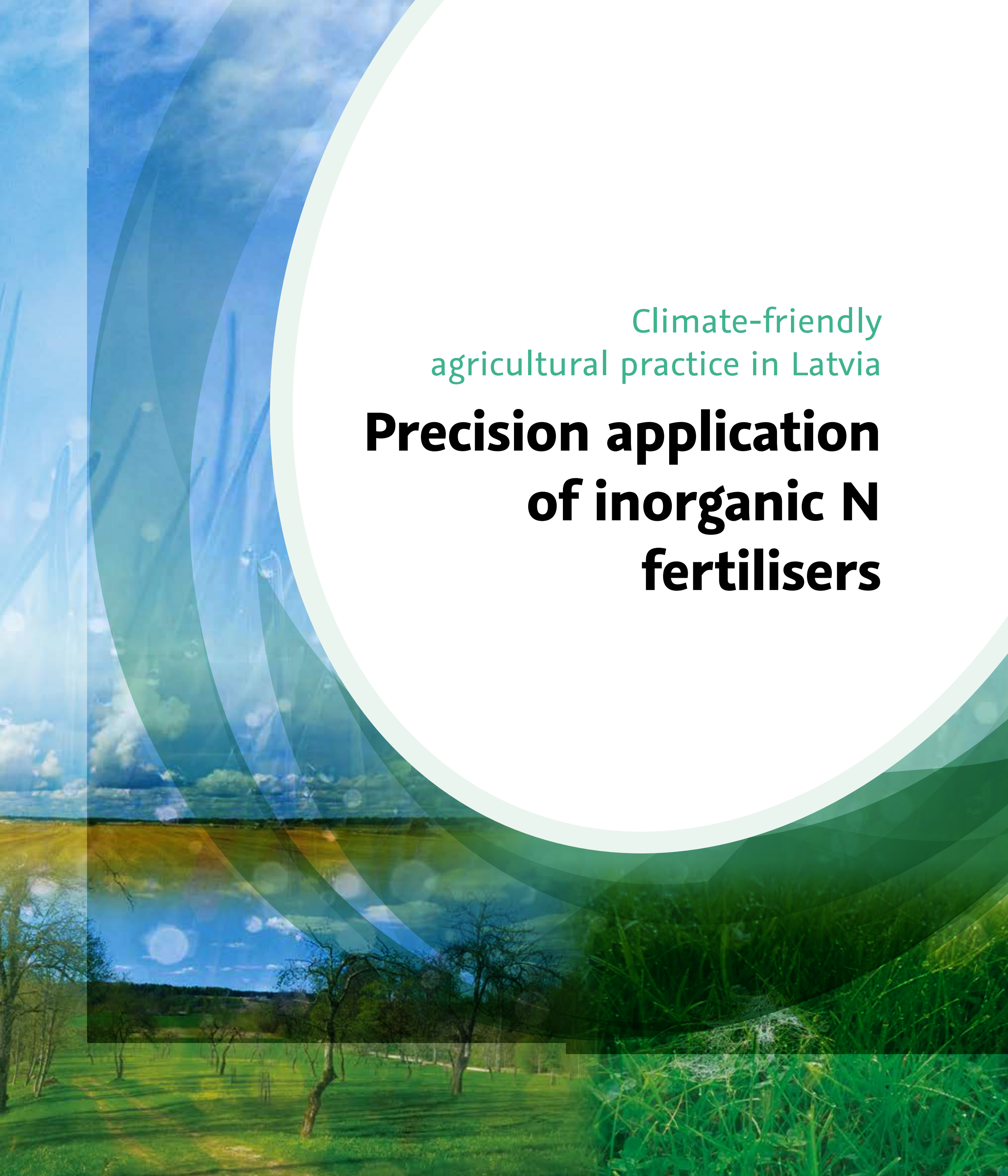


Climate-friendly agricultural practice in Latvia

Precision application of inorganic N fertilisers

Aim of the precision application of inorganic N fertilisers

Precision application of inorganic N fertilisers is a set of harmonised measures using information technology capabilities (Global Positioning Systems (GPS), sensors, software, applications, specially equipped spreaders etc.) in the planning of fertiliser schemes and spreading.

