Chapter 16
Ecological Reclamation of Acid Soils

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Abstract Compared with traditional liming practice, applying alternative sources of lime in bands with organic manure reduces leaching from coarse-textured *Sod-podzolic* soil: lime by almost six times, soluble organics and nitrate by 1.8 and 2.9 times, respectively. In *Podzolised chernozem*, the same amelioration technology increases the population of earthworms and microorganisms, thereby activating self-renewing and regulating processes. Perennial grasses, legumes and Sudan grass are effective phyto-ameliorants; their beneficial effects manifest through resilient soil aggregates and the accumulation of organic matter.

Keywords Acid soil · Localized reclamation · Alternative lime sources · Leaching · Phyto-amelioration

Introduction

The beginning of the third millennium has witnessed the beginning of a new phase of development with the realization that nature is not limitless and needs care and protection. For millions of years, soils accumulated rich reserves of biogenic elements and energy; now that we understand the decline of soil fertility caused by mismanagement and pollution, society is seeking ways to encourage sustainable, environmentally oriented use of our common wealth. One example is purposeful activity towards resource conservation and environmental safety in agriculture.

In Ukraine, in recent years, liming to ameliorate soil acidity has been sadly neglected. In landscapes that are dominated by acid soils, there has been a sharp deterioration of soil physical properties, depletion in calcium and magnesium, destruction of buffer mechanisms and weakening of biological sustainability and biodiversity. Lack of calcium in the soil retards root development and plant growth,

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D. Dent and Y. Dmytruk (eds.), *Soil Science Working for a Living*,
DOI 10.1007/978-3-319-45417-7_16

leading to lower crop yields; in animals, it causes diseases such as rickets, weak cardiac activity and haemophilia—so lack of calcium in the soil feeds through the food chain to endanger public health. And soil acidification drives toxic, mobile aluminium into surface waters; reservoirs adjacent to acidic soils become acidified and hazards arise because aquatic ecosystems support food chains involving almost all wild animals (Deriy and Ilyuha 2000). Mercury, for instance, occurs in only meagre concentrations in soil but becomes mobile in acid conditions and enters drainage water as monomethyl mercury. This mercury accumulates in the tissues of invertebrates and fish and becomes more concentrated along the trophic chain so that consumption of fish may be poisonous. Furthermore, acidified water dissolves heavy metals from water pipes; drinking this water is bad for us (Ivashura and Orekhov 2004).

Considering the widespread acidity in Ukrainian soils (Baliuk et al. 2012), it is obvious that measures are needed to improve their fertility and agro-environmental status (Mazur and Barvynsky 1993; Martin and Pitblado 1984). The issue is not only to optimize soil fertility but, also, to conserve the resource and enhance the environmental functions of soils. It is well known that liming improves the fertility and agro-ecological properties of acid soils but the cost has become prohibitive. An innovative approach is to make use of waste products as ameliorants. However, care should be taken to avoid harmful consequences—so we need an ecological and functional approach. The Sokolovskyi Institute for Soil Science and Agrochemistry Research has developed a resource-saving and environmentally safe technology of chemical reclamation (Truskavetsky 2003; Tsapko 2003) and this article highlights the impact on soils of lime ameliorants from various sources. We also review prospects for environmentally benign phyto-amelioration.

Local land reclamation technology is a cost-effective way to maintain and improve fertility. Its key mechanism is the fixing of calcium in the soil by application of ameliorants in discrete bands along with organic fertilizers (Truskavetsky 2003; Truskavetsky et al. 2003). Under these conditions, calcium and organic matter combine as calcium humates that resist leaching (Tsapko 2006). Moreover, localised reclamation involves fewer passes of farm machinery that degrade the soil. Each pass of machinery and, especially, each inversion of the topsoil shifts the acid–base balance and nutrient regime—causing significant damage to soil ecology, especially to earthworms and micro-fauna.

Materials and Methods

The study was carried out on two soil types: coarse loamy *Sod-podzolic* and fine loamy *Podzolised chernozem*. In the sandy loam *Sod-podzolic* soil, we studied the intensity of leaching of nutrients under various reclamation technologies: the traditional application of fertilizers and calcium ameliorants to the soil surface followed by ploughing; maintenance application, similar to the above but using only one quarter to one third the amount of lime and fertilizer; and local reclamation technology, ploughing fertilizers and ameliorants to a depth of 20–25 cm and reducing the amount by 5–8 times compared with traditional practice.

