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Threats to the Soil Resource Base *of* Food Security in China and Europe

A report from the
Sino-EU Panel on Land and Soil

Gergely Tóth and Xiubin Li (eds.)

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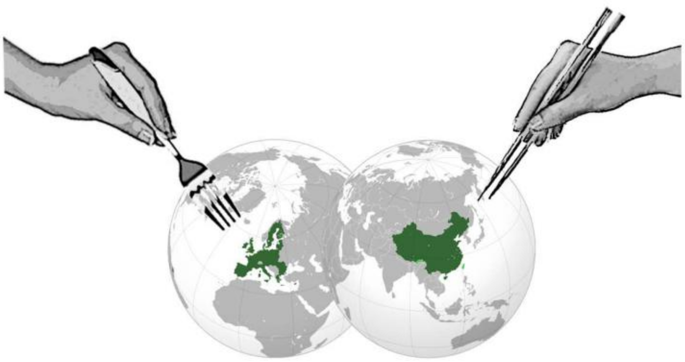

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Institute for Environment and Sustainability

Contact information
Gergely Tóth
Address: Joint Research Centre, Via Enrico Fermi 2749, TP 280, 21027 Ispra (VA), Italy
E-mail: gergely.toth@jrc.ec.europa.eu
Tel.: +39 0332 786483
Fax: +39 0332 786394

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AUTHORS

Mariam Akhtar-Schuster	University of Hamburg, Hamburg, Germany
Winfried E.H. Blum	University of Natural Resources and Life Sciences, Vienna, Austria
Chunyuan He	Southwest University, Chongqing, China
Arwyn Jones	European Commission Joint Research Centre, Ispra, Italy
Tamás Kismányoky	University of Pannonia, Georgikon Faculty, Keszthely, Hungary
Xiangbin Kong	China Agricultural University, Beijing, China
Xiubin Li	Institute of Geographical Sciences and Natural Resources Research Chinese Academy of Sciences, Beijing, China
Guobin Liu	Institute of Soil and Water Conservation, Chinese Academy of Sciences, Yangling, China
Luca Montanarella	European Commission Joint Research Centre, Ispra, Italy
Stephen Nortcliff	University of Reading, Reading, United Kingdom
Renfrang Shen	Institute of Soil Science, Chinese Academy of Sciences, Nanjing, China
Gergely Tóth	European Commission Joint Research Centre, Ispra, Italy
Jianbing Wei	Guangdong Institute of Eco-environment and Soil Sciences, Guangzhou, China
Zhifeng Wu	Guangdong Institute of Eco-environment and Soil Sciences / Guangzhou University Guangzhou, China
Qingyuan Yang	Southwest University, Chongqing, China
Bo Zang	Southwest University, Chongqing, China
Ganling Zhang	Institute of Soil Science, Chinese Academy of Sciences, Nanjing, China

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1. Introduction

Luca Montanarella

Following the 2008 food crisis there has been a renewed interest in global soil resources for food security. Addressing the fundamental question: "Is there enough soil for feeding the world population?" has become a priority item in many research organizations and has triggered a number of recent development in soil science as well as in global soil policy and governance. The recognition that the amount of fertile soils available for food production is fixed (ca. 1 600 Million hectare) and that the growing population will have to find ways to survive on a rapidly decreasing amount of per capita cropland (ca. 0.2 ha/per capita) requires to set new research and policy priorities. While on one side we need to increase our per hectare food production by increasing yields especially in developing countries, we also need to start to be concerned about protecting available fertile soil resources for future generation. Irreversible (in human time frames) soil degradation processes, like erosion, compaction, contamination, acidification, etc.… need to be stopped, together with a new approach to land use changes affecting productive soils, like urbanization, infrastructure, etc.… All these considerations have pushed soils up the political agenda, with major initiatives being recently launched by FAO (Global Soil Partnership) as well as by the European Commission (Roadmap for the Sustainable Use of Natural Resources, Guidelines for limiting soil sealing, etc.) Of particular relevance has been the debate at the Rio+20 conference addressing sustainability issues linked with soil and land resources. The proposal by the EU for a binding "Zero Net Soil/Land Degradation" target has unfortunately not been supported by other countries in the world, nevertheless a final agreement on a future "world without land degradation" could be achieved. Indeed stopping the depletion of fertile soils should be a priority for all countries in the world. Urban expansion on prime agricultural land should be stopped and international recognized criteria for spatial planning should be introduced, stimulating urban expansion on unproductive areas and/or recycling abandoned areas and contaminated sites. The EU and China have a leading role to play in this respect. Both in the EU and China fertile soil resources are limited. We need to move forward to protect these resources and reorient economic development towards sustainable use of natural resources, especially limited soil resources. China, as well as Europe, hold some of the most fertile soils in the world. Depleting these soils for urban expansion, housing and infrastructure is totally unsustainable and is pushing more and more for compensating with fertile land in other parts of the world in order to maintain the necessary food production. The recently termed process of "land grabbing" is the ultimate consequence of such unsustainable developments. Searching for fertile land in other parts of the world, especially in developing countries, is posing a sever threat to local populations and may trigger major migratory movements and social unrest. We need to learn how to make the best use of our soils, and this requires the establishment of solid indicators and data for the full assessment of the various soil functions and for making the right choices when deciding for alternative land uses. This is the main focus of the activities of the joint Sino-European Panel on Land and Soil (SEPLS) and the results of its work can become the reference not only in Europe and in China but also in other parts of the world.

2. Socio-economic background, current trends

Xiubin Li

Whilst maintaining agricultural production is still important the emphasis of current soil science is on the sustainable use of soils and limiting or removing the negative effects on other environmental components. This shows that the contacts between soil science and the environment and development issues are becoming more and more close than ever before. In this connection, to provide some insight into the issues of food security and soil resource protection, it is important to have an in-depth understanding of the processes of economic and social development, especially the trends of land-use change.

Europe and China are at different stages of economic development. Europe is a developed region, while China is still in the stage of rapid development. The perspective of a regional comparative study is one way to look into the future. Of course, this kind of study is much more valuable for the developing country in the comparison, but Europe can also benefit from the comparison since there are close food trade links between the two regions.

In recent years, some European scholars in their study of land use change in European and other developed countries, found a general rule in national land use pattern ——forest transition. They found that the forest area increased as the country transformed from a backward agricultural economy to a developed industrial economy. One reason is the out-migration from rural areas caused by the urbanization process. Of course, agricultural intensification and increased productivity in the lowland areas is also a contributing factor. Clearly, agricultural land abandonment or agricultural marginalization in the mountainous areas is exactly the reverse process of forest transition. In the late 1980s and early 1990s, agricultural land marginalization has become a hot topic in the European academic and political discussion.

It seems that agricultural land marginalization in mountain areas has resulted from emigration. A significant reason behind this however is the rise in the price of labor. Lewis (1954) proposed a model to explain the development of an agricultural country to an industrial one. In his model, the pre-transition economy is seen as a "dual economy" where agricultural and industrial sectors are independent of each other. In such a "dual economy", there is a lot of surplus labor in the backward agricultural sector, flowing to the high-wages' industrial sector in the process of economic development. In this case, the agricultural sector has to improve labor productivity in order to compete for the labor resources with the industrial sector. Farms in the plain have an advantage over those in the mountainous area in the competition of labor productivity growth, because the former can easily use machinery to replace human labor.

Some of the emerging market economies, such as Japan, South Korea and Taiwan, also experienced the same land-use change process in the 1960s and 1970s. The transitions occurred precisely after the Lewis turning point. This provides a perspective for us to observe mainland China's agricultural and land use change. In other words, the urbanization of the population, the price of labor, agricultural labor productivity should be the main focus of this observation.

The urbanization rate of China's population, less than 20% in the early 1980s, has now reached 50% after 30 years of rapid economic development. In accordance with the general laws of market-economy countries, the development of urbanization in the range of 25-75% will experience a stage of rapid development. This means that China will experience another two to three decades before the end the fast middle stage of its urbanization.

A prominent phenomenon accompanied by the rapid urbanization is the transfer of rural labor to the urban industrial sector. The amount of labor engaged in agriculture in the country reached its peak in 1991, and since then has gradually reduced. It had reduced 18% by 2008. Labor economists believe that China experienced the Lewis turning point in 2004. Consequently the wages of unskilled labor have increased significantly faster since then.

The rise in wages promoted the mechanization of agriculture, which can be evidenced by the increasing number of agricultural tractors. The figure for the whole country has increased of 1.5 times in the period from 1991 to 2008. Some 30% of the rise has happened after 2004. An apparent acceleration in China's agricultural labor productivity was observed in 2004 and subsequently. During the seven years after 2004, labor productivity in terms of volume of grain per working unit of labor increased by 75%.

Comprehensive and authoritative statistics on agricultural land abandonment in China are not publicly available at present. But if we look at the government's response on this issue, we can see that farmland abandonment has increased since the early 2000s. For example, on March 30, 2004, the State Council issued an urgent notice "to ask local governments to restore production of the abandoned arable land as soon as possible". In the ensuing years, the General Office of the Ministry of Agriculture issued the command requiring provinces to investigate and report data on abandoned arable land. It is reported that the abandoned land area as a proportion of the total cultivated area was about 6.78% in 2006 in Gansu, a province with a large proportion of sloping farmland.

The continuing increase in labor costs also affects multiple cropping farming. In the era of farmland shortage, the climate-determined growing season was exploited to the limit and consequently multiple cropping was widespread. However, costs of farming for the crops grown in "marginal seasons" were much higher due to a higher frequency of natural disasters. These crops tended to have lower land and labor productivity. In the process of reduction in the size rural labor force, such crops were given up since they cannot support high labor productivity and hence a high wage. In recent years, the land use change from double cropping rice to single cropping rice has been very common in South China, resulting in the decline of the multiple cropping index. The rotation of winter wheat and summer corn (two crops a year) is the main farming system in the North China Plain, but as a "marginal season crop", the sown area of winter wheat in the northern part of the plain has decreased about 17% during past decade.

The agricultural land marginalization discussed above is not a universal phenomenon in China; in fact, farming in some other areas has shown a reversed trend, i.e. intensification. This type of agriculture, including the cultivation of vegetables, fruits and flowers, usually has higher labor productivity and is often located in the suburbs of large cities. During nearly three decades of rapid economic growth and improved living standards, demand for such products has increased quickly. Consequently the rise of the unskilled labor wages is narrowing the income gap between urban and rural residents. It can be predicted that the growth in demand for vegetables and fruits will continue.

In summary, China's current agricultural land use changes show three major trends: marginalization in mountainous areas, extensification in lowland areas, and intensification in the suburbs. In all cases, farming on sloping lands is the main reason for soil erosion. Therefore, the abandonment of mountain slope farmland is undoubtedly a significant contribution to the protection of soil resource. The decline of multi-cropping index may reduce soil pollution from fertilizer and pesticide application in lowland areas. However, the extensive use of machinery is likely to cause soil compaction in these areas. Application of fertilizers and pesticides in the intensive peri-urban agriculture is often higher than for grain farming and has the potential to produce very serious soil pollution.

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Lewis, W. Arthur (1954). “Economic Development with Unlimited Supplies of Labour,” Manchester School, 22: 139-191.

3. Assessment of threats to soil resources

Winfried E.H. Blum

Eight main threats to soils were defined by the European Commission (COM(2002)179 final; COM(2006)231 final and SEC(2006)1165 final): sealing, erosion, contamination, loss of organic matter, compaction, loss of biodiversity, salinisation, and inundations and landslides.

These different threats vary in space and time and can occur in different combinations, e.g. sealing by urbanisation, together with contamination and erosion.

– The main problem is an exact assessment of these threats, in order to take actions against soil losses and degradation, which are endangering food security, including drinking water resources.

For this purpose, within the framework of the soil protection policy in Europe, an approach was developed, using indicators for understanding and managing complex ecological systems, such as soil resources. The basis of this approach is the indicator framework DPSIR, distinguishing between driving forces (D), pressures (P), deriving from these drivers, the state (S), e.g. soil losses or soil degradation, caused by these pressures, the impact (I) of this state, which can be direct or indirect and the response (R), which means actions in order to counterbalance or remediate the losses or degradation, see Figure 1.

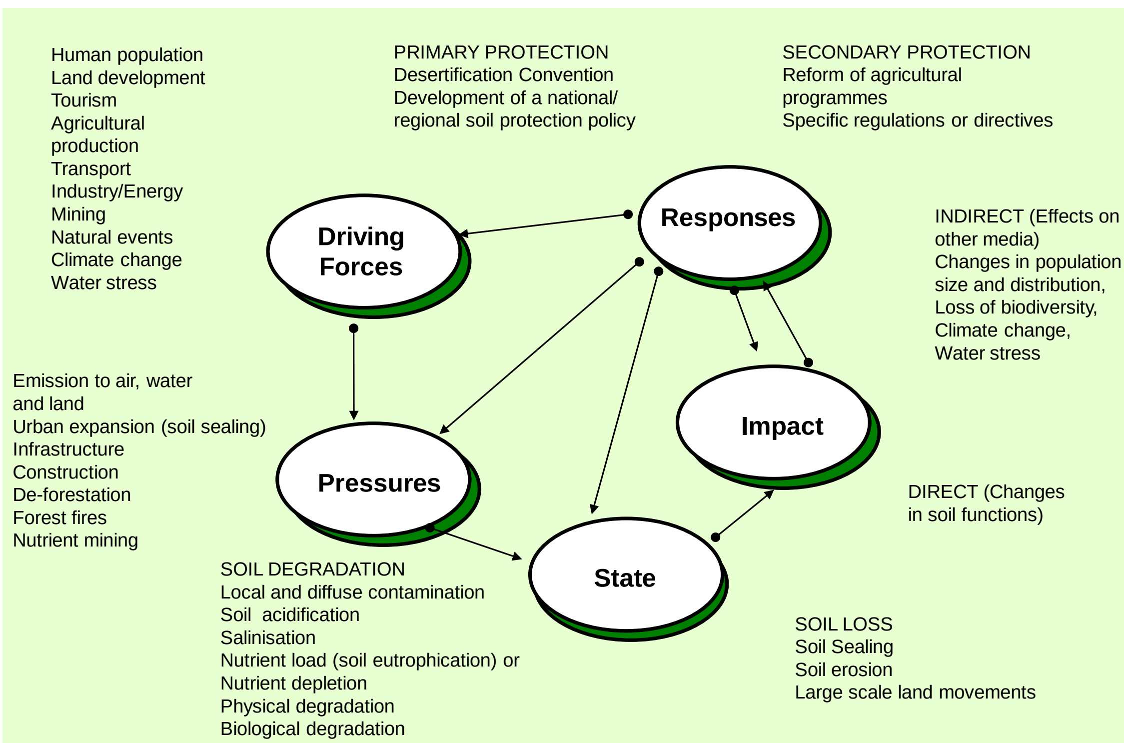

Figure 1. The DPSIR framework applied to soil

Indicators used in this framework must show 4 characteristics:

policy relevant, focusing on the real demands; analytically sound, based on science and revealing a clear cause-response relationship; easy to interpret and understandable at the grass-roots level (stakeholders), as well as for decision makers and politicians; easily measurable and therefore feasible and cost effective in data collection, processing and dissemination.

It was shown that with this indicator framework, it is possible to define the main land management goals, the operational approaches and the sciences, which must be involved in order to be successful (see Table 1).

Moreover, through this approach, the application of new management concepts is possible, including interdisciplinary and multidisciplinary efforts, bringing together technical, ecological, cultural, social and economic aspects. This indicator framework approach can bridge between science and technology on one side and stakeholders, decision makers and politicians on the other side, thus sharing information between those who have it and those who need it.

