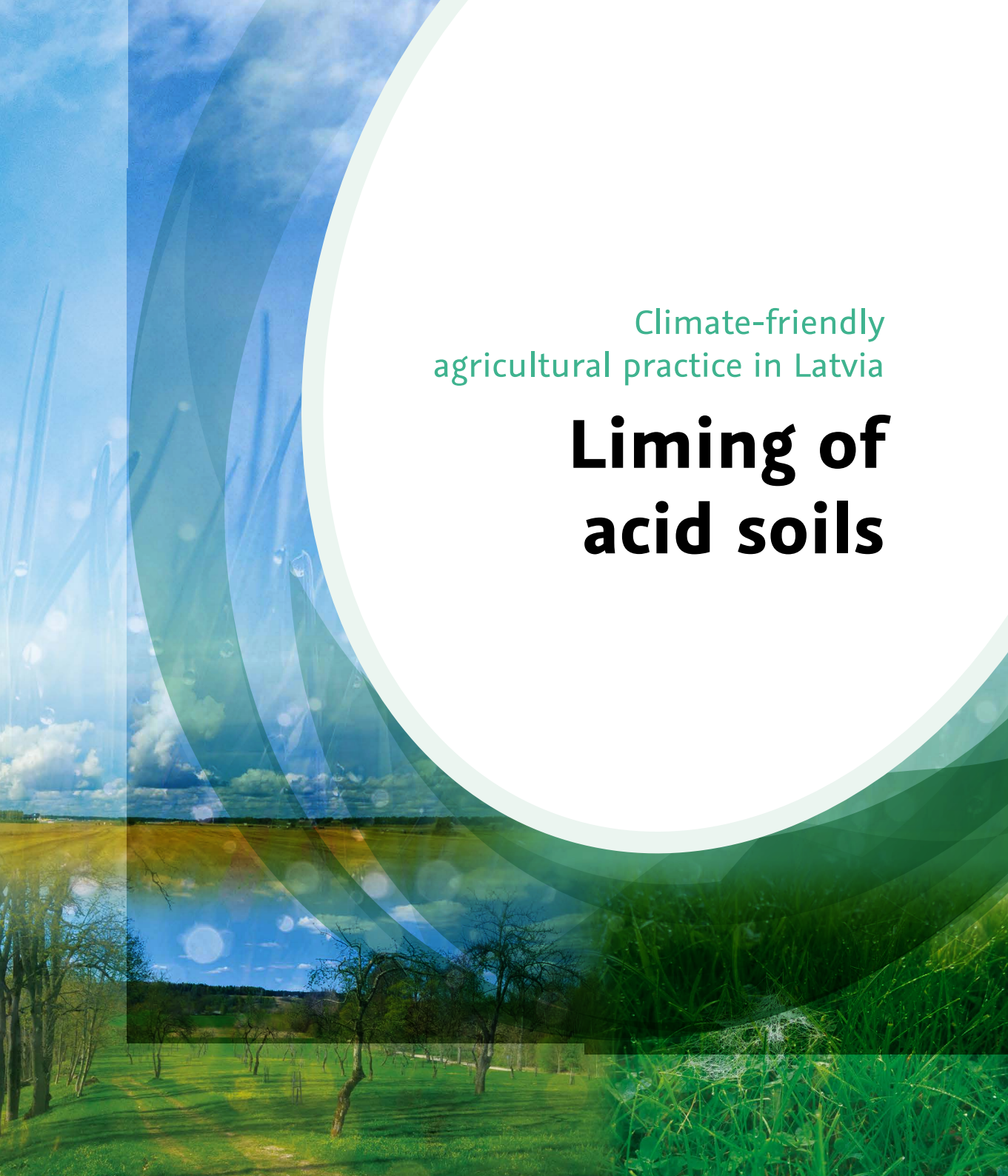

Climate-friendly
agricultural practice in Latvia

Liming of acid soils

Agronomic significance

Liming is required, since:

- increasing attention is being paid to the cultivation of protein crops and nitrogen-fixing crops; thus, the regulation of soil response is a decisive measure;
- only certain legume species, such as lupine or alsike clover, can grow in a more acidic soil;
- topicality of liming is also related with the increased amount of precipitation, which fosters leaching of nutrient elements, including calcium, from the soil.

Calcium, together with humus, forms the soil structure and the capacity of water and air, and determines its response. Acidic soil is low in calcium; however calcium is the main nutrient for plant growth. Without soil liming, the soil structure degrades and thickens more quickly, it creates an adverse moisture and air regime for plants; the process of nitrification on acid soils is also disturbed leading to the deterioration of micro-organisms activity and the activation of plant diseases spreading. Therefore, the yield declines.

