AGRICULTURAL SOILS IN EUROPE – SPECIAL DEMANDS RELATED TO INTENSIVE AGRICULTURE IN AN INDUSTRIALIZED ENVIRONMENT

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Summary

Europe is characterized by mostly fertile soils under intensive agricultural use. The capacity of soils to sustain food production is very high. However, some of the actual soil uses endanger soil fertility and the quality of food and drinking water. Efforts to limit soil degradation and the remediation of degraded sites are ongoing all over Europe since further increase of soil degradation is expected.

A high level of fertilization causes excessive nutrient saturation of soil. Although yields increase with increasing nutrient content, the quality and health of plants tends to decline. Nutrients are leached from soil to water, causing eutrophication. Agrochemicals, e.g. pesticides, help to ensure high yields and product quality, but may also detrimentally influence the environment. While effects on soil are mostly limited to reversible inhibition of soil biota, unwanted translocation into food plants and especially water endangers food quality. The intense use of heavy machinery has dramatically increased soil compaction and erosion in Europe.

Land conversion for urbanization, industrialization and traffic leads to considerable and increasing soil sealing. In addition, emissions from industry, domestic heating and traffic affect soils even in remote regions via atmospheric deposition. In recent decades the content of numerous pollutants considerably increased in agricultural soils of Europe. The input of acidic substances has caused a strong acidification especially of forest soils, resulting in soil and forest degradation.

To overcome the obvious problems, legal regulations were established by the European nations, and a turning away from industrialized modern agriculture towards more sustainable land has been ongoing for some years.

Collectivized and thus industrialized agriculture in the Eastern European countries under socialist government resulted in similar environmental damage. Since the political transition in the early 1990s, agriculture is being re-organized in these countries, resulting in opportunities for sustainable land use but also in problems related to capital shortage and insufficient supply of goods.

1. Introduction

The European continent has a land surface of 10.5 million km^2, of which 55% is agricultural land and 25% is under forest. In 1995, 57% of the farmland was arable land, 35% permanent grassland, and 8% perennial crops. Europe consists of 45 independent states, 16 within the European Union (EU). A cool moderate climate prevails, with polar to subpolar conditions in the far north to warm moderate subtropical climate in the south. Eastern Europe and the central part of Spain is characterized by continental steppe climate; the Mediterranean area exhibits summer dryness. The islands and large coastal areas have oceanic climate conditions.

Among the major soil types under agricultural use are ferralic Cambisols and chromic Luvisols in the Mediterranean countries. Cambisols predominate in northern Europe, Luvisols and dystric Gleysols prevail in western and central Europe. These regions are separated from the Chernozems and mollic Gleysols mainly found in the central and southern parts of eastern Europe by a belt characterized by Phaeozems. The very south of Russia and central Spain is dominated by Kastanozems. Average soil fertility is high. Limitations are cold temperatures and a short vegetation period in the north and limited water supply during the vegetation period in the south and south-east.

Agricultural productivity is very high, especially in the member countries of the EU. In most states the degree of self-sufficiency is larger than 100%; most European countries export agricultural goods. Significant imports are fruits, and animal feeds by countries specialized in animal production like Belgium and The Netherlands. The degree of mechanization is mostly high, although the average size of farms is below 40 ha. Only in eastern Europe, due to former collectivization, farms sizes are much bigger.

Large parts of Europe are among the most densely populated and industrialized areas of the world. Average population density is 83 inhabitants km^{-2}. Thus, soils are intensively used and have to fulfill a multitude of socioeconomic and ecological demands, e.g. plant production, a source of ground and drinking water, area for settlement and recreation. Over-intensive use of soils by modern, in some cases even industrialized farming and

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inputs from traffic, households and industry often impose too heavy a burden on the buffer, filter, and transformation functions of the soil, resulting in contamination of the food chain and/or groundwater, as well as the destruction of plant and animal species. A high degree of mechanization in agriculture results in increasing soil compaction. These problems are now widespread at continental level as industrialized agriculture has spread to regions with less fertile and more vulnerable soils, such as the Mediterranean area.