Table 1. Concept for integrated land management

	MAIN LAND MANAGEMENT GOALS	OPERATIONAL APPROACHES (see Fig. enclosed)	SCIENCES INVOLVED
1	To understand the main processes in the eco-subsystem soil; induced by threats	Analysis of processes related to the 8 threats to soil and their interdependency: erosion, loss of organic matter, contamination, sealing, compaction, decline in biodiversity, salinisation, floods and landslides	Inter-disciplinary approach through co-operation of soil physics, soil chemistry, soil mineralogy and soil biology
2	To know where these processes occur and how they develop with time	Development and harmonisation of methods for the analysis of the **State (S)** of the 8 threats to soil and their changes with time = **soil monitoring** in Europe	Multi-disciplinary approach through co-operation of soil sciences with - geographical sciences, - geo-statistics, - geo-information sciences (e.g. GIS)
3	To know the driving forces and pressures behind these processes, as related to cultural, social, economic, ecological or technical, local, regional or global developments	Relating the 8 threats to **Driving forces (D)** and **Pressures (P)** = cross linking with EU and other policies (agriculture, transport, energy, environment etc.)	Multi-disciplinary approach through co-operation of soil sciences with political sciences, social sciences, economic sciences, historical sciences, philosophical sciences and others
4	To know the impacts on the eco-services provided by the sub-system soil to other environmental compartments (eco-subsystems)	Analysis of the **Impacts (I)** of the 8 threats, relating them to soil eco-services for other environmental compartments: air, water (open and ground water), biomass production, human health, biodiversity	Multi-disciplinary approach through co-operation of soil sciences with geological sciences, biological sciences, toxicological sciences, hydrological sciences, physio-geographical sciences, sedimentological sciences and others
5	To have operational tools (technologies) for land management available	Development of operational procedures for the mitigation of the threats = **Responses (R)**	Multi-disciplinary approach through co-operation of natural sciences with engineering sciences, technical sciences, physical sciences, mathematical sciences and others

W.E.H. Blum and J. Büsing, 2004

4. The impact of urbanization and infrastructural development on land resources

4.1. Background

Xiubin Li

Urban sprawl is an inevitable result of economic industrialization and population urbanization. Excessive urban expansion has brought many negative impacts to the environment and health. In this process, the loss of agricultural land resources is an important issue because it is directly related to food security. Especially in the densely populated Europe and China where land resources are already in short supply, the loss of farmland to urban sprawl is undoubtedly the focus of food security policy.

Since the 1950s, European population has grown by more than 30 percent, whilst the population of European cities has grown by 80 percent. At the same time, the urbanization rate of the population continues to grow. Especially in Central Europe, the rate increased from 50% to 70% in the last 3 decades. During the past three decades, China's urbanization speed is unprecedented, the urbanization rate increased from 20% to 50%. It means that the urban population increased by 400 million.

The Chinese official statistical data show that urban sprawl has speeded up since the early 1990s. The average annual increase of built-up land was about 351,000 ha in the period from 1991 to 2008, representing an average annual increase of 1%. After China's accession to the WTO (World Trade Organization) in 2001, the speed was even higher, as much as 384,000 ha per year in the period from 2002 to 2005.

Urban sprawl has occupied a large area of farmland. Some 3.27 million ha of farmland was converted to built-up land since the early 1990s according to the official statistical data. It is estimated, based on the official data, that farmland contributes 53% of the new built-up land. Some 182,000 ha of farmland is lost every year due to urban sprawl. But many scholars believe that the official data underestimate the actual loss of farmland. Based on a national land survey using remote sensing technologies it was found that farmland contributed 60 to 80% of built-up land expansion in the 1990s.

Cities are usually developed on flat land. As a result, the land occupied by urban expansion is generally good quality arable land, whose productivity is generally much higher than those in remote areas. A comparison of the productivity of the farmland lost to urban sprawl and the newly cultivated land in the period from the mid 1980s to the mid-1990s, indicates that in terms of grain yield per unit area the former is about 70 percent higher than the latter.

Future expansion of urban land and the occupation of cultivated land depend on the development of the urbanization of population. Although the level of urbanization in Europe as a whole is currently 75 per cent and will reach its matured level soon, the rapid urbanization process in Central and Eastern Europe has not been completed. In accordance with the general laws of market-economy countries, urbanization will usher in a period of rapid development when the urbanization rate is in the range of 20-75%, as is so called the accelerated middle stage of urbanization. This means that China will probably experience another two to three decades before the end of the accelerated middle stage of its urbanization. On the other hand, the scale and speed of urban expansion are highly differentiated spatially. In this connection, in-depth understanding on this issue will undoubtedly need regional case studies. This section will discuss in detail the urban sprawl in Central Europe and in the more developed eastern city group and the western city group in China where development is just beginning.

4.2. Case studies

4.2.1. An analysis of arable land loss influenced by urbanization: A case of Chongqing

Qingyuan Yang, Bo Zang and Chunyan He

Effective protection of arable land resources is essential to food security and economic development, but at present, loss of arable land is primary major concern. This paper will use relevant data about the urbanization of Chongqing and the changes in cultivated land area between 2000 and 2010 to illustrate the arable land loss resulting from urbanization through three aspects: land urbanization, population urbanization and industrial structure urbanization, and seek to provide guidance for the healthy development of regional urbanization and the improvement of policies for arable land protection.

Study regions

Chongqing is one of the four municipalities[1] of China, located on the upper reaches of the Yangtze River in the southwest of China, with an area of 82.4 thousand square kilometers, about 0.86% of the county. 94% of the total area is mainly hilly and mountainous. Divided by Yangtze River and Jialing River, the central urban districts are famous as "landscape municipality " in China. The arable land acreage is 24.44 thousand square kilometers in 2010, which is 0.074 hectare (ha) per capita, less than national average of 0.106 ha. 95.30% of the total arable land is sloping land, and in particular the area of land with slopes of 15°is 48.20%, and over 25°is 16.10%. It can clearly be seen, scarcity and poor quality are the main characteristics of the arable land in Chongqing.

Chongqing, situated at the junction between the eastern developed region and the western undeveloped region of China, is in a significant strategic position in China. Based on the survey data of the 6th population census which was put out in April 28, 2011, the resident population of Chongqing is 28.8 millions, contributing 2.42% of the total population of China, and the urban population is 53.00% of the total population. In recent years, Chongqing has been one of the fastest developing regions in China, and GDP per capita reached 4000 dollars (4028.57 dollars) in 2010. Chongqing is very extensive, with two obvious different types of area based on socio-economic level and urbanization (Fig.1): one was called "one-hour economic circle", and the other was called "the two wings". The former includes central urban districts and its surrounding areas, which are the key areas with good development conditions and great potential in broad terms in the long run; the latter includes northeast and southeast of Chongqing, with a large agricultural population.

[1] four municipalities refer to Peking, Shanghai, Tianjin and Chongqing.

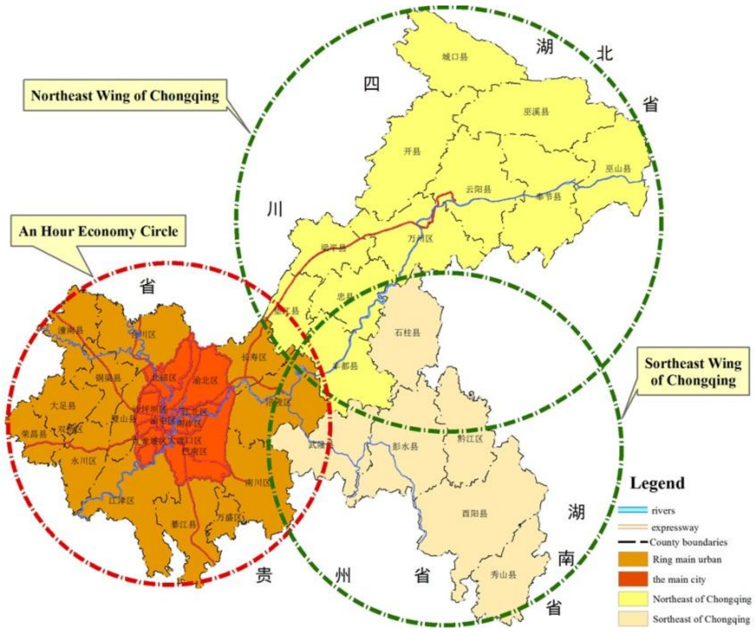

Figure 1. The spatial pattern of Chongqing: one circle and two wings

Promoting urbanization must not only consider the three core strategies urbanization, industrialization and urban-rural unification in Chongqing but also the important measure to realize the harmonization of urban-rural development. Three aspects illustrate the future development strategies for Chongqing' urbanization based on the requirements put forward in *the "twelfth five-year" program outline of Chongqing economy and social development*: firstly, to promote the construction of an urban system based on the development model called urban agglomerations with metropolis, which is connected with organic cohesion, coordinated complementary, so that it can absorb many more rural laborers; secondly, speed up construction of six central cities, and make full use of their leading role in the construction of a new pattern in which metropolis drives urban and the urban drives the rural areas. Thirdly, promote the construction of municipal central towns, and enhance the driving function of central towns to promote the urbanization of the whole area.

Methods and data source

Methods

The core to the urbanization is the transfer process of the structures of employment, economic industry and urban-rural community[1].The process of urbanization can be shown in three aspects: the land urbanization or space urbanization, which represents the expansion of the urban space (expressed by the supply of construction land, the supply of increment urban land especially); the population urbanization (rural to urban migration), and will measure it with the ratio of non-rural population and urban housing area per capita, and the third one is urbanization of industrial structure, as is shown through the transfer of production factors such as capital and labor force from agricultural industry to non-agricultural industry, and which is comprehensively reflected by the share of secondary and tertiary industrial output value in GDP, the share of secondary and tertiary industrial output value, and the number of industrial enterprises above a designated size, and then measure the arable land loss affected by urbanization based on the correlation analysis among each indicator with the quantity of arable land.

The central urban districts in Chongqing are the regions of concentrated primary population and manufacturing in the process of urbanization, which also have a great effect on the arable land loss. This research will describe the arable land loss influenced by urbanization in two perspectives: the expansion of urban land and the direction of expansion, measured with the velocity, intensity and direction of urban land expansion, using the formulas as follows:

$$V = (UA_{t+i} - UA_i)/t \qquad (\textit{Equation } 1)$$

$$Q = ((UA_{t+i} - UA_i)/tUA_i) \bullet 100\% \qquad (\textit{Equation } 2)$$

$$DMI_t = (L_t - L_i)/L_i \qquad (\textit{Equation } 3)$$

$$Ne = (S_t - S_i)/(UA_t - UA_i) \qquad (\textit{Equation } 4)$$

In the Equations, V stands for the velocity of urban land expansion, UA_{t+i} and UA_i stand for the urban land area in the year of $t+i$ and the year of i respectively, and t stands for time with a year as the unit. Q stands for the intensity of urban land expansion, DMI_t stands for azimuth indicator in some direction at the time of t, L_t stands for the length of an azimuth axis, and the L_i stands for the longest azimuth axis in the plane form of the municipality at the time of i. Ne stands for the ratio indicator of the direction of space expansion, S_t and S_i respectively stands for the area in a certain direction at time of t and i, while UA_t stands for the urban land area at the time of t.

Data sources

The data in this paper are in four broad groups. Firstly, arable land area comes from the survey data of land use change in Chongqing among the years from 2000 to 2008, the data of the second national land investigation, and the land use change survey based on the second national land investigation. Secondly, the data of land supply is based on the statistical data of 40 districts and counties from 2000 to 2010 by Chongqing Municipal Land Resources and Housing Administrative Bureau. Thirdly, the expansion data of construction land is based on the supply data of urban construction land from 2000 to 2010, while the data for space urbanization uses the decoded data through RS images from Landsat5TM which were taken in September 23th 1995, September 16th 1999 and September 18th 2010, with all the images adopting UTM projected coordinate system. Lastly, each indictor for urbanization comes from *Chongqing Statistical Yearbook* 2001-2011.

The effect of land urbanization on arable land loss

With the rapid urbanization of Chongqing during the years from 2000 to 2010, land supply for urban construction was phasic increasing, which has increased the pressure on arable land protection. From the year 2000 to 2010, urban construction land supply growing rapidly and along with large fluctuations. On the whole, the supply increased from 14.65 km^2 in 2000 to 106.79km^2 in 2010. On average, the amount of the supply during "The Tenth Five-Year" differed significantly from "The Eleventh Five-Year", with the former 31.39 km^2 while the latter rising to 70.15km^2. According to the research of the *Twelfth Five-Year Plan for Chongqing state-owned construction land supply*, during the "Eleventh Five-year" period, the land supply was predominated by increment; the newly-increasing construction area was 208.59 km^2; the stock of urban land was 190.11km^2; the increment quantity was 52.30% of the total land supply; it had totally caused an arable land loss about 144.68km^2.

Whilst urbanization is advancing, both the speed and the intensity of the urban land expansion have been accelerating greatly. In different periods of time, land expansion is the comprehensive performances of plural driving factors that are promote multiple cities extended in space [2]. Tab 1 shows, in years 2000-2010, land use in central urban districts of Chongqing has increased by 234.93km^2, which is equivalent to 50% of the whole municipality of 1995 (In 2000, the construction land area in central urban districts was 419.22km^2) with an expansion rate of 26.10km^2/a and an expansion intensity index of 14.75%.

Table 1. Land expansion of the main districts during 1995-1999 and 2000-2010

	Expansion area（km^2）		Expansion rate（km^2/a）		Expansion strength（%）	
year	1995-1999	2000-2010	1995-1999	2000-2010	1995-1999	2000-2010
value	72.66	234.93	12.11	26.10	11.61	14.75

Urban land expansion inevitably leads to the loss of arable land. From 2000 to 2010, the construction land of Chongqing was in a period of rapid expansion, resulting in a decrease in arable land year on year with an annual reduction of 364.49km^2 (Tab 2), and there are distinct patterns. The years 2002-2003 show an annual reduction of 1526.92km^2 and years 2004-2008 an annual reduction of 59.00km^2. It can be seen that arable land loss was dramatic in the years 2002-2003. One of the reasons is the increase of land supply. Land supply of the whole municipality rose from 13.41km^2 in 2001 to 30.28km^2 in 2002, and the built up area increased from 559.89km^2 to 654.95km^2. So the scale of expansion, to a certain extent, caused arable land loss. The second reason was the "policy of Grain for Green", which was the primary factor of sharply loss of arable land during the year 2002-2003. In order to prevent the destruction of vegetation, soil erosion, and other adverse consequences caused by the rapid urbanization, Chongqing started the project of "Grain for Green" in 2002. In 2002 and 2003, the amount of arable land loss from this project accounted for 88.76% and 88.96% of the total arable land loss [3]. After 2004, great importance was attached to the transform of urbanization—the shift from the mode of extensive development to the mode of intensive development, which made the stock construction land—the existing state-owned building land—fully utilized, the supply of stock construction land accounted for 64.84% of the total in 2007, and 56.71% in 2008, curbing the trend of the rapid loss of arable land in the years 2005-2008. In 2009-2010, to ensure land was available for a large number of major construction projects such as "Liangjiang New District"—a new development area built by the Central Government of China in

2010, land supply increased, which is 71.75% of the total in 2009 and 76.69% in 2010, causing arable land loss subsequently.

Table 2. Arable land decrease and construction occupation during 2000-2010

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Decrease (km^2)	116.6	289.1	1632.1	1421.7	90.1	55.5	50	48.8	50.3	10.3	151.5
Occupation (km^2)	24.9	61.7	37.	56.2	12.6	9.9	8.9	29.2	24.6	50.3	16.4
Rate (%)	21.3	21.3	2.2	3.9	14	17.9	17.8	59.8	49	48.7	10.8

The proportion of abandoned arable land used for construction during the years 2000-2010 has shown “three stages”, in which the years 2000-2001 was the slow decrease stage, the years 2002-2003 was stage of slowly use and the years 2004-2010 was a period of rising stage. After Chongqing became one of the municipalities in China, the Three Gorges Reservoir construction and immigrant relocation took up much arable land, besides, the urbanization effect began to show, so the share of arable land taken up by construction was constant at 21.36% in years 2000-2001 (Table 2). In years 2002-2003, due to the strengthening of the land consolidation, the share reduced significantly. In years 2004-2010, this proportion hasrisen gradually, due to some major construction projects such as “University Town”, which occupied arable land on the outskirt of the municipality.