Aims of the measure:

- **economic:** to reduce the costs for the application of inorganic N fertilisers;
- **agronomic:** to maintain and increase crop yields without reducing the soil quality;
- **environmental:** to reduce the losses of inorganic N fertilisers applied and the emissions of nitrogen oxides produced in the environment.

Essence of the precision agriculture

The GPS, or more specifically, Global Navigation Satellite System (GNSS), has gained high popularity in a wide range of areas of human life. Precision guidance (steering) systems of rural techniques, which calculate and ensure the optimal trajectory of mobile techniques in the field, have been widely recognised; thereby, saving fuel consumption and time and delaying technical wear. However, agricultural technique only equipped with the GNSS is not yet the precision agriculture. It is based on the understanding that the chemical composition - pH, phosphorus, potassium and other minerals - of each square metre of soil may vary significantly as well as soil density, water permeability etc. Precision agriculture is based on the soil research, its composition maps and techniques that ensure the application of the variable sowing rate. Therefore, at each point of the field determined by the GNS system, the exact amount of additional fertiliser or lime required is provided according to the soil composition maps.

Global experience has shown that the overall benefits of such a field treatment method are up to 20% fertiliser and up to 30% lime savings, with a yield increase of up to 15%. Such field tillage method reduces the costs of farm management process and leads to significantly lower emissions of chemical amounts in the environment. Precision agriculture method is not limited to soil fertilisation control, it includes both the acquisition and maintenance of yield data and a long term linking of yield changes with a continuous land treatment process and fixation of climatic conditions. The software also allows calculating the investment rate up to which the best return is achieved as well as drawing up a map of projected and earned income by field sections.

Positive effects

- Prevention of the human factor (so that the plants are not fertilized).
- To ensure efficient fertilization, monitoring is performed - collection and analysis of production results.

Negative effects

- In some cases, failures in fertilization (for example, a constant amount is used for the first fertilization).
- Serious problems can occur if the amount of phosphorus and potassium in the soil is not taken into account, but only focuses on N according to the sensor readings. The presence of agronomist and logical approach is necessary. Approaches should be combined. Mean doses of P and K and N should be given by using a precise

technology approach.

- Fertilizer maps in their exact approach are based on the harvest data of previous years obtained from satellite maps, the plant but not the soil is fertilized. There may be side effects such as e.g. the condition of the drains.
- Approaches to analyses performed in Latvian and German (or other) laboratories differ. Thus, alignment is necessary, algorithm for using the DE technologies in LV. This issue is in the competence of the State Plant Protection Service, it is necessary to understand whether and how it is possible to align the results of analyses.
- The granulometric composition of the soil does not change in a short period of time, it is a stable indicator. In biomass maps that use the precise approach, the sample is taken from the biomass but not the soil type or granulometric composition, which is consequently ignored.
- • The problem of accurate technologies, which are currently used in Latvia, is soil sampling without soil information but just basing on biomass and field colour, e.g. on compaction and moisture, rather than soil maps. It is necessary to understand how the results of national soil maps and agrochemical monitoring could be used, which is also the competence of the State Plant Protection Service.

Two approaches may be identified for the precision application of nitrogen fertiliser following the system dynamics:

1. Classic precision management system. Soil maps with different layers of information are being developed, including post-harvest measurements in the autumn and pre-season soil analysis and the nitrogen content in the harvested yields. All possible information should be collected annually and accumulated from year to year for such an approach to be sufficiently effective. The so-called prescription map containing data on how much nitrogen is required at each point of the geographical coordinate of the field is calculated from the soil maps. This information is prepared in such a format that is comprehensible to the on-board computer of the field technique, which uses the variable rate applicator to provide the necessary rate of nitrogen at each field point based on the GNSS position signals.