An appropriate crop yield can be obtained on soils with a response (pH) range between 5.5 and 8.2 in the surface layer of 25 cm. Such a response provides a 20-80% porosity in the soil surface layer of 7.5 cm, a root spreading depth of 60-250 cm, a biomass of micro-organisms of at least 75-700 mg C kg-1 and the total carbon (C) amount of 15 -50 mg cm-3 in the soil surface of 7.5 cm. Soil acidification reduces the ability of crops to absorb nutrients; thus, reducing their yield and increasing the risk of nitrogen leaching and evaporation. In Latvia, the balance of $CaCO_3$ in areas with intensive use is often negative due to the leaching of calcium and magnesium compounds from the arable layer with precipitation waters, the neutralisation of the acidity

caused by harvests and mineral fertilisers. According to A. Kārkliņš, annually 200–250 kg of $CaCO_3$ per hectare leach out from clay soils and 450-500 kg per hectare - from sandy soils, while about 60 kg per hectare on average are removed with crop yields; though the amount of $CaCO_3$ required to neutralise the acidity generated by fertilisers depends on the type of fertiliser and the intensity of application.

Spread limestone flour.
Photo by Laura Kirsanova

Positive experience on farms in liming the soil

- Liming is differentiated according to the results of soil analysis or soil agrochemical research.
- Crop productivity increases significantly in the long run.
- Transport utilization is optimized to reduce liming costs.
- To make liming more efficient, a special spreader is used, the

Hindering factors for the implementation of the measure on a larger scale

- If the material is damp or wet, there are difficulties to embed it.
- Service providers are expensive.
- It is difficult to adjust to suitable weather conditions.

Aspects	Limitations	Solutions
Technological	Modern equipment (for example, with precise embedding) is not available.	To develop services for the use of modern equipment at an affordable price.
Environmental	• Lack of information on various liming materials. • The content of Mg and Ca and the ratio of these elements in the soil, which influences the choice of liming material, must be controlled.	Structured liming that is carried out in a differentiated manner according to the specific situation.
Economic	Expensive event, long payback period.	• Long-term economic benefits in a crop change or crop rotation system. • Promoting the use of local resources (liming material) • Maintenance measure in case of special terrain
Social aspects (knowledge, experience, cooperation)	Society does not see the potential benefits.	Promotion of positive examples.

Basic liming of soil

The **basic liming is aimed** at a radical improvement of the soil response throughout the depth of the whole arable layer for a longer period of time. This is done if the mineral soil response is below pH KCl 5.5 but the response of peat soils is below pH KCl 5.0. Liming material incorporated into the soil by the basic liming operates only for a certain period of time applying a full required rate, which is calculated according to pH, normally up to 5 years. Therefore, liming should be periodically repeated. The total amount of liming material ranges from 5 t to 8 t per hectare, yet it varies depending on the content of calcium in the liming material and the pH value. Repeated liming is also required if the soil is very acidic and the optimum soil response is not achieved through the basic liming.

Spreading of limestone flour
Photo by Laura Kirsanova

The decision on the use of the necessary liming materials is influenced by and is calculated according to the P_2O_5, K_2O, Ca and Mg content in mg kg^{-1} of soil. The recommended Ca to Mg ratio is 6.5: 1. The required liming material is selected based on soil agrochemical research or at least soil analysis.

Unburned limestone flour contains on average 34.5% Ca and up to one percent Mg, while unburned dolomite flour contains on average about 20% Ca and 11% Mg. For liming acid soils, in which calcium to magnesium ratio is less than 5: 1, it is necessary to choose limestone flour, while if Ca:Mg ratio is more than 8: 1, dolomite flour is more suitable for liming. If the ratio of calcium to magnesium in the soil is balanced, but its reaction is too acidic, it is more efficient to give the required dose of liming material with limestone flour and dolomite flour in a weight ratio of 1: 1.

Supporting liming of soil

When using nitrogen fertilisers, it is important to simultaneously perform soil supporting liming to neutralise the soil acidity caused by fertilisers. It is recommended to be done once every three years, with the application of 1.0-1.5 tonnes of $CaCO_3$ per hectare. The Institute of Agriculture has concluded in its study done by over 34 years that applying high and balanced rates of fertilisers (N135; P90; K135) the soil response had acidified even by 1.1 unit over a long period of time. The acidification occurred due to leaching and outflows without the application of liming materials. In turn, the soil acidity decreased nine years after the basic liming. A decrease of the acid response by 0.1-0.3 units characterises the efficiency of supporting liming. The application of mineral fertilisers incre-

Spreading of coarsely ground dolomite flour and spread coarsely ground dolomite flour
Photo by Laura Kirsanova

ases the application efficiency of liming material and provides the yield increase of crops and rape as well as it improves the botanical composition of perennial herbal grasslands.