Expansion effect of orientation on arable land loss

The arable land loss is influenced by the amount of the expanded urban as well as the direction of its extension. For example, if the geometric center of the central urban districts of Chongqing in 1995 is taken as the origin (Fig.2), the east-west direction as the horizontal axis, north-south direction as the longitudinal axis, it is possible to divide the municipality into 8 quadrants regions (E, NE range area as first quadrant, counterclockwise ranked 8 quadrant regions), and overlay this on the map of urban spatial distribution in different time periods (Fig.3, Fig.4).

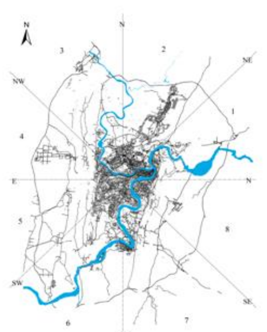

Figure 2.
Built up areas in 1995

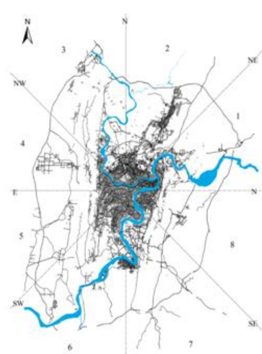

Figure 3.
Built up areas in 1999

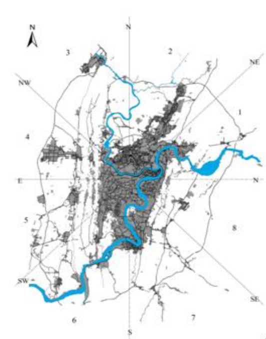

Figure 4.
Built up areas in 2010

In different periods, the amount of urban expansion in different quadrants is different, showing the characteristic of disequilibrium. From 1995 to 1999, the largest extended range was in first quadrant and second range, followed by the third direction of the second quadrant, and they were 16.04km^2, 10.75km^2 respectively. The smallest one was in the fourth range of the second quadrant, and its acreage is 5.22km2, accounting for 7.19% of the increase of urban land at the same period. Early in the development of the municipality of Chongqing, the main axis of expansion of the central urban districts was “north-southwest". From 2000 to 2010, the largest extended range was in the sixth range, increasing by 55.43km^2 and accounting for 23.59% of the increment of central urban districts at the same period, and the growth rate is 6.16 km^2/a. The smallest extended range was in the eighth range, and it was 9.50km^2 with the growth rate of 1.06 km^2/a.The expansion of the urban land in the central urban districts generally appears like an extension of the pattern of “southwest -northeast" (Fig. 4). This resulted from two factors: on the one hand, it comes from the constraint of topographic condition of nature, the central urban districts lie in the valley with the mountains to the north-east, and the other side by the Yangtze, Jialing River, determining the extended direction of “southwest-northeast”. On the other hand, it is the outcome of the scale of industrial drive. On the other hand, it is the outcome of the scale industry drive. The development and construction of Liangjiang New Area, the sustainable development of Northern New Area, the establishment of airport industrial park and bonded port of the Cuntan area, conduct the increasing speed of the expansion of urban land use in north district of central urban districts. The construction of College City in Shapingba district and the sustainable development of The West Wing microelectronics Park and garden area of Nan’an district expand the pace of the development in west and south of central urban districts, and lead the urban to expand from the direction of “southeast-northwest”.

From 1997 to 2010, the quantity of arable land occupied by construction land in each district or county showed obvious spatial differences. The larger amount of arable land occupied by construction land was concentrated in the southwest and northeast of the central urban districts. The loss of arable land in these districts constituted 73.16% of the loss of the whole municipality. This exactly matches the influence of urbanization of the central urban districts. Chongqing is a typical landscape municipality, and the share of sloping land in the urban development area will increase, while the condition of the remaining arable land will get poorer with lower fertility, there is the phenomenon of both quantity and quality falling together.

The effect of population urbanization on the arable land loss

The amount of arable land decreased in the reversed "S" shaped curve year by year between 2000 and 2010, and it was divided into three stages (see above). According to Fig.5, the trends of the arable land loss clearly show these three stages in the periods between 2000 and 2010. (1) Slow decrease stage (2000-2001). At that stage, Chongqing had just become a municipality. Although the Central Government provided some special policies and significantly enhanced capital input, the growth rate of urbanization was still low and the rate of arable land area declined by 15.00%/a. (2) Rapidly decline phase (2002-2006). With the rapid economical development, the municipality's urban population and urban housing area per capita entered a period of rapid growth in 2002, which significantly reduced the amount of arable land by an annual average decline of 23%. (3) Steady lowering stage (2007-2010). The main reason causing a steady decrease in the use of the arable land was the connotative development of the municipality's urbanization and the rising ratio of the supply of stock construction land

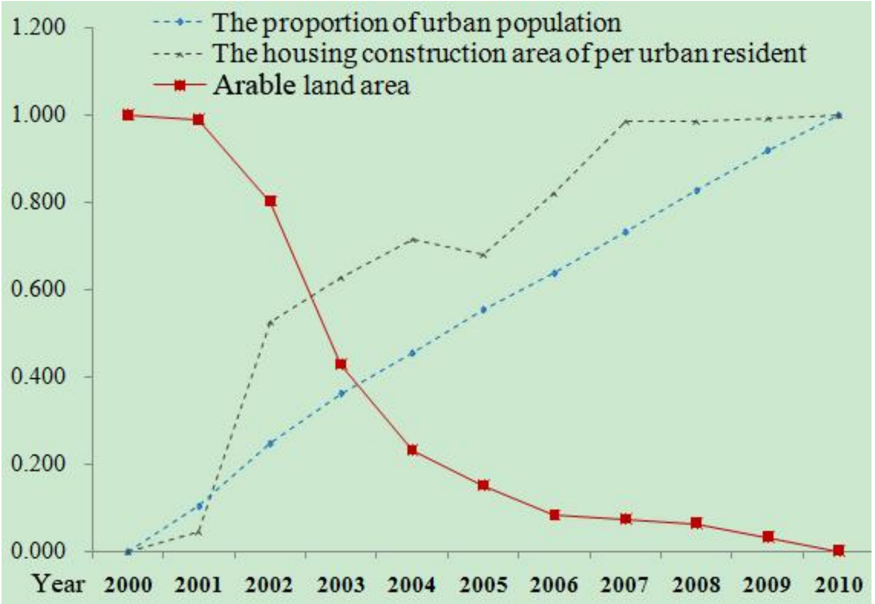

Figure 5.Relationship between population urbanization and the amount of arable land

The data of vertical axis in the above figure is the result of standardization. The standardized method is minimum and maximum standardization. Standardization data= (raw data - minimum) / (maximum - minimum)

Urban population ratio and the urban per capita housing construction area have a significant negative correlation with the amount of arable land. The correlation coefficient of urban housing construction area per capita and the amount of arable land was -0.954 and -0.939 respectively with the quantity of arable land, and the significant probability value was 0.000, which meant they had a significant correlation with the amount of arable land (correlation coefficient > 0.95). The trend of the urban population ratio and the urban housing construction area per capita, the annual increase of those two indicators being 4.34% and 14.10%, were in opposite directions compared with the amount of arable land decreasing trend The annual increase for the supply of incremental construction land—the amount from conversion of agricultural land to construction land—for the same period was 68.47%, which would increase the tension of the land expansion for the existing urban construction, resulting in the continued loss of arable land.

Population flows and the spatial differences of the urbanized population will also affect the arable land loss. The average reduction of arable land is used to show the arable land loss rate and the average rate of the proportion of urban population shows the population urbanization rate. During the period 2000 to 2005, the area of arable land decreased fastest in the central urban districts, followed by the northeast area (Tab 3). The growth rate of the urbanized population was most rapid in the central urban districts (5.78%), followed by the surrounded areas (4.34%), but urbanized population of the "two wings" areas had a strong marginal effect on the arable land loss, in which the northeast area was stronger than the southeast. For the northeast, when the urban population increases by 0.22 percentage point, the amount of arable land decreased by 1 percentage point. At this stage, the driving force of economic and social development was mainly concentrated in the "one-hour economic circle". The development model of the urbanized population in the "two wings" is still unreasonable due to the lack of funding input and supporting policy, and meanwhile it has occupied a lot of arable land.

Table 3. Relationship between arable land loss and the population urbanization rate during 2000-2005 and 2006-2010

area	2000-2005			2006-2010		
	rate of arable land loss (%)	The rate of change of urbanization (%)	elasticity	loss rate (%)	The change of urbanization rate (%)	elasticity
main city	-13.97	5.78	-0.41	-25.14	7.61	-0.30
ring areas	-8.42	4.34	-0.52	-3.00	10.45	-3.48
northeast	-13.47	2.90	-0.22	1.44	5.52	3.82
southeast	-6.45	2.18	-0.34	5.21	12.03	2.31

elasticity=average rising of the ratio of urbanized population/ average falling of arable quality. The elasticity refers to the marginal effect on the farmland loss by urbanized population, and smaller the absolute value of elasticity is, the marginal effect is stronger, and vice versa. If the elasticity is positive, it shows urbanized population would not cause arable land loss, that is benign relationship between urbanized population and arable land quantity, and vice versa .

In 2006-2010 the largest rate of arable land loss was in the central urban districts (-25.14%), followed by the surrounding central urban districts (-3.00%). The southeast area had the fastest growth in the urbanized population (12.03%), followed by the surrounding central urban districts (10.45%). The level of urbanized population in the “two wings” regions had achieved a mutual benefit with the amount of arable land because the "one circle two wings" strategy, the concepts to "give priority to the special" urban development and the protection of arable land ecological functions were implemented in November 2006. And the elasticity coefficients for the level of urbanized population and arable land quantity were 3.82 and 2.31 respectively.

The effect of the industrial structures on arable land loss

Chongqing is dominated by secondary industry. In 2010, the output value in the primary, secondary and tertiary industry took up respectively 8.65%, 55.00% and 36.35% of the whole municipality. From 2000 to 2010, the share of secondary and tertiary industries in Chongqing, GDP is increasing in general (Fig 6). In 2000, the share of secondary and tertiary industries in GDP made up 82.20%. In 2010, it was 91.40%, in which the share of industrial output value was 84.83%, this was mirrored by large scale arable land loss. It is a trend for the industrial structure urbanization that the share of the primary industry decreases and that of the secondary and tertiary industries increases. However, the development of the secondary and tertiary industries, especially the secondary industry needs much land for construction. The increase of industry and construction drives the large scale expansion of urbanization, and at the same time, speeds up the arable land loss. The increase of the share and contribution of tertiary industry indicates the enhancement of intensive use of urban land, which is beneficial for the protection of arable land [4]. The accelerating of the growth of the service sector will not bring about further loss of arable land, but the intensive resource can enhance a city's service function, and then improve the quality of urbanization. But judging from the present situation in Chongqing, there is still a considerable time before the benign relationship between tertiary industry and the arable land quantity.

In 2007, secondary industry, exceeding tertiary industry, became the leading industrial activity of the whole municipality, judging from the proportion and contribution rate of secondary and tertiary industries. In 2000, the proportion of secondary industry made up 38.90% in three industries and its contribution rate is 55.50%. In 2010, these increased to 55.00% and 68.60%. Compared with secondary industry, tertiary industry was obviously less competitive, but it maintained its proportion at 42.40%, although its contribution rate fluctuated, it showed a sustained increase from 2004 to 2006. This illustrates the weakness in the developmental basis of the tertiary industry, and it is closely related with the focus on the scale of industrial park in Chongqing. Secondary industry increased rapidly from 2002 to 2006 when the area of arable land decreased rapidly. The increasing scale of secondary industry obviously creates much more pressure for the protection of arable land.

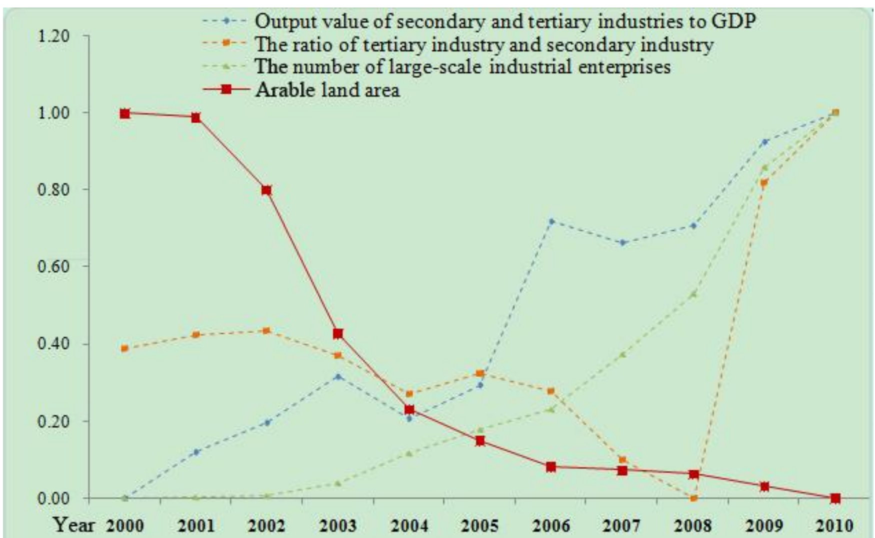

Fig.6 The relationship between the industrial structure and the amount of arable land

The data in Fig.6 has the same meaning of Fig.5 and is the result of minimum and maximum standardization.

Conclusions

(1) In the process of urbanization in Chongqing, the large amount of construction has resulted in substantial arable land loss. During the "Eleventh Five-Year" period, the scale of incremental construction land supply accounts for 52.3% of the whole supply. From 2000 to 2010, the additional use of land by construction was 30.00km^2 each year on average. This situation leads to intensification of the conflict between urbanization and arable land protection. So it is essential that urbanization must be based on proper protection of arable land.

(2) The region of rapid urbanization is important for the protection of arable land. What is more, the timing and direction of the expansion of the central urban districts became important factors affecting

arable land loss. From 1995 to 2010, the central urban districts of Chongqing spread reducing substantially the area of good arable land in these districts. It also resulted in the reduction in the quality of the arable land of whole municipality. Therefore, more attention should be given to protecting arable land in those areas.

(3) The direction and rate of urbanization leads to spatial differences of arable land loss. During the years from 2000 to 2005, urbanization in the central urban districts was at its highest rate and the arable land loss also was the greatest, due to the large inflow of population that occupied much arable land. From 2006 to 2020, the surrounding areas were regarded as important for the central urban districts expansion. Therefore, population urbanization changed from the previous “export” to “input”, coupling with its rapid growth, which caused a great loss of arable land. To ensure steady escalation of urbanization, reasonable actions to divert the flow of population urbanization and properly controlling its rate are important.

(4) The low proportion of tertiary industry is not good for the positive interaction between the urbanization and arable land protection in Chongqing. Therefore, adjusting and optimizing industrial structures as well as raising the level of intensive land use are important ways to mitigate the loss of arable land. So the improvement in the share of tertiary industry and its contribution rate will result in more intensive urban land use, thus reducing the arable land loss. To achieve the win-win situation between urbanization and arable land protection, it is essential to increase the share of the tertiary industry steadily.

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4.2.2. Farmland loss due to urban and peri-urban development in Pearl river delta

Zhifeng Wu

The Pearl River Delta

The Pearl River Delta located between latitudes 21°400N and 23°000N, and longitudes 112°000E and 113°200E, is the third biggest river delta in China. Pearl River Delta is alongside the Pearl River estuary where the Pearl River flows into the South China Sea. It includes nine cities of Guangdong, named Guangzhou, Shenzhen, Dongguan, Zhuhai, Foshan, Zhongshan, Huizhou, Jiangmen and Zhaoqing. East Pearl River Delta (EPRD, Fig. 1) (located between 22°27′-23°09′N and 113°31′-114°37′), the study area, consists of Shenzhen and Dongguan and has been one of the most economically dynamic regions in China since the start of economic reform in 1978. EPRD borders Hong Kong that allowed an advantage of short channel to absorb FDU and in consequence stimulated the local economy. The socioeconomic development has initiated the fast urbanization and changed the landscape pattern. The need for space to accommodate the increased population and booming industry led to an ever-growing urban expansion through encroachment of non-urban land especially agricultural land. During this time, a large amount of agricultural land was lost in EPRD because of rapid urbanization and the feeble land management.