2. A sensor-based approach that does not even require the use of GNSS. The sensor system performs the soil analysis and calculates the required rate of nitrogen for each field point in real time mode. Here, the measurement data are one of the main sources of information. Crop cultivation and horticulture have a well-established set of tools for measuring different variables with sufficient precision (e.g. mass, volume, temperature, relative humidity, air and fluid flows etc.). These instruments are usually based on a sensor that comes in direct contact with a solid substance, liquid or gas.

Efficiency of the precision cropping system

In the conventional farming system, the same fertiliser rate is applied to the entire field area to obtain the planned yield. However, in places where the content of respective element is insufficient due to the soil composition or any other circumstances, it does not reach the desired amount even after fertilisation. However, the concentration of nutrients in the soil is exceeded in the areas where their amount has been at the desired level before fertilisation; thus, over fertilising certain areas. Consequently, there is a situation that after fertilisation, the spreading of nutrients necessary for plants is not even within the entire field area: some places are over fertilised, some – under fertilised. The use of GNSS and relevant agricultural machinery and equipment makes it possible to identify the level of soil fertility in field plots and to adjust the fertiliser rates by computer, depending on the location in the field; thus, resulting in a reduction in the total volume of fertiliser spreading and possible increase of gross yield by corresponding variations.

It is possible to save fertiliser, fuel and other material resources by knowing the yield-reducing factors within the field; hence, achieving higher profitability of production.

Fertilisation

The efficiency of fertiliser application depends on a number of factors, including the impact of weather conditions, availability of nutrients in the soil and seasonal cycles. The research results show that better efficiency indicators for nitrogen fertiliser have been achieved by using lower nitrogen fertiliser rates (Ruža, 2014). By increasing nitrogen fertiliser rate from 30 kg to 210 kg per hectare, the application of nitrogen in various trial plots decreased differently. For example, the nitrogen application rate in the research and study farm "Pēterlauki" decreased from 62.72% to 46.90%, while in Stende the decrease was from 75.59% to 58.76%.

The content of phosphorus in the soil is more persistent than the content of nitrogen, so the results of soil tests can be used for several years. This means that the economic benefit of the soil study is also more stable. Differentiated application of nitrogen fertilisers is relatively more complicated because the recommended nitrogen fertiliser rate, based on the objective of higher revenues, often correlates poorly with the actual economically optimal nitrogen rate; although the potential economic and environmental benefits of such practice would be high. Nitrogen fertiliser variable rate application models often differ depending on the field and specific seasonal weather conditions, even at the same location. Therefore, it is complicated to create a prescription map and studies have shown no consistent advantages in ensuring high yields and greater efficiency in nitrogen application compared with the same nitrogen application across the field. The real-time sensor system allows "feeling" the crop's need for nitrogen at the moment when the crop has the greatest potential for nitrogen application during the crop formation period. As a result, nitrogen is applied only when and where it is necessary. This method is based on the reflections of light from the plant foliage or the control of chlorophyll content, which indicates the nitrogen stress in the plant. Such an optical method can be used to create nitrogen prescription maps for the whole vegetation period based on stress caused by crop nitrogen, rather than projected profit levels. This new approach to differentiated nitrogen application reduces risk, it can easily be used for precision fertilisation and it is ecologically sustainable.

Commercially available “Go Crop Sensing MDL-N ” and “OptRx Crop Sensor AgLeader ” systems equipped with sensors are real-time operating systems. The sensors of both systems indirectly assess the level of chlorophyll (greenness), the amount of biomass, calculate the vegetation index and determine the standardised differential vegetation index. The amount of nitrogen fertiliser to be spread is varied depending on the nitrogen supply for plants and the size of residue mass: lower (10 – 20 kg ha^{-1}) – if the supply is good and higher (up to 120 kg ha^{-1}) – if the supply is insufficient.

