the tractor doesn't need a cabin, which in turn makes it smaller and lighter than the big modern machines. Because of their lighter structure, machinery causes less soil compaction, and the soil structure can be expected to improve and give better yields.

Several tractors controlled by one farmer

In the future, technology might make it possible for one farmer to simultaneously control several small tractors. Production performance will be similar to that with large machines, and because of the automation, tractors will be able to work around the clock. In addition to remote-controlled tractors, MTT is also studying many other topics, which will affect agriculture and food industry in the future. Researchers are developing functional foods and new uses for plants. Life-cycle analyses help to obtain the most benefit from agricultural products with minimal environmental damage. New paths are also sought with the help of gene technology and biotechnology.



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