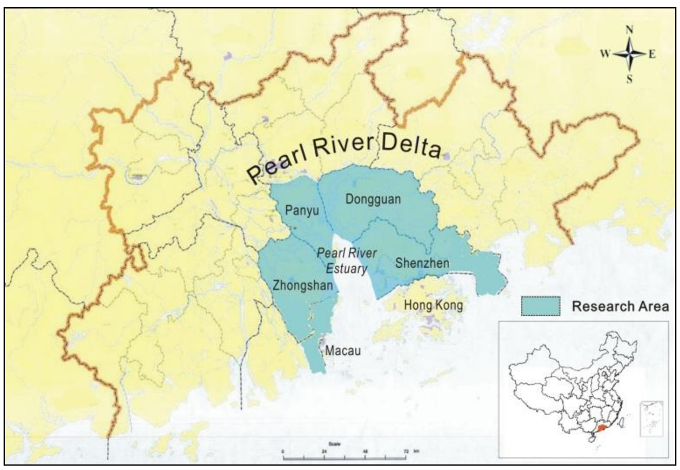

Figure 1. Location of the Pearl River Delta

Rapid urban development in Pearl River Delta started in the end of 1970s, when China central stimulated economic growth by embarking on series of ambitious reforms. Because of rapid industrialization and urbanization, the CAPRE region is witnessing a dramatic land use change.

Farmlands loss in Pearl River Delta

The phenomenon of urban development is one of the major forces driving land use change. The speed of urbanization has been most prominent in the Pearl River Delta in South China during the past two decades. The 20th century witnessed some of the most dramatic land transformations of earth's terrestrial environments in this region. The phenomenon of sprawling urban development is one of the major forces driving landscape change. It has been tightly coupled with economic growth.

Results from the remote sensing analysis indicate that the total area and average annual rate of farmland loss for the CAPRE between 1979 and 2005 were 2406.75km2(63.6%) and 92.57 km2/a respectively. There was a significant decrease in the amounts of farmland with the largest loss rate of 131.58km2/a between 1990 and 1995 (Tab. I). Total built-up area for the CAPRE nearly increased 30 times during the study period, from 97.89km2 in 1979 to 2856.10km2 in 2005. The farmland loss almost had a same rate with built-up growth when other land use types kept relative stable states (Fig.2). Farmland loss and urban growth rates are strongly related to foreign investments, politics and policies in Pearl River Delta[7]. This relationship is more obviously in CAPRE area. Markovian analysis of the land use changes show that a major change is to converted farmland into built-up land. The change detection reveals that 76.4% of loss farmland was converted into built-up land during 1979-2005. The built-up land amounts to 36.8% of total area in 2005.

Table 1. THE FARMLAND LOSS RATES OF DIFFERENT PERIODS (UNIT: KM2/A)

Periods	**1979~1990**	**1990~1995**	**1995~2000**	**2000~2005**
Transform in	46.56	88.61	81.63	60.27
Transform out	141.36	220.19	124.55	177.36
Loss rate	94.80	131.58	42.93	117.09

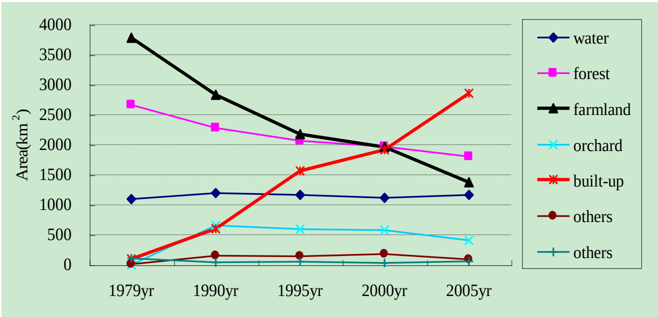

Figure 2. The land use change of CAPRE from 1979 to 2005

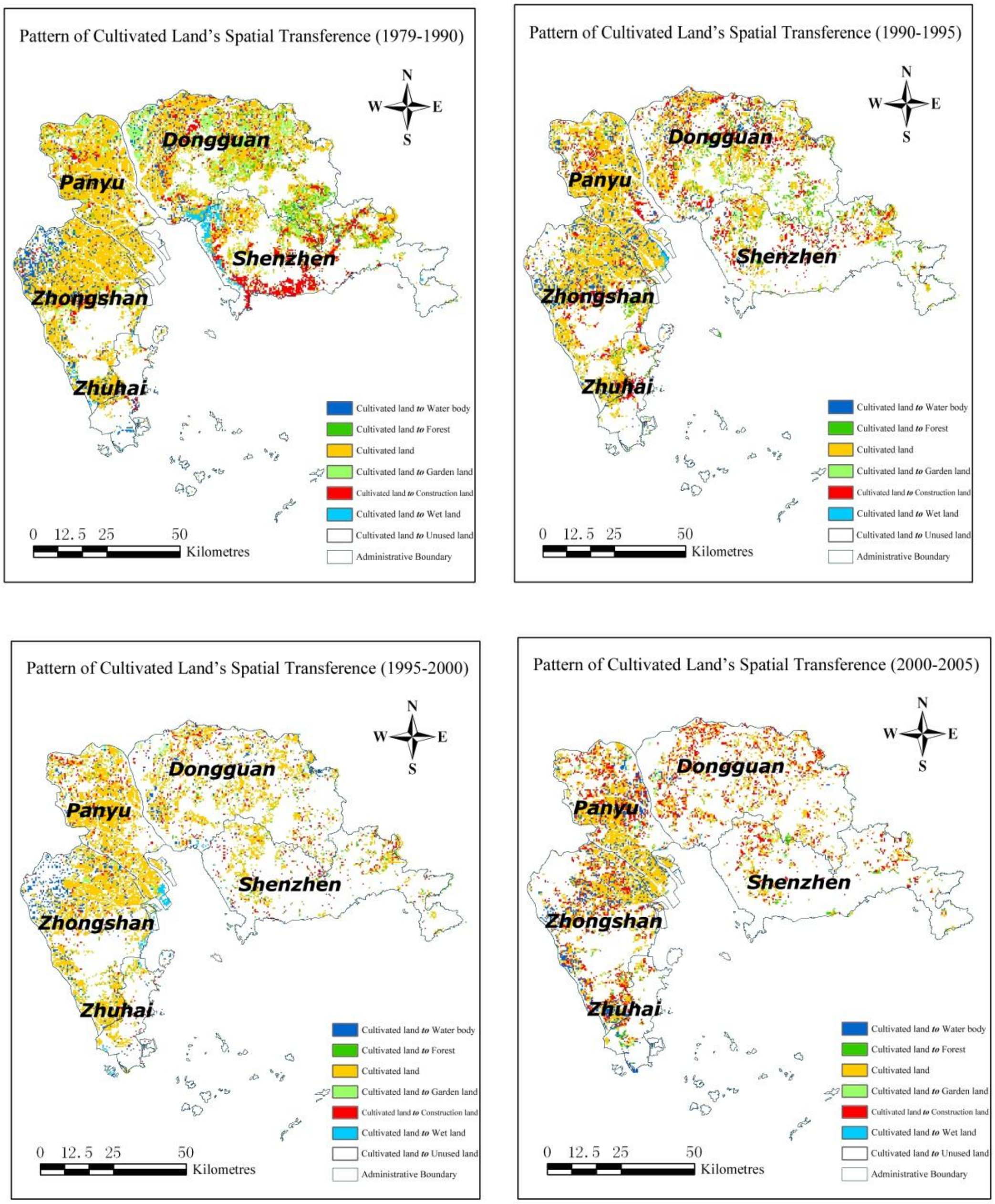

Figure 3. The spatial patterns of farmland loss in different period

There are distinct differences of farmland loss and urban built-up land expansion in different stages. Overlay analysis show the spatial patterns of farmland loss in 4 stages (Fig.3). From the figure 3a, it is clear that the main farmland-to-urban changes were taken place in Shenzhen nearby Hong Kong during the 10-year period. In second stage 1990-1995, not only did farmland-to-urban changes display in Shenzhen but also there was a significant transformation sprawl all over CAPRE (Fig.3,b). Deng Xiaoping visited South China to reassure investors that China would continue to pursue reform and open policies. This led to the resumption of foreign investments and development projects that consumed lots of land resources. The third stage 1995-2000 is a relative stable stage. Farmland loss rate decreased and extent shrink (Fig.3,c). Economy developing speed and built-up land development were accelerated after 2000. Farmland loss was very dispersed again in CAPRE (Fig.3,d). Fig.3 also indicated that a high proportion of urban development as represented by built-up areas occurred in good quality farmland. Because flat farmland has good accessibility and is close town or transport line. The above analyses reveal the spatio-temporal variations of farmland loss, which reflect the dynamics and complexity of economic and polices factors in the CAPRE.

Farmlands loss in relation with urban growth in the Pearl River Delta

Farmland loss and built-up land expansion is much related in the Pearl River Delta.

The spatial temporal pattern of urban growth in Pearl River Delta has been recognized as an integrated consequence of a various driving forces, including economic, social, and political factors, topography, land prices, population, and so on. Spatial heterogeneity of these factors could cause different types of urban growth.

There were three main types of urban growth recorded: infilling, edge-expansion, and outlying. Infilling refers to the development of non-urban area which surrounded by old urban area. Edge-expansion refers to the newly developed urban area which spreading out from the fringe of existing urban area. Outlying growth means the growth of newly developed urban area which has no direct spatial connection with the existing urban area. Some kind of urban growth has been cited for its negative impacts on natural resources, economic health, and community character.

Case 1

Dongguan is an important industrial city located in the Pearl River Delta. It borders the provincial capital of Guangzhou to the north, Huizhou to the northeast, Shenzhen to the south, and the Pearl River to the west.

It is also home to the world's largest, though mostly empty, shopping mall, New South China Mall. City administration is considered especially progressive in seeking foreign direct investment. The three neighboring municipalities of Guangzhou, Dongguan, and Shenzhen are home to over 25 million residents, accounting for a large proportion of the Pearl River Delta Region's population.

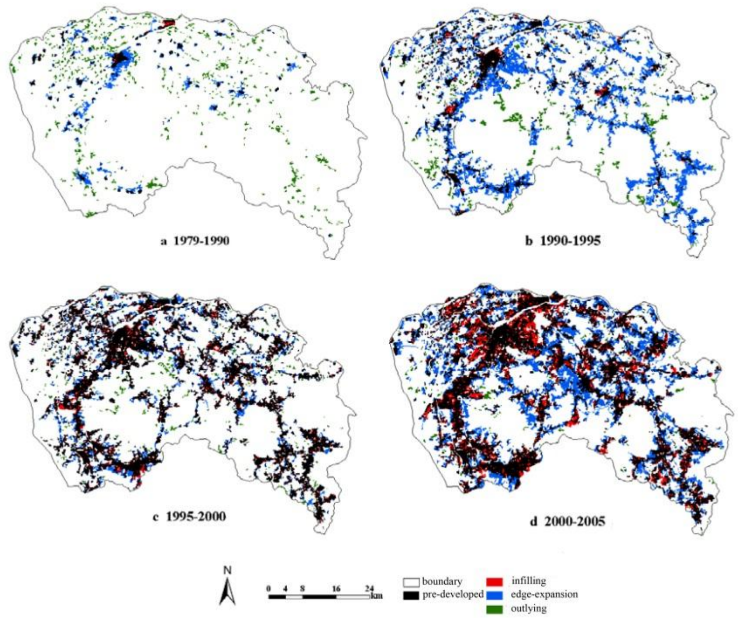

Figure 4. Three urban growth types in Dongguan in the four periods

As can been seen from Fig. 4, urban growth shows distinct growth patterns during the different periods in study area. In the first period 1979–1990, urban growth was dominated by the outlying growth and infilling growth was less (Fig. 4a). During the period of 1990–1995, outlying growth decreased, while the edge-expansion growth became the dominant type (Fig. 4b) and infilling growth increased as well. In this way, a multi nuclei urban pattern was formed in Guangzhou. During the period of 1995–2000, the outlying-type growth was still decreasing, and the edge-expansion type and the infilling growth became dominant (Fig. 4c). During the last period 2000–2008, edge-expansion and infilling growth remained dominant.

Case 2

Shenzhen is one of the most successful Special Economic Zones (SEZs) in China. It currently also holds sub-provincial administrative status, with powers slightly less than a province. Shenzhen is now one of the fastest growing cities in the world. The unprecedented construction land sprawl rates have occurred over the last two decades in Shenzhen. Compared to the pattern before the economic liberalization， the change of land pattern caused by the urbanization was huge.

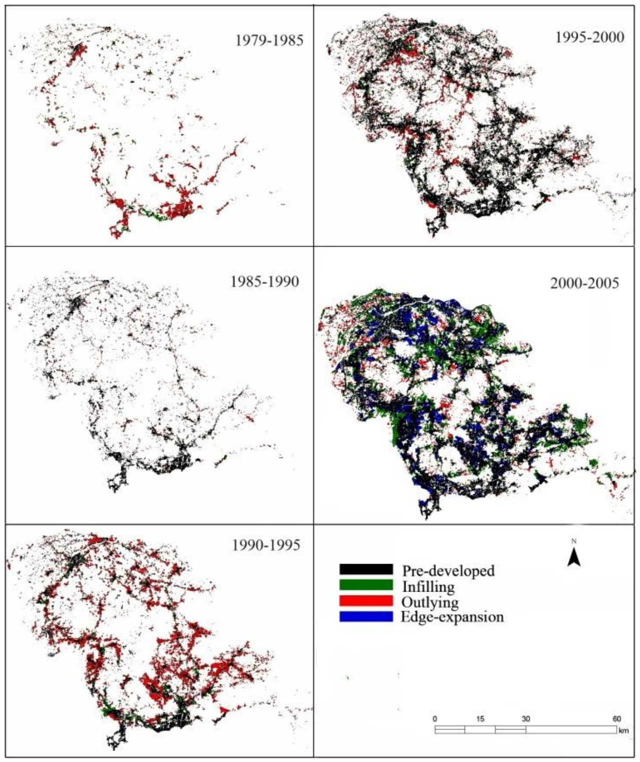

Figure 5. Three urban growth types in Shenzhen and Dongguan (EPRD) in the four periods

Figure 5 Shows us the change about the sprawl categories in Shenzhen and Dongguan (EPRD) from 1979 to 2005. With the process of industrialization and the urbanization, the urban area in Shenzhen increased continuously.

Outlying sprawl, as the arbitrary and unsustainable expansion style, was the main expansion category before 1995, and was seen scattered in all three counties. Rural land, especially fertile land, was seen to have good accessibility for effective traffic conditions and was therefore transformed into urban area during 1979–1995 predominant through outlying sprawl. Later, the Governor and the planner began to notice the importance of intensive utilization and the savings that would be generated and began to pay attention to the Shenzhen Land Use Planning and Shenzhen Urban Planning principles (set in 1997) to standardize land development. The result was a gradual decrease in the aimless outlying sprawl effect. Even during 2000–2005 (which recorded the largest urban area expansion over any period), the proportion of outlying sprawl against the entire expansion decreased to 20.59% from what was the highest proportion of 84.03% recorded during 1990 and 1995. All these measures indicate that the land use plan introduced and controlled by the Governor was meeting its objectives to control the arbitrary urban sprawl.