The Scandinavian countries are very concerned about soil liming and it is estimated that annually it is required to incorporate into the soil up to 300 kg of calcium (Ca) per hectare. Therefore, Sweden, where the soil is mainly formed on rocks and stones, has higher yields than in Latvia.

The amount of GHG emissions per unit of production decreases with the increase of crop productivity.

Environmental impact

Soil and plants growing in the soil affect both the GHG emissions and their fixation. Larger nitrogen oxide (N_2O) emissions arise from the fallow soils in the after-rain period compared with emissions from nitrogen fertilisers during the crop growth. During nitrification N_2O emissions increase from more acidic soils, while they are equal to 0 from drier soils. The emissions increase to 0.065 µg of N_2O with the increase of humidity both due to nitrification and denitrification. In Latvia, as a result of the denitrification process, 10% of the mineral nitrogen in the soil is

transformed into N_2O and N_2. The results of scientific research indicate that the reduction of N_2O emissions from acidic soils also during heavy rainfall periods, when emissions are caused by nitrification, is possible by increasing the soil pH level. Liming has been shown to reduce the greenhouse gas emissions of farms due to the decrease of N_2O flow.

Spreading of sieved limestone
Photo by Laura Kirsanova

Sieved limestone
Photo by Laura Kirsanova

Priekšrocības:

- Soil liming has both direct and indirect impact on the GHG emissions. Increasing the soil pH will reduce N_2O emissions from nitrification.
- Long-term studies done in Canada on the effect of liming on crop cultivation practices (Soon, Arshad, 2005; van Roestel, 2014) indicate that fertiliser consumption decreases by 20% on average for cereals, rapeseed and legume, as a result of liming.
- The consumption of nitrogen differs from farm to farm; hence, a significant reduction of nitrogen refers to economically strong intensive crop and dairy farms as well as to mixed crop and livestock farms.
- Liming of acid soils contributes to a more complete absorption of

plant nutrients incorporated into the soil by fertilisers, limits the spreading of plant diseases, creates a plant-friendly moisture and air regime, improves the soil structure and activates microorganisms.

Disadvantages

- Liming results in CO_2 emissions.
- Liming has no direct impact on the GHG reduction.

Impact on the farm economy

A problem case is analysed to illustrate the effects of acid soil liming on the farm economy. The case analysis is based on the following assumptions: the soil is acidic; 4 t of granulated Nordkalk are spread per hectare for the basic liming; repeated liming is carried out every third year – of supporting liming - 1 t per hectare every third year. The agrochemical study of soil is variable and it depends on the area of the surveyed UAA as well as on whether the study results are linked with the GPS or not. Therefore, EUR 19 per hectare were assumed as the indicative costs of soil agrochemical study. Spreading expenditure assumes the machinery as a fertiliser spreader, while fuel consumption is 9.4 L ha^{-1}, fuel price is EUR 0.80 L^{-1}, time for sowing one hectare is about 10 minutes, salary is EUR 850 per month or EUR 5.31 per hectare. The annual increase in wheat yield is 0.5 per year, its price is EUR 160 per tonne. The yield increase will be lower if the soil response is neutral and there is no shortage of nutrients.

Possible benefits and costs of liming acid soils

COST ITEM	COSTS (WITH "+")/BENEFIT (WITH "-"), EUR HA^{-1}		
	in Year 1 when the basic liming is done	in the year when no liming is done	in the year when the supporting liming is done
Soil agrochemical study	+19	-	-
Consulting services	+3	-	-
Transaction costs	insignificant	insignificant	insignificant
Liming material purchasing expenses	+120,25	-	+30
Spreading expenditure (fuel, work)	+7,61	-	+7,61
Yield increase	-76	-76	-76
Reduction in N consumption	-1,08	-1,08	-1,08
Relative costs	**+72,78**	**-77,08**	**-39,47**

Source: authors' calculations

The results obtained show that the implementation of this measure requires a farmer to pay extra costs of about EUR 73 per hectare in Year 1. However, additional costs will be smaller in the following years, since the agrochemical study of soil is not required every year but every 6 years as well as the soil liming material will have to be purchased every three years and the liming rate is smaller than in Year 1. In addition, the costs are offset by additional benefits from the yield growth and reduction in nitrogen consumption. Consequently, the implementation of this measure pays off for the farmer starting with the second year following the implementation of the measure, and is financially profitable.

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