In a small-area field experiment on fine loamy *Podzolised chernozem,* we determined the effects of different calcium ameliorants on numbers of micro- and meso-fauna in the plough layer. We also investigated the effects of lucerne, soybean, mustard, Sudan grass, lupin and sainfoin on soil condition.

The selection of soil samples and determination of physical and chemical parameters were made using certified, conventional methods. Accounting of soil invertebrates was performed using Gilyarova's method with hand excavation and breaking up of soil samples (Byzova et al. 1987).

Results and Discussion

Figure 16.1 contrasts the intensity leaching of nutrients from coarse loamy *Sod-podzolic* soil under maize with different ameliorative technologies. Leaching of calcium (lime) is reduced by local cultivation compared with traditional practice: sixfold in respect of lime (from 215.5 to 35.3 kg/ha), by 1.8 times in respect of water-soluble organic matter (from 21.7 to 12.1 kg/ha), and by 2.9 times in respect of nitrates (from 43.0 to 14.9 kg/ha). Deployment of organic fertilizers in bands in the subsoil was the most effective in terms of reducing unproductive losses of

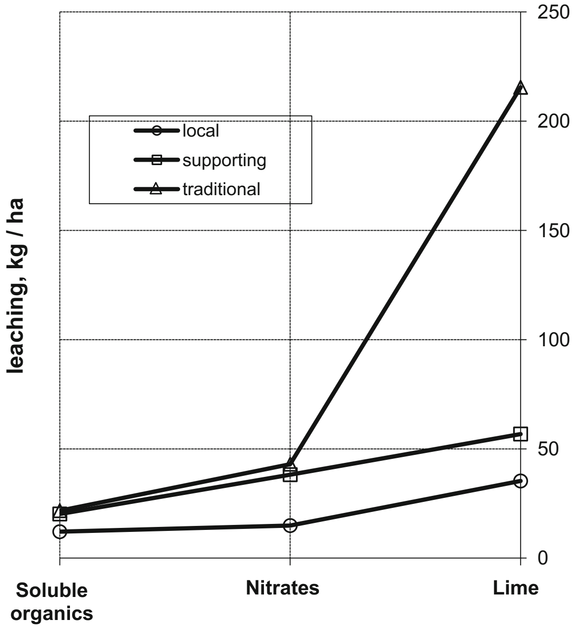

Fig. 16.1 Seasonal leaching of materials from the root zone of sod-podzolic soil under different reclamation practices

Table 16.1 Change in numbers of micro- and meso-fauna in the surface (0–20 cm) layer of *Podzolised chernozem* influenced by lime ameliorants (individuals/m^2)

Variant	Micro-fauna (*Micro-arthropoda*)						Meso-fauna (*Lumbricidae*)		
	Collembola			*Oribatida*					
	1[a]	2	3	1	2	3	1	2	3
Control	213	320	160	80	160	80	9.0	14.6	16.0
Slaked lime	–	160	80	346	480	240	16.3	33.6	21.3
Dolomite	293	320	213	186	240	186	8.7	30.0	12.3
Cement dust	320	373	240	160	186	80	17.3	10.3	12.0
Red sludge	80	160	80	133	160	–	20.6	6.0	8.0
$HIP_{0.5}$	58.4	77.9	38.9	72.8	38.9	38.9	1.1	4.0	2.1

[a]1—2012; 2—2013; 3—2014

nutrients. Thus, local reclamation technology improves the quality of subsoil and surface water.

In *Podzolised chernozem*, liming encourages optimal conditions for crop growth and for the soil organisms that make humus. Given that self-regulation and self-renewal of soil fertility depend on soil organisms, we counted their numbers according to the kind of calcium ameliorant applied. Liming increases the number of *Lumbricidae* through changes in soil pH—so the numbers of all kinds of earthworms were increased by all ameliorants—except red sludge in the first and second year after application when their numbers declined, indicating a toxic effect. Similar changes are observed in soil micro-fauna (Table 16.1).