Conclusion and Disscussion

Rapid urban growth in the Pearl River Delta has led to severe environmental issues as urban development encroached upon cultivated land. The loss of agricultural land is alarming in the Pearl River

Delta. In Pearl River Delta, most regions surrounding the urban areas are used for agriculture. After the implementation of economic reform and opening-up policy in 1979, several new development districts of various types such as Special economic development zones, and High-tech industry zones were established to attract foreign investment. These new development industrial zones were constructed in rural areas, usually on agricultural land because of a low developing cost. The rapid urban expansion resulted in agricultural land loss. As the rapid urban expansion between 1979 and 1995 encroached on a large amount of cropland, the central government started to implement stricter land use management measures. The '*Ordinance for the Protection of Primary Agricultural Land*' was implemented in 1994. With the implementation of the cropland protection strategy and the change of administrative boundaries in 2000, most future growth types may turn out to be infilling, a trend which is already evident. When the growing space has been compressed and urban form has become more compact, however, the main form of urban growth may return to outlying growth. Apparently, the loss of agricultural land is inevitable in fast growing regions, but planning may focus on minimizing this amount in the future. Considering that urbanization in Pearl River Delta is rapid, it is necessary to pay attention to land policies and the role of urban planning in Pearl River Delta. While agricultural and economic policy reforms have raised economic development, they have also caused problems in agriculture land loss. Therefore, a key question facing policymakers now is how to manage urban growth and its direct and indirect consequences. Therefore, a sustainable land development strategy guiding future directions and patterns of urban growth needs to be developed to minimize the amount of cropland loss caused by urban expansion.

4.2.3 Cropland loss due to urban and peri-urban development in Europe[2]

Gergely Tóth

Introduction

Food security in Europe is based on the crop output of its land resources. Land resources also contribute to the supply of biofuels and other raw materials, provide a platform for most human activities and secure a series of environmental services (Blum 2005, Bouma, 2006). The performance of these land functions– which are often carried out at the same place at the same time – is conditioned by ecological and socio-economic factors. Socio-economic factors influence land availability for food production, land use allocation, and land use efficiency. Ecological factors set conditions for the use potential of land, including productivity potential of agricultural areas but also set limits to environmentally acceptable inputs. Optimization of land utilization to secure adequate biomass production for food, feed, and energy in Europe while keeping land provision for other uses and maintaining good environmental status is in the focus of European and national policies (CEC 2005, 2006; EC 2011; Dwyer 2011). The progress in the understanding of dynamics in multifunctional landscapes (Farrell and Anderson 2010) and the existence of operation monitoring systems in many European countries to detect land use change and soil sealing (EC 2011) provide tools to address the problem of land take for policy planning and implementation.

However, current trends show that the principles laid down in the EU's Thematic Strategy on the Sustainable Use of Natural Resources towards more sustainable production patterns in Europe (CEC 2005) are far from achieved. On the contrary, the conversion of land resources towards artificial surfaces is ongoing, consistently decreasing the availability of fertile land for future generations (EC 2011). According to recent studies artificial surfaces have been growing, from the baseline year of 2000 with an average of 3.4% in 36 European countries until 2006 (EEA 2010). This figure illustrates the significant loss of land potential for biomass production in Europe. In addition to the loss of productive potential, land-take has a series of environmental consequences, ranging from biodiversity decline to reduced potential for carbon sequestration (Prokop et al 2011). In recognition of the problems created by land conversion, the EU has announced its resource efficiency roadmap (CEC 2011) setting a target of no net land-take in the European Union by the year 2050. However, the principle of sustainability also implies that low quality land should be subject of conversion to artificial surfaces, while compensating it with land of higher quality. Strategic land use planning and environmental impact assessment often lack elements of soil quality; therefore, the soil quality component is rarely integrated into the policy-making processes either. This is partly due to the data availability on local to national scales (Jones et al. 2005), partly to complexities of soil and land qualities (Blum et al. 2004, Karlen et al. 2001), and partly to lack of expertise in the planning circuits (Tzilivakis et al. 2005). However, there are attempts to provide integrated tools to include land quality in land use planning at local and regional scales (Tóth and Németh 2011, Vrscaj et al 2008).

[2] This chapter is an extract of the article: Tóth G. 2012. Impact of land-take on the land resource base for crop production in the European Union. Science of the Total Environment 435-436 p202-214. For full references, see this article.

In the current study we aimed to provide new data and knowledge of trends of cropland resources decline caused by land take in a spatially explicit manner in the EU and to quantify the quality (productivity) of croplands lost in the conversion to artificial surfaces. To achieve this aim, we analyzed the extent and productivity of croplands that have been converted to artificial surfaces during the seven year study period. We used the following land take definition of the European Commission (EC 2011): "Land take is the increase of artificial surfaces (housing areas; green urban areas; industrial, commercial and transport units; road and rail networks; etc) over time."

A comprehensive assessment of change in cropland quality (Tóth et al. 2007) was out of the scope of the current research; however, we aimed to provide an overview of changing crop production capacities in the EU member states due to land take. While land take from croplands are the focus of this paper, preliminary analysis on land take from other land cover types are also provided. With additional analysis of population and economic data the dependency and characteristics of land take on underlying socioeconomic factors was also assessed.

Databases used

The SoilProd data

The spatially explicit Soil Productivity Model for Europe (SoilProd; Tóth et al. 2011), developed at the European Commission's Joint Research Centre, Ispra, was used in the current study. The SoilProd model is developed to support planning and monitoring of resource use efficiency and sustainability of agricultural land use. In the SoilProd model ranking of soil productivity in Europe was performed based on eight major climatic zones of the continent. Climate zones were derived from the 35 climate areas described by Hartwich et al. (2005). Soils (second level taxonomic soil units) of each zone were classified into five inherent productivity classes of the corresponding zone. Soil productivity estimates for the ranking were established on the basis of the original taxonomic component (second level taxonomic soil units) and soil attribute information of the Soil Geographical Database of Europe (SGDBE; EC 2003). In parallel, Soil Typological Units (STU; EC 2003) were also rated according to the available water capacities of topsoil and subsoil. Soils were grouped into four classes on the basis of their water storing capacity.

In the next step of the productivity assessment, an evaluation matrix was set up with eight climatic zones and five inherent productivity classes and four available water capacity classes. Productivity scores between 1 and 8 were assigned for each cell in the matrix, based on the complex evaluation of the climate dependent relative inherent fertility of soils. Score 1 represents the lowest and 8 the highest soil productivity. The corresponding inherent productivity scores were assigned to each STU in the SGDBE. Spatially weighted averages of inherent productivity scores were calculated for each Soil Mapping Unit (SMU; EC 2003) on the bases of the proportional areal shares of the STUs within the mapping units.

Inherent productivity classes were established by means of soil productivity before human interference. Correction measures based on topographic conditions were finally applied to arrive at the final Inherent

Soil Productivity Index (ISPI). Correction coefficients of slope and aspects applied in the D-e-Meter land evaluation system (Tóth 2009) were adapted for our continental scale study.

To evaluate the biomass productivity of soils on arable lands the model was extended with a new module. Since productivity of soil is only partly due to its inherent fertility, but also due to the effect of management, mainly nutrient input, the effect of fertilization was considered in this module. While acknowledging the importance of the applied technology of soil use on the actual productivity of soil on a detailed scale, such distinctions were out of the scope to be directly incorporated in our continental scale study. The goal of our study was solely to determine soil productivity – i.e. the capacity of soil to supply nutrients, water, and rooting medium for plants – in a comparative manner and not to assess the effects of management. It was not the goal of the SoilProd model to evaluate all management related yield responses of soils; however, the influence of fertilization was considered. To do this, a Fertilizer Response Index (FSI) was assigned to each soil unit in the eight climatic zones. Soils with the largest relative fertility increase received the maximum of 8 points and soils with little influence of fertilization received 1 point.

To calculate soil productivity for the cropland land use type, the inherent soil productivity and the fertilizer response scores were aggregated. A weight of 1 was applied for the inherent fertility index and a 0.25 weight was used for the fertilizer response indices. The composite Cropland Productivity Index (CPI) was calculated as:

$$CPI = ISPI + (0.25*FRI) \qquad \text{/eq. 1./}$$

Where
CPI = Cropland Productivity Index
ISPI = Inherent Soil Productivity Index and
FRI = Fertilizer Response Index

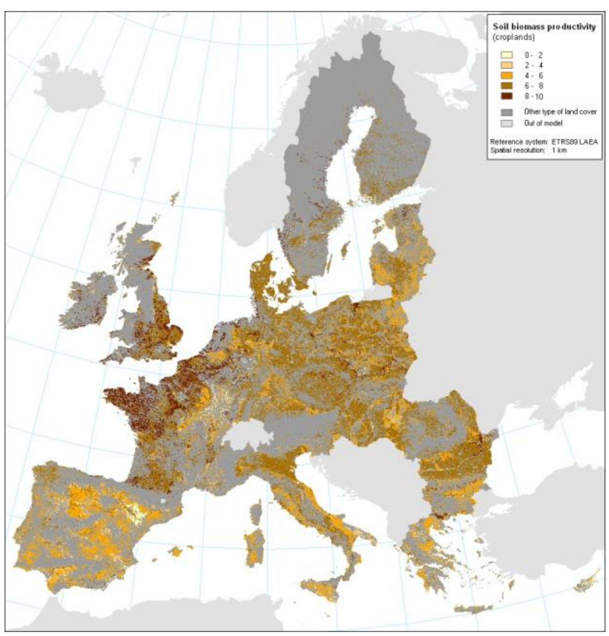

Figure 1. Estimated cropland productivity in the European Union (result of the SoilProd model)

The spatially explicit results of the SoilProd model (Figure 1.) were validated with remote sensing derived productivity indicators produced from SPOT VEGETATION decadal data (Ivits et al. 2011). The Geographically Weighted Regression (GWR) method was selected to validate the model results with measured productivity indicators. Geographically explicit spatial application of both the cropland and grassland productivity model showed high consistency with the data obtained from remote sensing, indicated by adjusted coefficient of determination (r2) values of 0.74 and 0.85 for the continental datasets, respectively. The validation process thus proved the reliability of the biophysical SoilProd model (Tóth et al. 2011).

CORINE land cover data

To assess the changes in cropland allocation and land take in the EU, the CORINE land cover (CO-oRdination of INformation on the Environment; CLC) database (EEA, 2011b) was used. The CLC database provides information on land cover (and changes) in European countries, including member states of the European Union (JRC-EEA 2005). CORINE Land Cover data from two years (2000 and 2006) was used in the land take analysis. Data from 24 EU member states was available for both 2000 and 2006. The datasets for both years are based on the same classification scheme, including 44 land cover classes organized into three hierarchical levels (CEC-EEA 1993). After regrouping the CLC classes we focused our assessment on "Cropland" and 'Artificial land' (Table 1.). Besides all arable land categories we considered land cover classes with substantial annual crop inclusions as croplands as well. We used all CLC categories of 'Artificial surfaces' in the new 'Artificial land' category.

Table 1. Land cover classes used for the analyses and their corresponding original CLC classes

Land cover classes of the current study	CLC classes (CLC code) CEC-EEA (1993))
cropland	arable land (211, 212, 213) heterogeneous agricultural areas (241, 242)
grassland	pastures (231) natural grassland (321)
plantations	permanent crops (221, 222,223) heterogeneous agricultural areas (243, 244)
artificial land	artificial surfaces (111, 112, 121, 122, 123, 124, 131, 132, 133, 141, 142)
forest (and semi natural areas)	Forest and semi natural areas (311, 312, 313, 322, 323, 324)
non-productive land	beaches, dunes, sands (331) bare rocks (332) sparsely vegetated areas (333) burnt areas (334) glaciers and perpetual snow (335)
waters and wetlands	wetlands (411, 412, 421, 422, 423) water bodies (511, 512, 521, 522, 523)

Country maps

To delineate land areas of 24 EU member states for the spatial analysis of land take impact the shape file provided by ESRI (2003) was used.

Methods

In this study we analyzed changes of the land resources by member states of the EU considering the areas affected by land take from cropland to artificial land between 2000 and 2006 and the productivity level of the croplands converted to artificial land. Both the quantity and quality of cropland converted to artificial surface were assessed using maps produced by the SoilProd cropland productivity evaluation model and the CLC datasets.

Calculation of cropland area converted to artificial surfaces

CLC data for the year 2000 (EEA 2011) were used to establish baseline values for the areal extent of croplands. Artificial lands, grasslands, plantations, forests and semi natural areas, non-productive land and waters and wetlands were also delineated in the dataset. An assessment of gross cropland conversion to artificial land as well as calculation of percentage cropland conversion ratios by countries were performed using the CLC land cover change database (EEA 2011).

Spatial delineations and areal crop productivity calculations

Productivity of croplands was evaluated for all areas of the CLC database classified as arable lands or complex cultivation patterns including annual crops (Table 1). A cropland productivity map was created using spatial delineations of the SoilProd map with the 2000CLC map for 24 EU member states. Subsequently, we made similar delineations for those areas which had changed from cropland to artificial surfaces between 2000 and 2006 according to CLC2000 and CLC2006 databases. Sum and mean of productivity indices were calculated for the hectares of cropland areas in the countries. The same calculations were also performed for the lands converted from cropland to artificial land between 2000 and 2006 using the methodologies described below.

Calculation of losses in productivity potential

We calculated the loss in biomass production potential of croplands in relative terms. The following analyses were carried out:

- Assessment of the quality (productivity) of the lost cropland for individual countries relative to the average quality (productivity) of their croplands in the baseline year. Results are provided in % of the mean productivity index for the countries.

$$QLCL = (MCPIlost) / (MCPI2000) \qquad /eq.\ 2./$$

Where:
QLCL = Quality of the lost cropland compared to the countries' means. Quality in this expression corresponds to the level of relative productivity.
MCPI = Mean Crop Productivity Index of all the cropland areas of the country

- Calculation of biomass production potential loss due to cropland conversion to artificial land between 2000 and 2006, proportional to the baseline measured at year 2000, for individual countries using equation 3.

CPPlost = 100 * (CAlost * MCPIlost) * (CA2000 * MCPI2000) -1 /eq. 3./

Where:
CPPlost = crop production potential losses between 2000 and 2006 in % of the baseline
CA = cropland area (ha)
MCPI = Mean Crop Productivity Index of the cropland areas

- Relationships between population growth statistics and cropland conversion to artificial land and the quality of converted cropland were analyzed. We applied linear and non-linear regression models to explore and characterize these relationships.

Calculation of per capita productivity loss

To complement the analysis on the changes of the cropland resources base, we also calculated the loss of land resources in wheat yield equivalents on a per-capita basis for the separate countries. We expressed the loss in wheat equivalents to highlight the food security aspects of the land take.

Mean yield values derived from time series (annual data from 2000-2010) of official Eurostat (2012) country wheat yield statistics were used. A linear regression analysis was performed to establish numerical relationships between mean productivity indices of 24 EU member states based on the SoilProd model and long term average wheat yields of these countries. The resulting regression model (eq. 4) was significant at a 0.05 confidence level and had a coefficient of determination (r^2) of 0.72.

Equation 4. was used to calculate the wheat producing potential of croplands converted to artificial land in EU member states.

wheat yield in t*ha-1 = -7.5 + (2.1*CPI1-n) /eq. 4/

where:
CPI1-n – mean crop productivity index of the land units 1-n.

The model parameters highlight that the model is applicable for estimating wheat yields for lands with a CPI above 3.5. Productivity loss expressed in productivity scores (relative indices) were translated to kg*ha-1 wheat yield values. Official Eurostat (2012) population statistics were used to communicate the results for the countries on a per capita basis. Calculations were made using equation 5.

$$\text{WPLannual\_per\_capita\_i} = \frac{\sum_{1-n}\left(-7.5 + (2.1 * \mathrm{CPI}_{\text{1-n}})\right)_{lost}}{POP_{MS_i}} * \frac{1}{6} * year^{-1} * 1000 \quad \text{/eq. 5/}$$

Where
*WPLper_capita = annual loss of cropland resources in EU member state i; expressed as per capita wheat productivity loss (kg wheat * person-1* year-1)*
CPI1-n = Crop Productivity Indices of each (1-n) land units (in ha) in the member state i
POPMSi = population of the member state i.
1/6 = coefficient to derive annual value from changes in 6 years (2000-2006)
1000 = coefficient to convert tons to kilograms

Results and discussion

Land take trends in the EU between 2000 and 2006

The European Union, based on the analysis of 24 member states, lost 0.27% of its cropland due to conversion to artificial surfaces in the period between 2000 and 2006. The rate of land take was highest in croplands followed by grasslands, plantations, and forests, respectively (Table 2.). This sequence of land take rates suggests that land conversion to artificial surfaces follows the historic trends also in the 21st century with continuing conversion of more productive land. The historic trend originates from the establishment of the first human settlements which occurred on prime land. We focused our further analysis on croplands to explore the country and region-specific characteristics of land take from this land use type.