The application of nitrogen spreading sensors for monitoring nitrogen and determining its spreading rate is a more expensive measure; its expenses are around EUR 27 500. Precision fertilisation incorporation equipment can also be rented for approximately EUR 27 (excluding VAT) per day, and it can also be received as a service. A simpler method is to use a nitrogen tester. Its price is around EUR 2100.

[1] Available at: *www.ntechindustries.com/greenseeker-saakums.html*

[2] Available at: *www.agleader.com/products/directcommand/optrx/*

Aspects	Limitations	Solutions
Technological	Discrepancy between soil analysis and fertilization recommendations.	• The technology must allow sensors to integrate the results of analyses performed in Latvia. • It is necessary to regulate the soil reaction by using liming material and to equalize the supply of potassium and phosphorus in the soil by spreading them in a differentiated manner.
Environmental	Requirement to limit nitrogen fertilizers to 170 kg ha^{-1} in nitrate sensitive areas	The risk of nutrient leakage into the environment in the event of fertilization is reduced.
Economic	An expensive event, investment in machinery and equipment is required	• More efficient use of mineral fertilizers. • In the long run, the investment in the introduction of precise technologies pays off.
Social aspects (knowledge, experience, cooperation)	• It is necessary to have agronomic knowledge: understanding of the need for nutrients for crop production and nutrient circulation in the soil. • Skills and opportunities for information are required.	• Providing of knowledge on the circulation of minerals in natural environment and their impact on the environment and biodiversity. • Cooperation between farms in using precise technologies

Implementation of precision fertilisation on the farm

In Latvia, full-cycle precision nitrogen application technologies are not widely used as they require additional investment by farms. However, there is demand and there are several private companies in Latvia offering this service. Usually, the introduction of precision nitrogen application technologies on the farm is a set of measures consisting of the following activities: development of a soil absorption map, soil sampling and analysis, planning and calculation of fertiliser recommendations and installation of equipment on the farm.

The agrochemical research of soil provides an insight into its fertility. The main parameters are: soil response (pH), organic matters, content of mobile phosphorus fosfora (P_2O_5) and potassium (K_2O) content in the soil, but in order to assess the suitability of the soil for the cultivation of certain crops, it is advisable to determine the exchange of magnesium (Mg), calcium (Ca), mobile sulphur ($S\text{-}SO_4$), boron (B), copper (Cu), manganese (Mn) and zinc (Zn) to judge on the suitability of soil for growing certain crops. The amount of fertiliser is calculated taking into account the agrochemical characteristics of the soil to allow a farmer obtaining high and quality yields.

Practical experience

SIA AgTech cooperates with one of the largest farms in Latvia "Vilciņi1", where NPK fertilisation is carried out with the GPS differentiated fertilisation maps, nitrogen fertilisation - with the help of the *AO Greenseeker* sensor, which regulates the fertiliser rate depending on the density of sowing and the green mass index; thus, the plant receives exactly as much as it needs.

***AO GreenSeeker* optical sensing system for nitrogen application.**
Source: archive of the farm "Vilciņi-1".

The sprayer is equipped with an automatic nozzle shut-off function as well as it electronically adjusts the required rate. The spreaders ensure automatic adjustment of fertiliser rates as well as limit spreading of the road edges.

A base meteorological station for measuring air temperature, wind speed and direction, amount of precipitation, atmospheric pressure, soil and air humidity is installed on the farm to store and compare meteorological data continuously; thus, enabling the farm to monitor the relevant data on the computer at any time and any location.

The precision agriculture technique on harvesters and tractors helps identify the situation on every field plot. The yield data may vary from 3 t to 8 t per hectare by individual field plots. Seeing these differences in yield, the farm manager, using information obtained from the precision agriculture technologies, can balance the fertiliser and cultivation technologies depending on the yield levels.