The main problems for soils in Europe are irreversible erosion losses (mainly in the Caucasus, south and central Europe) and soil sealing caused by urbanization and infrastructure development (mainly in western and northern Europe) as well as point and diffuse contamination. Approximately 4 million ha farmland are subject to soil salinization. The incremental loss and deterioration of Europe's soil resource is expected to continue, and will probably increase as a result of climate and land-use changes. From the European Environmental Agency it was estimated that 220 million ha of soil in Europe (11% of the degraded soils worldwide) are degraded due to one or several of the above mentioned processes.

It must be stated that soil degradation is not a problem exclusively related to Europe; indeed it is an even bigger problem in other areas of the world. However, in a densely populated continent like Europe the loss of fertile soil and its functions within the ecosystem cannot be compensated by easily shifting to virgin land.

2. Soil Changes Caused by Intensive Agriculture

2.1. Fertilization

Many soils in Europe exceed the nutrient status required by plants due to high mineral and even higher organic fertilizer inputs. About 30% of municipal sewage sludge is spread onto agricultural land. In recent decades plant and animal production became increasingly separated, leading towards an industrialized, land-independent animal production. Consequently, animal feed is imported into such farms, while excreta cannot be recycled on-site according to the nutrient demands of soils and plants. In the worst case, soils are abused as dump sites for excessive loads of manure or sewage sludge. Although fertilizer consumption slightly decreased during the last decade, nutrient loads from agricultural sources remained high, particularly in northern parts of western and central Europe, where livestock production is intensive. In 1992/93 the excess fertilizer application, above the requirements of the crop, added to agricultural soils in Germany amounted to 118 kg N ha^{-1} and 8 kg P ha^{-1}, with large regional differences.

Both N and P are essential elements for plant growth, but excesses are hazardous. An accumulation leads to the saturation of soil exchange sites and leaching or run-off from the soil to ground- and surface-waters, where it causes eutrophication. Numerous aquifers have nitrate concentrations above the EU limit for drinking water of 50 mg NO_3 l^{-1}. It was estimated that 90% of this nitrate load originates from agriculture.

Low CEC and high hydraulic conductivity of soil promote the transport of nutrients from soil to groundwater. Especially N from readily soluble nitrate or ammonia fertilizers is rapidly leached from soil because it is only weakly sorbed. From the P applied to soil with fertilizer, on average 40% is not used by plants but is retained in the soils. This portion is potentially susceptible to translocation. P input into surface waters mainly stems from run-off, erosion and drainage of fertilized soils. Recently reclaimed wetlands are suspected to be considerable sources of leached P. Huge areas of marshland and moorland in particular in northern European countries were drained in past centuries and converted to agricultural, fertilized land. After re-wetting to restore these moors, a remobilization of P is observed.

An excess of nutrients also affects plants and food quality. Plants become more susceptible to pathogens, especially fungi, lodging of grain increases, and the storage quality and taste tend to decline. Nitrate, which is particularly hazardous to young children, becomes enriched. On the other hand, the content of valuable essential amino acids and protein also increase in grain receiving excessive nutrient supply.

However, while the environment and food quality are negatively affected by a nutrient surplus, this is not true for the soils themselves. When soils were treated with increased amounts of livestock manure, combined with additional mineral N, P and K in long-term field trials, highest yields were obtained from the plots with the highest fertilizer amendment. However, returns to additional fertilizer were low and only a combination of manure and mineral fertilizer resulted in a 4 to 10% higher yield. Thus, mineral fertilizers cannot compensate for the improving effects of organic manure on soil fertility. The addition of mineral fertilizer and solid manure increased soil pH and soil organic matter (SOM) by up to 20 mg C g^{-1} soil. The SOM was enriched in lignin, fatty acids, aliphatics and organic N-compounds, reflecting the higher activity of the soil biota. An excessive nutrient content affects organisms in that flora and fauna adapted to low and moderate nutrient content are replaced by other species.