Among the studied countries, the largest total cropland area loss occurred in Spain, followed by France (Table 2.). Land take in these two countries accounts for approximately half of the total land take in Europe. Germany and Italy, two countries with large land areas are next on the list, while fifth place is occupied by the Netherlands, a country with limited land resources. While most of the other, smaller member states have a lower position on the list indicating gross cropland consumption, the order of countries changes if converted land areas are compared to their total available cropland areas. We found no correlation between the extent of artificial areas within a country in the baseline year (2000) and the rate of land take in the study period.

The proportional loss of cropland area in relation to the countries' total cropland areas (Table 2.) was the highest in Cyprus (1.83%), the Netherlands (1.55%), and Ireland (0.86%). These figures indicate the high speed of land conversion in these countries during the study period. Data in Table 3 also show that the rate of land conversion was generally higher in the western part of the EU than in the new, eastern member states. The Czech Republic and Hungary are two eastern member states with relatively high conversion rates of cropland to artificial surfaces between 2000 and 2006, although still lower than the EU average.

During the study period Latvia had an exceptionally low rate of cropland conversion to artificial surfaces. Nevertheless, there are no countries among the studied EU member states that manage their land resources without a loss in agricultural productive potential at the beginning of the third millennium. The problem is truly of universal nature in the EU, even though regional differences exist regarding its magnitude.

Quality (productivity) of cropland converted to artificial land

The conversion of productive land resources to artificial surfaces affects all land cover types, thus lands with all different levels of productivity, albeit to varying degrees (Table 2). This phenomenon was found to be similar when the land take of croplands with different productivity levels was analyzed. According to our calculations based on data from 24 member states, there are considerable differences both in the extent and the quality of the agricultural land lost to land take (Table 2. and Figure 2.).

Table 2. Extent of land-take from main land cover types (to artifical land) in the EU between 2000 and 2006

country	conversion to artificial land from:						
	cropland (ha)	**cropland (% of country total surface area)**	**cropland (% of land surface area[3])**	**cropland (% of cropland area in 2000)**	**grassland (% of grassland area in 2000)**	**plantations (% of plantation area in 2000)**	**forests (% of forest area in 2000)**
Austria	4457	0.10	0.12	0.26	0.16	0.06	0.05
Belgium	2208	0.12	0.15	0.18	0.07	0.05	0.15
Bulgaria	1858	0.04	0.04	0.05	0.14	0.06	0.01
Cyprus	6703	1.09	1.28	1.83	2.35	1.31	0.58
Czech Republic	7710	0.17	0.18	0.23	0.65	0.10	0.04
Denmark	9727	0.25	0.28	0.34	0.10	0.15	0.06
Estonia	1522	0.10	0.11	0.18	0.14	0.07	0.08
Finland	2122	0.03	0.04	0.13	0.40	0.00	0.04
France	56140	0.13	0.17	0.26	0.14	0.22	0.06
Germany	49473	0.19	0.21	0.31	0.17	0.12	0.07
Hungary	11574	0.17	0.19	0.22	0.33	0.18	0.05
Ireland	5680	0.29	0.37	0.86	0.35	0.24	0.11
Italy	40509	0.16	0.18	0.37	0.07	0.12	0.02
Latvia	335	0.02	0.02	0.02	0.03	0.01	0.01
Lithuania	2609	0.05	0.06	0.09	0.07	0.07	0.01
Luxembourg	67	0.16	0.17	0.08	0.98	0.00	0.04
Netherlands	20531	1.07	1.25	1.55	1.23	1.16	0.22
Poland	14133	0.06	0.07	0.09	0.08	0.06	0.03
Portugal	7497	0.29	0.32	0.31	0.52	0.18	0.38
Romania	6177	0.04	0.04	0.07	0.04	0.05	0.01
Slovakia	2791	0.08	0.07	0.16	0.02	0.06	0.01
Slovenia	350	0.05	0.06	0.09	0.01	0.03	0.05
Spain	78342	0.27	0.29	0.48	0.37	0.28	0.12
Sweden	5903	0.04	0.05	0.19	0.19	0.01	0.03
EU24	338418	0.14	0.16	0.27	0.21	0.16	0.06

[3] With reference to the total land surface area (excluding waters and wetlands)

With regard to the quality of converted cropland, Italy, Slovakia, and Spain converted the better quality cropland from their reserves to artificial land (Figure 2.). This comparison shows that infrastructural development in these countries happens at the high cost of the natural resources. Bulgaria, Cyprus, Estonia Latvia, Luxembourg, and Slovenia are examples of countries where artificial land is developed in areas with less fertile soils. Although examples presented here might seem to reflect conscious or less careful spatial planning, one must be careful with these assumptions. In reality, economic development takes place independently from local land quality and planners in most cases face a trade-off between economic growth (infrastructural investment) and conservation of land resources.

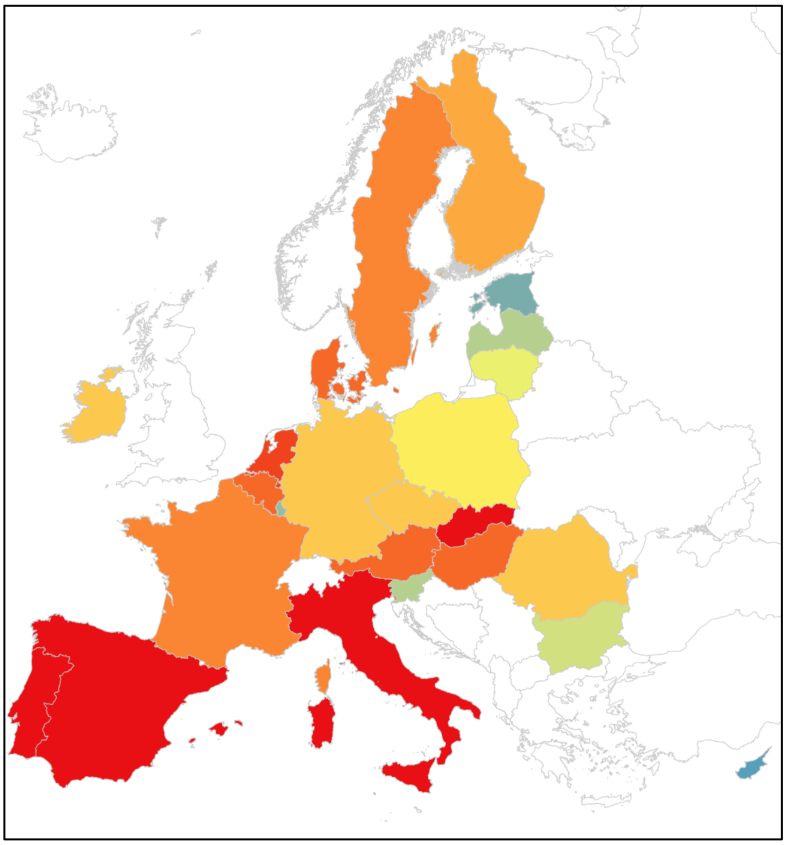

Figure 2 Quality of lost cropland in EU member states (relative to the countries' average cropland productivity; 1 = average crop productivity of the country)

Considering regional patterns of the quality of land taken from agricultural production (Figure 3.) we can observe differences between regions of most EU countries. These differences are found both across borders and within countries. Although in Spain, Italy, and Slovakia a much higher percentage of good quality land is converted to artificial land than in other countries (as also reflected by Figure 2), even within these countries there are regions where urban sprawl and infrastructural development are concentrated on poor to average quality land. The case of Austria, where higher quality agricultural land from within the southern Alpine regions and the easternmost province are taken, illustrates the complexity of the land take issue within a single country. From the point of view of resource use efficiency of cropland, the predominantly tourism-driven economy of southern Austria is comparable to the eastern part where economic growth is driven by other sectors. However, with regard to the loss of agricultural capacity, the type of regionally dominating economic sector seems to be largely neutral. Contrary to what has happened in Austria, the case of Estonia, with one of the highest economic growth rates in the EU illustrates that there is a possibility for growth without abandoning sustainable land use targets. Although a comprehensive assessment of the socioeconomic components of land-take was not among the aims of our research, our findings are in line with the studies of Galeotti (2007) and Klijn (2004). Nevertheless, further studies are required to explore the driving factors behind conversion of cropland of different productivity levels.

A closer look at the metropolitan areas illustrates how the decline of cropland and its quality is determined by urban expansion and peri-urban infrastructural development. In metropolitan areas of Barcelona, Berlin, Bratislava, Bucharest, Bremen, Copenhagen, Genoa, Hamburg, Milan, and Vienna infrastructural investment occurred on the higher quality land between 2000 and 2006 (Figure 3.). Although it is hard to believe that none of these regions had sustainability strategies in place, it is certainly true that economic development dominates over the issue of land conservation. Budapest, Paris, and Warsaw – most likely with well-designed sustainability strategies and implementation plans in place – were able to spread their urban growth to areas with less productive land. With regard to the ecological conditions of urbanization, cultural aspects might play a role in the changing landscape structure, including land-take (Nassauer 1995, Verbung et al. 2004).

Without questioning the conscious urban and regional planning of any of the regions of Europe, we can assume that the general - and historical - tendency in Europe to consume quality land around urban areas remains unchanged in many places.

Impact of land conversion on crop production potential of the EU

The EU – based on the assessment of 24 member states lost 0.26% of its crop productive potential between 2000 and 2006. However, the loss of agricultural production capacity follows different patterns among its member states, depending both on the quantity and the quality of agricultural land converted to artificial areas. As seen in Figure 3, the proportional productivity loss of cropland potential was the highest in the Netherlands (1.57%) followed by Cyprus (0.84%), Ireland (0.77%), and Spain (0.49%), respectively. The Netherlands in particular loses its basis for crop production at an exceptionally high speed. If we take the high population density of the Netherlands into account, we can assume that the security of local food supply -based on cropland resources productivity - accounted for the greatest loss in this country.

The tendency of losing cropland potential is faster in western and southern Europe than in the eastern part of the EU. While all eastern member states convert their croplands to artificial areas at a lower rate than the average of the EU (24 countries), it is only Belgium, Finland, Luxemburg, and Sweden from the northern and western part of the continent which have relatively lower rates of cropland conversion. These data call attention to the role of socioeconomic drivers of cropland conversion. Although the exploration of the complex driving forces-impact-response process was out of the scope of our study, we investigated the relationships between population and land take characteristics in the EU.

The average loss of 0.27% of croplands and 0.26% of crop production potential in the investigated 24 member states between 2000 and 2006 might be compensated by technological advancement which result yield increases (Fisher et al. 2010). However, we are of the opinion that considering the environmental consequences of increased input intensity, the indicated loss is quite alarming from both the point of view of the sustainability of land use and from the point of view of food supply of the continent and the globe.

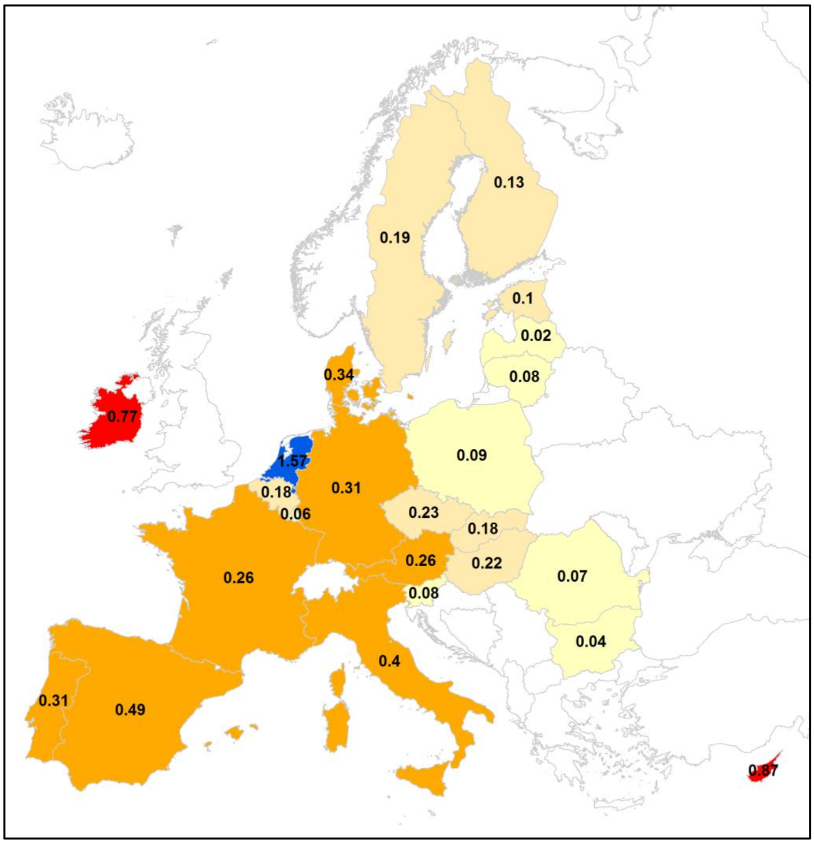

Figure 3 Loss of crop production potential due to land-take in the EU between 2000 and 2006 (in % of the potential in the baseline year)

Loss of crop production potential in EU member states in wheat equivalent

To illustrate the magnitude of the problem, the lost land quality reserves between 2000 and 2006 are also expressed in wheat equivalents by member states (Figure 4.) Denmark experienced the largest loss of food production capacity, with more than 4 kg/year/citizen in the study period, expressed in wheat volume. Ireland and Cyprus are next with above 3 kg/year/citizen followed by Spain, the Netherlands, Hungary, and France with more than 2 kg/year/citizen loss of productivity potential in wheat equivalents. From the perspective of the remaining cropland resources the most severe situation is in the Netherlands, due to the low level of per capita cropland resources. Further 9 member states have a per capita loss of production potential equivalent to more than 1 kg wheat production in each year during the study period. It is only Bulgaria, Latvia, Luxemburg, and Slovenia where this figure is under 0.5 kg/year. The sum of the annual losses of crop productivity of the 24 studied countries due to conversion of croplands to artificial land was as high as 659.000 tons wheat equivalent. This figure is estimated to reach as high as 700.000 tons for the whole of EU 27 countries.

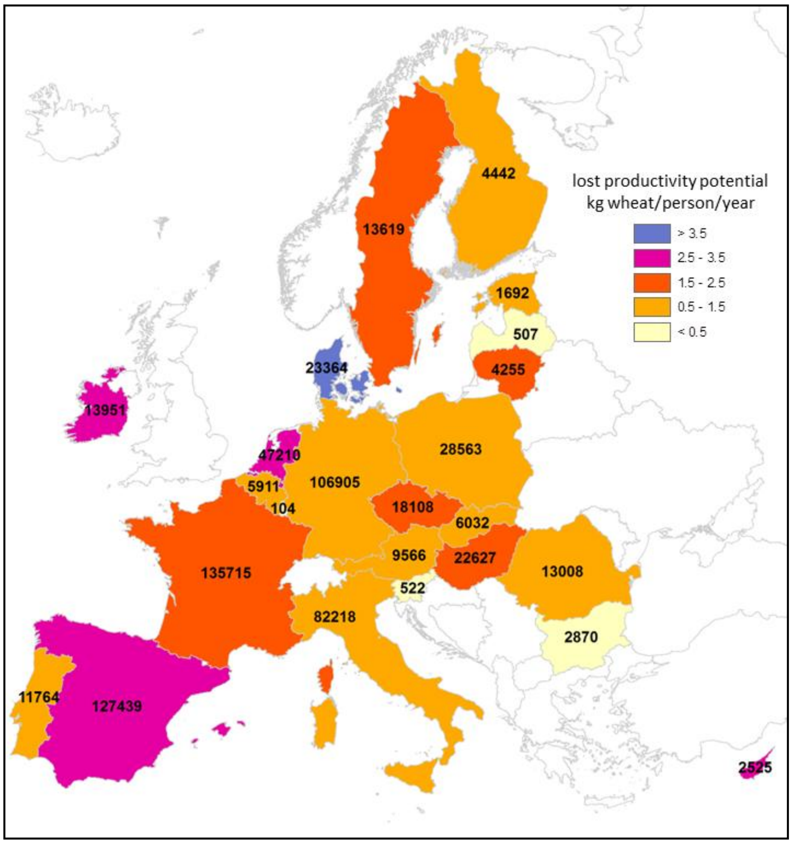

Figure 9 Annual per capita and total national losses of cropland productivity potential in EU countries expressed in wheat yield equivalents (2000-2006) figures in legend: per capita losses (kg/person) figures on the map: national sums (tons/country)

Our current study focused on croplands only and a comprehensive impact assessment of all components in the land use changes processes was not within its scope. However, considering the extent of land take from all land cover types (Table 2.), and assuming lower biomass producing potential on non-cropland areas, we estimate the overall loss of biomass producing potential in the EU due to land take to 1.8-2 times that lost on croplands.