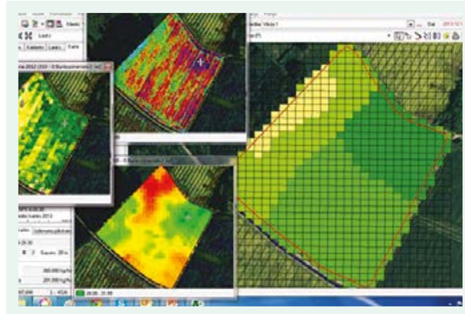
GreenSeeker operation map.
Source: archive of the farm "Vilciņi-1".

All the necessary information is stored in the agricultural software *AO Agrar Office AgroWin*, which makes it easy to manage, document and analyse the obtained information, to keep records of farm field works and use of resources, to summarise data on yields and to prepare reports on fertilisation. Fertilising tasks are made for spreaders for the precision spreading of fertilisers as well as orthophoto maps, topographic maps, amelioration maps and yield data maps are stored.

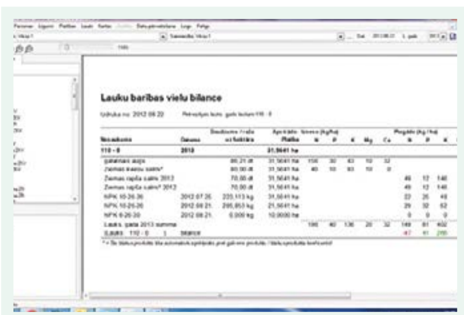
Yield map. *Source: archive of the farm "Vilciņi-1".*

The farm "Vilciņi1" has equipped most of the technique with the GPS facilities: sowing and soil cultivation is done with the GPS automatic steering *John Deere auto track*, which ensures precision steering control. Automatic and parallel steering systems reduce soil compaction, prolong the operation of machinery, work is performed faster, more precisely and economically; thus, obtaining perfectly straight technological tracks and avoiding overlap between drill drifts. Consequently, farmers save working time, fuel and plant protection products.

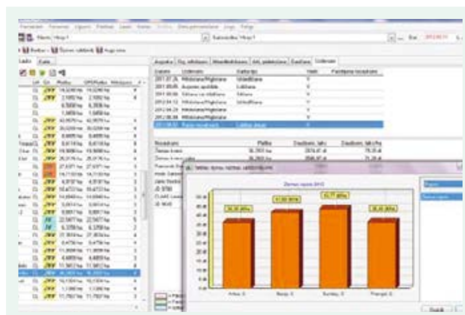
Harvester equipped with a tool for yield recording. *Source: archive of the farm "Vilciņi-1".*



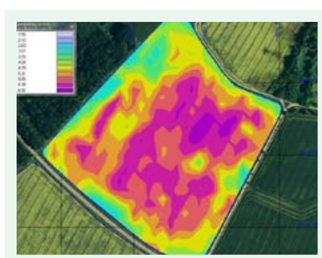
Data from GreenSeeker sensors, yield maps and soil tests are used for the analysis of field conditions. *Source: archive of the farm "Vilciņi-1".*



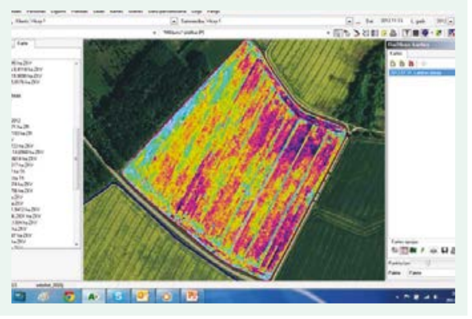
Field history with the soil agrochemical content. *Source: archive of the farm "Vilciņi-1".*



Field history. *Source: archive of the farm "Vilciņi-1".*



Source: archive of the farm "Vilciņi1".



Map for differentiated spreading of phosphorus and calcium in the autumn.
Source: archive of the farm "Vilciņi-1".

Fuel map. *Source: archive of the farm "Vilciņi-1".*

Incorporation of precision fertiliser.
Source: archive of the farm "Vilciņi-1".

Precision steering.
Source: archive of the farm "Vilciņi-1".