In *Podzolised chernozem,* liming creates a favourable habitat for earthworms, which are intolerant of acidity (Holhoeva 2004). Earthworms consume plant debris, mineral soil particles and microorganisms, and void casts enriched with lime and humus, which combine as stable complexes including calcium humates. The casts are, in themselves, water-stable soil aggregates. And they stimulate biological activity; their micro-flora generate enzymes, antibiotics, amino acids, vitamins and other biologically active substances that destroy pathogens (Bityutsky et al. 2005). Thus, the increase in the number of earthworms in a limed soil activates self-renewing, regulative soil processes and improves its agro-ecological condition.

Calciferous glands in the earthworm gut neutralize acids formed during the decomposition of organic matter—so the casts have a neutral reaction; paradoxically, even in the absence of liming, they can neutralize soils of low pH. For example, in Kharkiv region, acid soils have not been limed since the 1980s yet the area affected by acidity has declined. We guess that neutralization of soil acidity has been accomplished by biological factors and, above all, the increase in the earthworm population under reduced chemical loads (mineral fertilizers, herbicides, fungicides, etc.). Worms mix the soil to a depth of two metres, reaching the underlying loess that contains 25–30% calcium carbonate so a substantial amount of $CaCO_3$ enters the upper layers of soil in worm casts. This natural soil reclamation contributes to self-renewal and self-regulation of soil fertility.

It has been known for a long time that liming contributes to the formation of soil aggregates, coagulates colloids and improves soil tilth and aeration—but there was no scientific explanation. In our view, the combination of lime with organic matter in the form of calcium humates may be explanation enough. Most likely, the benefits accrue indirectly due to improvement in the habitat for earthworms. And earthworms improve soil agro-ecology by forming water-stable structure, improving aeration and water permeability, enriching the soil in humus and nitrogen, inhibiting pathogenic micro-flora and revitalizing beneficial micro-flora.

It needs to be said that progress in agriculture is due not only to the use of fertilizers, ameliorants, pesticides and other chemicals, but also the potential of plants to create soil fertility. Phyto-amelioration is achieved by introducing into the crop rotation acid-tolerant crops that not only withstand the acid reaction but, also, transport calcium from the lower to the upper layers of soil. This is accomplished by perennial grasses and legumes such as lucerne, sainfoin, lupin and soya. Investigation of the structural aggregates of *Podzolised chernozem* showed that the growth of various phyto-ameliorants significantly affects the ratio of differently sized structural units; the highest degree of structure formation was observed under perennial grasses and lupin. The aggregate index, or *structuring factor*, describes the qualitative and quantitative composition of structural aggregate according to the formula:

$$K = A/B$$

where K is the structuring factor; A—the amount of macro-aggregates (0.25–10 mm)%; B—the amount of aggregates <0.25 and clods greater than 10 mm, %.

The structuring factor in upper 20 cm of the soil after 2 years phyto-amelioration was 8.3 under lucerne, 7.3 under lupin and 7.2 under sainfoin. This effect was due to the ability of the root system to ramify deep into the soil and lift calcium from the lower horizons, as well as the adding organic matter, which serves as a natural glue for soil aggregates (Sokolovskyi 1971; Williams 1949).

Phyto-ameliorants also increase the water resistance of soil aggregates: the greatest water resistance in the 0–20 cm layer after 1 year phyto-amelioration was achieved by sainfoin—0.9 compared with 0.6 under the control; under perennial grasses, the maximum value was reached in 20–40 cm layer coinciding with the greatest root mass. As well as perennial grasses, the annual Sudan grass (*Sorghum Sudanese*) is unrivalled in adding organic matter to degraded soils through its root system.

Conclusions

1. Compared with traditional liming practice, application of technology for *local cultivation* of acidic soil can reduce nutrient losses from leaching: lime by almost six times, soluble organics and nitrate by 1.8 and 2.9 times, respectively.

2. Increase in the population of soil organisms in *Podzolized chernozem* through liming activates self-renewing and regulating processes, thereby improving the agro-ecological condition of the soil.
3. Perennial grasses, legumes and Sudan grass are effective phyto-ameliorants. Their beneficial effects are complex but are displayed through resilient soil aggregates and the accumulation of organic matter.

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