Conclusions

The loss of agricultural land due to conversion to artificial surfaces is a common problem in the European Union, of which all regions are affected to a greater or lesser extent. Simultaneously, there are also considerable differences in EU member states both in the speed of land-take and in the quality of the land taken out from crop production in favor of artificial surfaces.

Spatial analyses of the land productivity and land use data show that the EU is experiencing a consistent decrease in production capacity.

Results highlight: (i) land conversion from different land cover types to artificial surfaces follows the historic trends in Europe with continuing consumption of more productive areas from its land resources; (ii) the conversion rate of croplands to artificial surfaces is growing with increased population growth; (iii) with the growing rate of population increase, increasingly higher quality croplands are converted to artificial surfaces, while with decreasing population poorer quality croplands are converted; (iv) countries with more advanced economies generally convert cropland at higher speed; (v) there is a negative correlation between annual economic growth and the rate of cropland conversion; (vi) many of Europe's large metropolitan areas expand toward higher quality land; and (vii) the EU lost an amount of cropland production potentials equal to approximately 700.000 tons of wheat grain, annually, during the study period.

These alarming figures point toward the unsustainability of current trends in land use allocations in the long term. Since economic growth has a negative impact on cropland availability our findings suggest that the land conversion problem might be solved through administrative measures. The main interdependencies we identified should be considered in land use planning and decision making.

The planning of peri-urban and regional development should, in any case, also rely on soil and land assessments.

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4.3. Similarities and differences between China and the EU

A comparative assessment was performed using the DPSIR analytical framework (see Chapter 3 for details of the methodology) to explore cause-effect relationships related to urbanization and infrastructural development, land resources degradation and policy response in China and in the European Union. As shown in Table 1, soil resource degradation driven by urbanization and infrastructural development has its roots in economic development as an underlying indirect driving force in both regions. Population increase is an additional driving factor in China, while the effect of population change is not as pressing in the EU in general, although it might be important regionally within the Union.

Table 1. Results of the DPSIR assessment:
threats from urbanization and infrastructural development to land resources

	China	European Union
Driving forces	D*: urbanization and infrastructural development ID**: population increase and economic development (industrialization)	D: urbanization and infrastructural development ID: economic development (industrialization)
Pressures	urban built-up land expansion (infrastructure construction, sealing) contamination, compaction, erosion, landslides	urban built-up land expansion (sealing), contamination, compaction, erosion, landslides
State	loss of soils (soil sealing), contaminated and compacted soils	loss of soils (soil sealing), contaminated and compacted soils
Impacts	D: farmland loss; increased (urban) water runoff; urban heat island effect; less biomass production decrease of green coverage and carbon stock, contaminated food chain ID: food security and food safety flooding, polluted air and water resources	D: farmland loss; increased (urban) water runoff; urban heat island effect; less biomass production decrease of green coverage and carbon stock, contaminated food chain ID: food security and food safety flooding, polluted air and water resources
Responses	primary farmland protection, research for new concepts for urbanization and industrialization, new legal instruments	research for new concepts for urbanization and industrialization, new legal instruments

*D= direct, ID= indirect

Physical pressures on the soil resources are similar in both regions. Urban area expansion and related degradation pressures, such as soil sealing, contamination, compaction, erosion and landslides are widespread problems in China and Europe. These pressures result in loss of soil resource by decreasing its spatial extent (eg. sealing by asphalt) and functionality (eg. contamination or erosion of the productive topsoil).

Decrease of open (vegetated) soil surfaces is concerning all land use types both in China and Europe, but the conversion rate to built-up areas is the highest from croplands. This physical impact of urban built-up area extension has very significant influences on regional and global food security. Apart from decreasing arable land area, the extension of built-up areas has a series of negative environmental consequence as well. These include increased flood risk, urban heat island effect, air pollution and pollution of water resources. Needless to mention the economic cost of eliminating these harmful impacts and any secondary effects which might arise from countermeasures (eg. energy requirement of house cooling).

In order to combat the negative impact driven by obvious socio-economic development, society needs coordinated responses. The arsenal of these responses spans from research for new concepts of urbanization and industrialization to prompt policy actions, including legal instruments. Primary farmland protection is a priority issue to address if food security is to be maintained in China.

The DPSIR comparative analysis of threats from urbanization and infrastructural development to land resources show a quite similar picture for the EU and China with one main difference: the issue of population dynamics. Other driving forces as well as pressures and impacts are similar. The combined global impacts of changes in land resources in these two regions of the world further underlie the need to search for collaborative actions.

5. Agricultural intensification, water use and food security

5.1. Introduction

Winfried E.H. Blum

Soils are not only producing biomass in the form of food, fibre and renewable resources. They also filter rainwater, because each drop of rain falling on the soil has to pass the soil before it becomes ground water, in many of the cases the only source of drinking water. This means that soils are fulfilling two basic needs of humankind: clean water and safe and sufficient food. In this context, it has to be clearly seen that there is a competition between food production on top of the soil and ground water (drinking water) production underneath, because products applied to soil for improving plant growth can also infiltrate soil and contaminate the ground water resources. Fig. 1 shows the soil contamination by diffuse air pollutants, and additionally the application of waste compost or sewage sludge, pesticides and fertilisers, used for improving or maximising agricultural plant production.

Depending on the prevailing physical, chemical and biological soil characteristics, this application has to be controlled in order to avoid that these products are transported towards the ground water table, contaminating drinking water resources. – Food can be transported over long distances without severe financial and economic constraints, whereas high quality water resources in general cannot be transported over the same distances at reasonable economic conditions.

Therefore, investigations are needed in order to balance between optimal food production and ground water production for clean water supply, taking into consideration the local soil and climatic conditions. Such a procedure requires some time and should be initiated as soon as possible, in order to find the right balance for satisfying both basic human needs: enough and clean food and enough and clean drinking water.

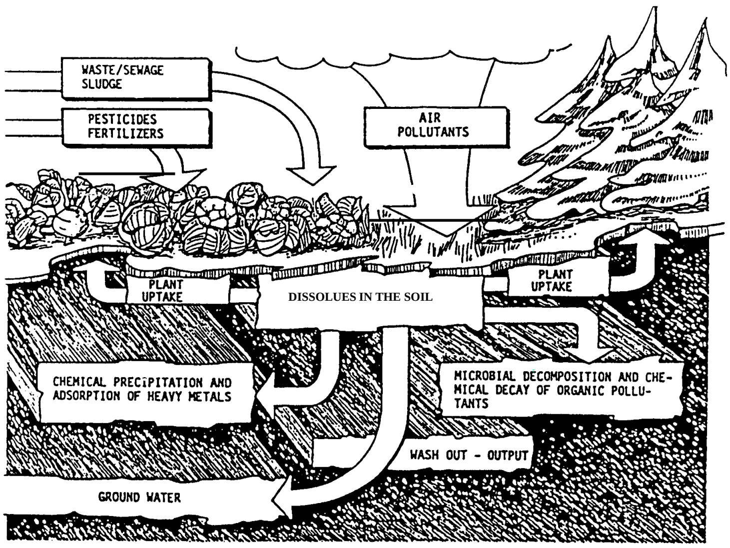

Figure 1. Soil contamination by fertilizers, sewage sludge and plant protection products, influencing ground water quality

5.2. Principles of sustainable soil management and land use on arable land

Tamás Kismányoky

When the world population reached 5 billion, at the end of the 1980s more and more doubts were expressed as to whether science would be able to guarantee the food supply of the growing population. Later it was realized that this problem could be solved. The reason for these doubts were the following:

- intensive agriculture was usually followed by an increase in erosion and the pollution of groundwater reserves;
- in intensively cultivated areas more energy inputs were needed / fertilizers, pesticides, farm machinery/ to achieve the same yield as before;
- the losses caused by diseases and pests were increasing;
- agriculture contributed to an increase in the greenhouse gases in the atmosphere;
- the former genetic heterogeneity of crops and farm animals was shifting towards homogeneity, leading to an increase in genetic vulnerability against biotic and abiotic stress;
- farmers required more financial support in both developed and developing countries to maintain former yield levels.

These disturbing facts urged a return to farming practices that are able to produce products with less energy but with more information that satisfy the demands. These renewed trends resulted in the concept of sustainable agriculture.

The definition of sustainable development for agriculture incorporates the basic elements of the definition given by the Brundtland Commission 'to meet the needs of present and future generations' but progresses further and involves the conservation of the natural resource base as well, making the use of environmentally non-degrading practices is an imperative. The various definitions given to describe sustainable agriculture contain many common elements. These are the following;

- The use of land as a natural resource.
- The conservation of resources, environment, land character and biodiversity.
- Maximal utilization of renewable natural resources.
- Maintaining and improving the economy and productivity.
- Improving the living standards of the rural population.

In this way continuous, quantitatively restrained but qualitatively limitless economic growth can be achieved, together with the conservation of resources and the environment in a broader sense, the protection of human health and an improvement in living standards.

There are some basic principles in the farming practice to satisfy the above mentioned requirements as follows:

- agroecosystems
- crop rotations

– farming by soilscapes

– managing zones within the fields

– managing noncrop period

– adaptation of conservation tillage

– organic matter cycles

– precision agriculture.

Agricultural ecosystems or agroecosystems, differ from natural ecosystems in both structure and function in a number of basic ways; agroecosystems are highly productive and have huge energy and material subsidies ‘labor, fossil fuels , pesticides , chemical fertilizers etc’. Agroecosystems tend to be very simple ecosystems and resemble the early stages of succession in natural systems, consequently they are therefore, inherently instable. Natural ecosystems are self-regulating and self-perpetuating; they display considerable continuity, while agroecosystems do not. Agroecosystems are not as diverse as natural systems because they do not have the wide range of genetic variability necessary to reduce the impact of variable environment conditions. Agroecosystems are managed by a strategy that varies considerably from nature’s balancing of productivity and the resulting progress toward stability. The sustainable agricultural paradigm toward sustainability is to alter the energy and material flows within current agricultural production systems to flows that are based on ecological principles. Successful soil management systems in the 21st century will be those that best incorporate ecological principles. There are many examples of ecologically sound concepts and cultural practices that could be implemented in production agriculture for the 21st century. New technologies ‘ precision technology’ will allow for managing soils in space and time on the basis of soils and their properties, management zones within the field, and processes active during the noncrop period. Such things as tillage, crop rotations, cover crops, alley cropping, alternatives to chemical pest control, manipulating genetic variability etc.

The crop rotations, adoption of conservation tillage and managing the organic matter cycles are in highlight in the case of sustainable soil management and land use. Crop rotation ‘ CR‘ in the narrow sense may be considered as a sequence of crops arranged in time and space and their regular re-establishment in the same field. CR in the wider-sense is a basis of plant production which integrates mutual interactions among crops, cultivation systems, fertilization systems, crop management and protection practices and other cultural and economic point of views, thus making an overall system of land use.

Specialized plant production implies a concentrated growing of a few crops. It raises a series of problems of biological, cultural, organizational and economic nature and makes it difficult to plan, design and establish effective crop rotation. Despite the difficulties it is necessary to provide the so called „biological minimum” even to rotation-independent crops i.e. that degree of concentration of crop species in rotation which will secure in its high and stable yields.

Improved production technology, especially the application of increased doses of mineral fertilizers, the new varieties and hybrids with a narrow genetic bases and use of high sowing densities, brought large increases of all field crop yields, but simultaneously, there occurred significant changes in the microflora.

Intensive use of crop rotation reduces the numbers of various pests and the need for applying pesticides to control them. It is also improves the preservation of predators and parasitoids, thus intensifying the nature regulation of pests in agrobiocoenosis. Crop rotation is an efficient and economical method of keeping the density of numerous pest species bellow the economic threshold.

CR is one of the oldest method of nematode control, too. CR effects the intensity of weed infestation in production fields and it provides better opportunities to control weeds by herbicides. Long-term monoculture changes the structure of the weed associations of cultivated fields. This is due to the use of selective herbicides, which successfully eradicate sensitive weed species which are then replaced by persistent and perennial weeds.

Fertilizers ‘ organic and mineral ‘ should be applied on the basis of plant and soil analysis and actual crop requirements for nutrients during one rotation. The placing and timing of the fertilizers are restricted in the frame of the CR. Nitrogen fixing annual and perennial legume crops reduce the N fertilizer input. Good crop rotations involve; the careful management of time, water, and nutrients.

Each crop in the CR will have specific demands for soil cultivation in respect of the primary and secondary cultivations, seed-bed preparation, selective cultivation and the fallow-season cultivations .The cultivations are done by different tools; plough, chisel, disk, rolls, harrow etc., which have special requirements for depth, time, soil conditions, residues. In case of CR the diversity of soil management ensured as well because the different crops need special soil cultivation methods.

Chemical and physical soil properties change with the plant production practices applied, among which the CR and fertilization interactions are particularly important. The effect of CR on soil properties depends on the root system of the crops grown. The given species in the CR influences the nutrient mobilization and uptake, the soil organic carbon content of soil, the C/N ratio, the pH value and many soil physical properties.

Crop rotations are natural resources among others to increase the yield of crops with lower industrial input. This is a tool in the land use activities to reduce undesirable environmental effects. CR meet the needs of the sustainable requirements in agriculture.

Soil tillage is an important technological process, which may determine the success of crop production. On the other hand, it may also induce agro-ecological and soil degradation problems. Consequently, soil tillage should be considered in terms of its impact on soil and environment conditions and on farm management. The main environmental risk factors of soil tillage are as follows:

- soil compaction
- water logging
- decrease in soil organic matter
- water and wind erosion
- deterioration in soil structure
- impact of soil biology
- impacts on soil chemical processes

Soil tillage methods can be grouped into three categories such as conventional tillage, conservation tillage and tillage designed to reduce specific constraints.

Conventional tillage is characterized by tilling the whole surface and using a moldboard plough as the primary tillage tool. An unreasonable length of cultivation time is required to obtain the soil conditions suited to the crop requirements and the energy costs are high. Tillage is classified as conservation tillage if the soil is not damaged while fulfilling the crop requirements or if the physical and biological state of the soil is improved with low energy input. The main feature of the this trend ‘ designed to reduce specific constraints‘ in a deterioration in soil quality as a consequence of inappropriate land use and soil tillage practices.

Soils are managed intensively during a certain period of the year most conducive to the production of a particular crop. Outside this period relatively little is done to manage the soil. The problem is that major degradation processes, such as erosion, leaching are often most intense during the noncrop period. A key to sustainability will be the extent to which agriculture will develop cultural practices to manage the noncrop period to minimize undesirable material flows from the agro-ecosystem. For example, cover crops could be seeded during the life cycle of a crop to serve ecologically important functions, including erosion control, suppression of pests, alteration of pest cycles, and fixation and biocycling of nutrients.