Summary of costs

An illustration of the costs of the measure is based on the analysis of a problem case consistent with the following assumptions: investments for the purchase of precision technologies amount to EUR 33 500, and in this case the costs are attributed to a farm with 500 ha of cereals area (according to experts, this is the optimum area for the purchase of precision technologies to make them pay off); hence, the investment costs are EUR 67 per hectare. Assuming an annual increase in wheat yields of 0.07 t per hectare (price is EUR 160 per tonne), the savings of nitrogen mineral fertiliser is 10 kg per hectare (price of nitrogen is EUR 0.12 per kg). Therefore, when introducing this measure, the farmer should consider additional annual costs of around EUR 77 per hectare in Year 1; they will be lower in the coming years. Furthermore, in years when precision nitrogen mineral fertilisation is spread instead of doing the soil tests, the costs are offset by additional benefits from the yield increase and the reduction in nitrogen consumption.

Possible benefits and costs of precision fertiliser application

COST ITEM	COSTS (WITH "+")/BENEFIT (WITH "-"), EUR HA^{-1}		
	in Year 1 when the measure is implemented	in the year when soil tests are done	in the year when soil tests are not done
Investment for purchase of precision technologies	+67	-	-
Soil agrochemical study	+19*	+19	-
Consulting services	+3	+3	+3
Transaction costs	insignificant	insignificant	insignificant
Yield increase	-11,2	-11,2	-11,2
Reduction in N consumption	-1,2	-1,2	-1,2
Relative costs	**+76,6**	**+9,6**	**-9,4**

Source: authors' calculations

Impact of the measure on the reduction of GHG emissions

Usually plants cannot fully absorb the mineral nitrogen fertiliser incorporated into the soil. There is some competition between consumers of nitrogen in the soil (plants, bacteria, fungi etc.); nitrogen of organic or inorganic origin is exposed to the impact of micro-organisms in the environment. Losses of nitrogen may occur during this process; nitrogen may leach from the soil in the form of nitrates and ammonium, while part of the nitrogen in the water is transformed into N2O and is released as emissions into the air. In addition, indirect emissions of CO_2 are generated by the operation of agricultural machinery in the process of spreading fertilisers and liming material. In addition, natural losses of nitrogen occur.

The average GHG emissions are 16 kg of CO_2eq per kg of applied nitrogen mineral fertiliser. By introducing the precision application of nitrogen mineral fertiliser on the farm, the reduction in GHG emissions may be achieved by balancing the supply of plant nutrients in the soil and envisaging the application of nitrogen mineral fertiliser consistent with the actual crop needs. The emission reduction effect stems from the precision management of the nitrogen fertiliser application, where balanced soil quality indicators ensure good plant vegetation, guaranteed nutrient intake, crop yield stability and yield growth with lower nitrogen mineral fertiliser application rates. The content of protein is the most important quality indicator on which the price of exportable wheat production depends. Export-oriented grain growers should be able to produce wheat with a protein content of 12-13.5%, which can be achieved by using high-yield, intensive-type varieties and appropriate nitrogen fertiliser rates. Planning to harvest a grain yield of winter wheat of 6-7 t/ha with a protein content of 12-13.5%, plants need around 180-220 kg of nitrogen per hectare. If the content of organic matter in the soil is 2–3%, winter wheat will use up to 120 kg of nitrogen on optimal weather conditions. Another 80-100 kg shall be provided with fertilisers. A farm with the precision nitrogen management will achieve a yield of winter wheat of 6.4 t/ha by applying 82 kg of nitrogen per hectare. In contrast, a farm where no agrochemical study of the soil was done, achieved a yield of winter wheat of 6.5 t/ha by applying 188 kg of nitrogen per hectare. The emission reduction effect stems from a reduction in the consumption of nitrogen fertiliser. The research done in Latvia has shown that the precision fertilisation management allows a significant increase of the nitrogen application efficiency and a decrease in the consumption of nitrogen by 8%.

Future opportunities of the precision farming.
Source: archive of the farm "Vilciņi1".

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