Fertilizers not only contain nutrients but also pollutants. Mineral phosphates may contain more than 70 mg Cd kg^{-1} (see Table 1). In central and western Europe about 4 g of Cd ha^{-1} yr^{-1} enter the soils via mineral phosphate fertilizers, while only 200 mg of Cd ha^{-1} yr^{-1} are withdrawn by plants. On a national scale, limit values exist for various heavy metals in mineral fertilizers but differ among the states and types of fertilizer. Pig manure often contains considerable amounts of Cu and Zn from feed additives. Sewage sludge and waste compost may contain heavy metals, PAHs, dioxins and polyhalogenated hydrocarbons. Therefore the maximum content of contaminants in sewage sludge and compost and the maximum amount spread onto fields per time period are regulated (see Table 1). In contrast, in most countries no such regulations exist for manure. Recently, pharmaceuticals like antibiotics and hormones given to livestock and humans were recognized in manure and sewage sludge applied to soils. It has been estimated that up to kilograms of antibiotics per hectare may annually enter agricultural soils and a concentration level similar to that of pesticides is easily reached. Additionally, pathogens, excreted from livestock and humans, can reach the soils via manure and sludge. These compounds and organisms might affect soil fertility and reach the food chain. However, knowledge about their environmental behavior is scarce.

When the concentration of pollutants in soil reaches trigger values below the limit values, the further input of pollutants, e.g. via fertilizers, is legally restricted in several

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countries. Land exceeding soil limit values for pollutants must not be used for further agricultural production. If not arranged otherwise, the farmer is liable for the damage and the subsequent required measures, e.g. soil remediation. However, legislation is mainly aimed at inhibiting the exceeding of such concentration limits. Rules for good agricultural practice were enacted that demand the balancing and recording of nutrient input through fertilization and uptake by plants, as well as the control of pollutant concentrations to protect soils, ground- and drinking-water.

Element	Soil	Sewage sludge	Bio-waste compost	Pig slurry	mineral P Fertilizer	
					Origin	Cd content
Cadmium	0.4-1.5[b]	5-10	1	0.6-1.3	USA	8
Lead	40-100	900	100	40-80	North Africa	19
Copper	20-60	800	70	60-90	Central Africa	70
Nickel	15-70	200	35	20-60	South Africa	3
Zinc	60-200	2000-2500	300	400-500	CIS	< 1

[a] according to the Klärschlammverordnung (sewage sludge regulation) and Bioabfallverordnung (bio-waste regulation) of Germany

[b] concentration limits vary with soil texture (sand, loam, clay)

[c] new and not yet enacted German concept for regulatory limits in manure

Table 1. Regulatory limits for heavy metals in soil and typical values for the heavy metal content of sludge and compost, and the cadmium content of different P fertilizers (mg kg^{-1}).

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The following internet-sites provide information on soils and soil degradation in Europe:

European Union: http://europa.eu.int

European Environment Agency: http://www.eea.eu.int

The Association for the Environmental Health of Soils (AEHS): http://www.aehs.com

Biographical Sketch

Sören Thiele-Bruhn was born in Kiel, Germany. He obtained his diploma in agricultural sciences at the University of Bonn, Germany, in 1992. From 1992 to 1997 he was a scientific employee at the Institute of Soil Science, University of Bonn. Working on “Polycyclic Aromatic Hydrocarbons in polluted Soils – Investigations on the Characterization, Optimization, and Prognosis of microbial PAH degradation and of the fraction available to plants” he obtained his Ph.D. in 1997. Dr. Thiele-Bruhn was granted a postdoctoral fellowship at the Pennsylvania State University from 1997 to 1998, carrying out research on TNT transformation and fixation in soil using labelled compounds and NMR spectroscopy. Since 1999 he has been working as a scientific assistant at the Institute of Soil Science and Plant Nutrition, University of Rostock. There, he is head of the group “Soil Biochemistry” with special focus on the fate and effects of antibiotic pharmaceuticals in soil. He gives courses in general soil science, soil ecology and soil protection, soil biology, and environmental analysis.

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