The functions of soil organic matter ’SOM‘ have a basic importance not only from an agricultural point of view but also for the ecosystem and the environment. The organic matter content of mineral soils varies between 0.5-6.0 %. Whilst the proportion of organic matter in a soil is not very high it has a key role to play in many soil functions and processes. The soil organic matter participates in various soil processes including biogeochemical cycling. There is always an equilibrium between the SOM and the plants, plant roots and residues. The transformation is one way in which the organic carbon pool is replenished. The functions of soil organic are of fundamental importance not only from the agricultural point of view but also from the point of view of the ecosystem and the environment.

In the case of carbon cycle and carbon balance in the soil some of the major processes influencing these worldwide are: the degradation of arable land resources, reduction in the land available for agricultural, urbanization, road construction and industrial development.

Intensive development began in the agriculture in the early 1950s in Europe leading to contradictory changes in the distribution of area according to land use, resulted in the significant decomposition of soil organic carbon and in erosion in the hilly regions. As a side-effect” of industrialization and the improvement of the infrastructure there was a significant decrease in the area of arable land. There were changes in crop production practice as well; changes in cropping systems, changes in the application of farmyard manure, fertilizer and lime and changes in the soil tillage system. Under the changing economic and environmental circumstances there is a great need for sustainable agricultural development, land use and soil management that is efficient and socially acceptable. One of the main constituent of this should be the maintenance of organic carbon pools in the soil. This can be achieved;

- rational land use / adapted to the agro-ecological conditions/
- improved crop production technologies, giving more attention to recycling of organic materials.

The pollution processes in agriculture differ fundamentally from the problems in other sectors e.g. industry. In agriculture pollution is caused not only by production processes but by natural processes, as well; such as soil degradation by erosion, during which phosphorus compounds may be leached into lakes and accelerate eutrophication processes. The general opinion is that in agriculture the main sources of pollution are pesticides, fertilizers and concentrated organic manure. In agriculture new forms of pollution have appeared, known as biological pollution. These include weeds, invasive plant and insect species, the toxins produced by fungi living on crops, and the presence in food of residues from the drugs used in animal husbandry. In the future great attention should be given to these new forms of pollution. The current controls on the use of pesticides are very strict and consequently pollution trought pesticides have reduced dramatically in the last two decades.

5.3. Impact of high intensity land uses on soil and environment in China

Ganlin Zhang and Renfang Shen

Introduction

With the continued increase of population and fast urbanization, food security has become one of the most serious challenges facing China. To continually strengthen the land use intensity, especially that of agriculture, is still a major measure to guarantee the country's food production. However, with that intensification negative effects of the intensive land uses have also emerged rapidly [1-3].

The Sino-European Panel on Land and Soil (SEPLS) was founded according to the collaboration memorandum signed between the Chinese Academy of Sciences and the European Union in 2010. This aims to advance the understanding of the current state of land and soil resources and potential environmental and socio-economic consequences of their future utilization patterns and to provide policy makers in both sides with a clear scientific view of these. The second seminar, following the first held in Ispra, Italy in 2010, was held in Nanjing in 2012. During the seminar, various issues related to land and soil use changes were discussed.

The main issues of agricultural and environmental challenges in China

Soils play a vital role in sustaining earth surface ecosystems and also provide with humans with non-renewable resources. As the major solution to solve the food security problem in China, intensive land uses have caused negative ecological and environmental impacts. The main conflicts between agricultural land use and environmental protection are reflected in the following aspects.

(a) High demand of food production and loss of arable land

As the most populated country of the world, the most outstanding challenge is the supply of arable land. Due to the large population (ca. 20% of the world) and relatively scarce arable land (ca. 7% of the world), the per capita arable land of China is only one third of the world average. A even more contrasting picture is China compared to that to United States and western Europe (Figure 1). The expectation of future population growth forces a continued increase of crop yield per unit, given that there is no room to expand the arable land. In 2012, the total population of 1.3 billion shares 580 million tons of grain production, while in 2030 those numbers are expected to be 1.6 billion and 720-800 million tons respectively. That is to say, by keeping the current arable land without any loss, the annual increase of per capita crop yield must reach at least 1% in the coming 20 years to avoid shortfalls.

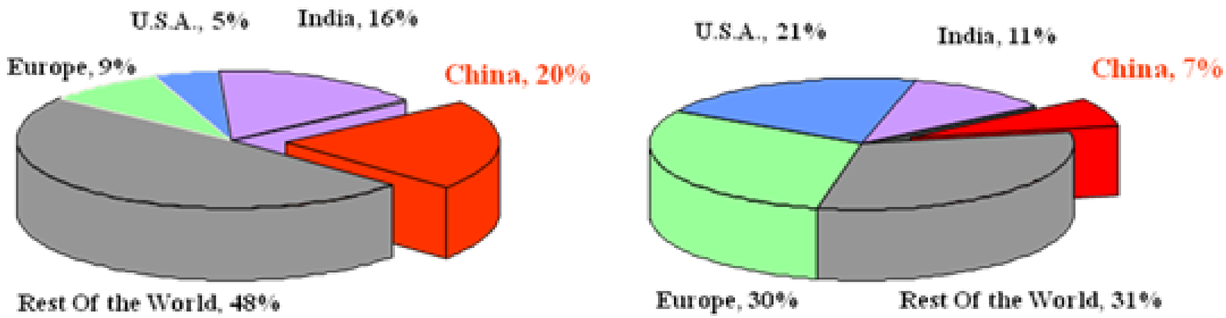

Figure 1. The population (a) and arable land (b) of China and other major regions

However, the loss of arable land in China is still an on-going trend as projected from the last three decades. The lost land is mainly flat and fertile areas taken by fast urbanization and industrialization. In addition, the shift of agricultural structure from crop production to high-value cash crops also contributes to the loss of food production potential. According to a recent report by the Ministry of Land Resources, the total arable land in China is only 120 million ha, which is a red-line that can not be crossed according to the national regulation. This corresponds to a per capita average of 0.090 ha, a fairly low number compared to the world average. Annually, the total loss of arable land in China amounts to some 60 000 ha.

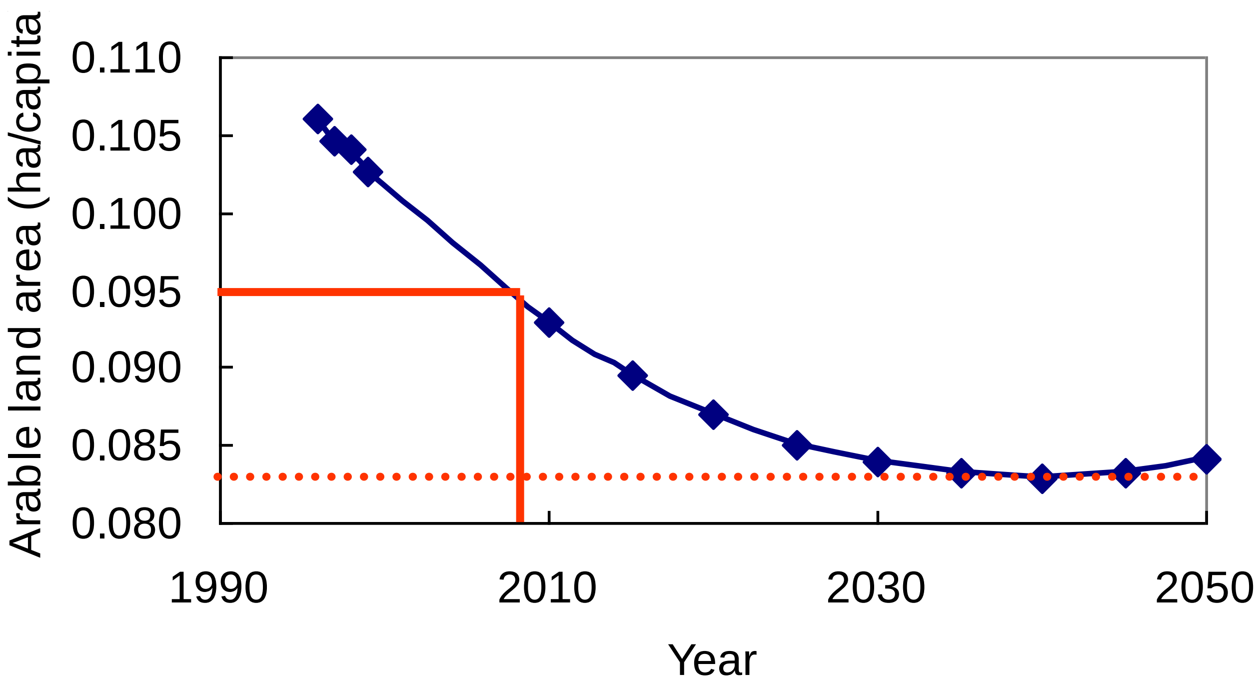

Figure 2. The current and projected per capita arable land in China

(b) The lowering of arable land quality

Long-term assessment of soil fertility in China shows that in some areas soil fertility has declined. From 1998 to 2005, high fertility cropland (average equivalent yield >5550 kg ha^{-1}) had decreased by 5.66%. Currently, such cropland accounts for 28% of the total, while the medium and low fertility cropland (average equivalent yield 1950-3600 kg ha^{-1}) accounts for 62%

Constrained by limited arable land, the only way to solve food security problem is to increase per unit crop production, which necessitates comprehensive measures including adopting genetically high production crops (such as hybrid rice), developing multiple cropping system, using more chemical fertilizers and enhanced greenhouse technology. However, due to the fragility of some intensive agricultural ecosystems, intensive human activities often lead to soil degradation. In particular, excessive agrochemicals often result in unbalanced soil nutrient conditions, soil acidification and decline of soil functional diversity. Agricultural land potentially threatened by fertility decline, soil erosion, secondary salinization and alkalinzation, industrial pollution and acid precipitation amounts to 64.7 million ha, i.e., 53% of the total cropland in China.

(c) Unbalanced nutrient supply and low nutrient use efficiency

Using chemical fertilizers is one of the most common practices to increase yield as reasonable application of fertilizers can improve soil nutrient status and increase crop yield [4]. The newest data from FAOSTAT shows that the average consumption of chemical fertilizers is more than 250 kgha^{-1} in China. China is the world's top chemical fertilizer consumer.

However, problems such as unbalanced fertilization and low use efficiency are common in many areas. The unbalance conditions include two aspects, i.e., regional unbalance and nutrient unbalance. There exists a large regional difference in the amount of fertilizers used, with high to extremely high use in the southeast China and low to medium use in central and west China. Also often high amount of fertilizers are used for horticulture especially for greenhouse vegetable cultivation. Although nitrogen and phosphorus have been over-used, potassium use has not been sufficient. The estimated dynamic change of nutrient balance in the soils of China is shown in Fig. 3.

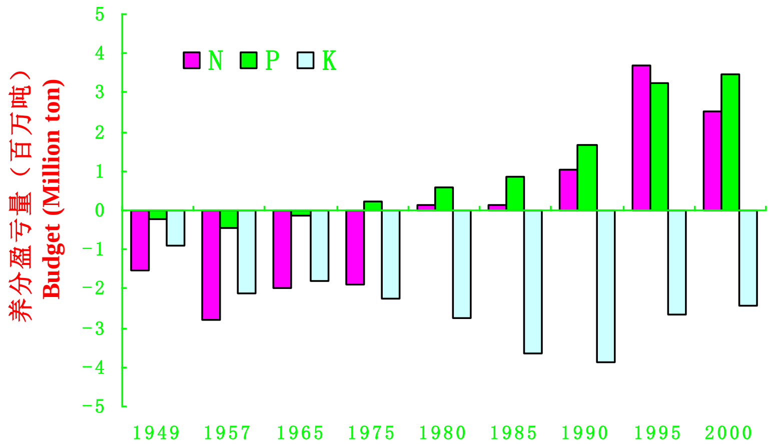

Figure 3. The estimated N, P and K balance in soils of China since 1949

Additionally, low use efficiency of chemical fertilizers causes off-site environmental problems. The discharge of excessive nitrogen and phosphorus leads to not only the eutrophication of surface water bodies, including lakes and near-shore seas, but also excessive nitrate in groundwater and crops. Artificial nitrogen fertilizers also contribute to the emission of N_2O, an important greenhouse gas[1].

(d) Soil pollution by over use of pesticide and other agricultural chemicals

The average consumption of pesticides in China is above the world average. Excessive pesticides enter into and persist in soil, threaten the safety of environment and food production[5]. It is estimated that currently there are about 16 million ha of cropland is polluted by organic pesticides. Residual pesticides in vegetables is often a threat to food safety in China.

(e) Insufficient water resource and low use efficiency

Water scarcity, in terms of both spatial and temporal demands, and low agricultural use efficiency have become the major limiting factors for agricultural development in China. The average water resource of China is 2173 m^3 per capita, which is only one fourth of the world average. Thanks to the monsoon climate of much of China, rainfall comes mainly during June and September, while spatially there is a pattern of high in south and low in north. For agricultural ecosystem, the shortage of water supply is estimated as 40 billion m^3 annually, mainly occurs in north China[6-7].

The scarcity of water is exacerbated by low use efficiency. The efficiency rate of irrigation water is only 40 ~ 50%, comparing with that of 70 ~ 80% in many developed countries[7].

(f) Worsening of soil and eco-environmental quality

Soil is an integral part of earth surface ecosystems. Intensified land use may strongly disturb the ecosystems, threaten food security and cause significant negative ecological and environmental impacts including instability of land ecosystems, unbalanced nutrient condition, soil acidification, salinization and biodiversity decline. Water and atmospheric environment are also affected as a result of overuse of agricultural chemicals.

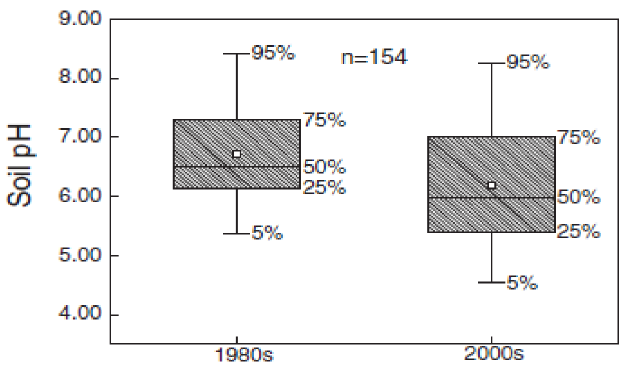

Figure 5. Lowering of soil pH between 1980s and 2000s as evidenced by long-term monitoring sites across 7 provinces in China[8]

As one of the indicators of soil quality, soil acidification rate is fast. Compared with that of the 1980s, soil pH had dropped 0.5 unit by the 2000s, especially in the southern part of the country where originally soils are acidic. Lower soil pH may also increase the toxicity of heavy metals.

Summary and beyond

The main agro-environmental problems of China are related to the responses of agricultural ecosystems to intensive management. The basic ecological rule of ecosystem stability means that purely pursuing the maximum output of agricultural ecosystems by increasing input of agro-chemicals but ignoring efficiency of materials and energy may lead to ecosystem degradation. Degradation of soil structure and chemical properties are simply the responses of the ecosystems, which may further affect their functions.

In order to protect the food security and food safety of the country, a better understanding of the systematic processes of land and soil, especially the interaction within soil and between soil and biological system, soil and water, soil and atmosphere, will ensure a balanced management practices to harmonize agriculture and environment to reduce the negative effects of intensive soil and land use.

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5.3.1. The positive and negative effects of agricultural intensification on soil carbon and environment in Huang-Huai-Hai plains,China

Xiangbin Kong

Introduction

China has succeed in feeding 22% of the world's population with only 7% of the world's arable land area (Piao et al.,2009) whilst increasing cropland's soil organic carbon(SOC) stock by between 311 to 401 Tg per year (Huang et al.,2006). It is known that food security had been achieved as a result of a substantial increase in the irrigated area at the cost of over extraction of groundwater (Liu et al.,2004) and application of high rates of nitrogen (N) fertilizer whilst there has been a loss of high fertility arable land caused by rapidly urbanization and industrialization (Kong et al., 2009). For example, grain production and fertilizer N consumption reached 502 million and 32.6million tonnes nationally in 2007, respectively, increases of 54 and 191% as compared with 1981(Guo, et al., 2010). At the same time, grain-derived water consumption had a good match with grain production (Fig.1.）.

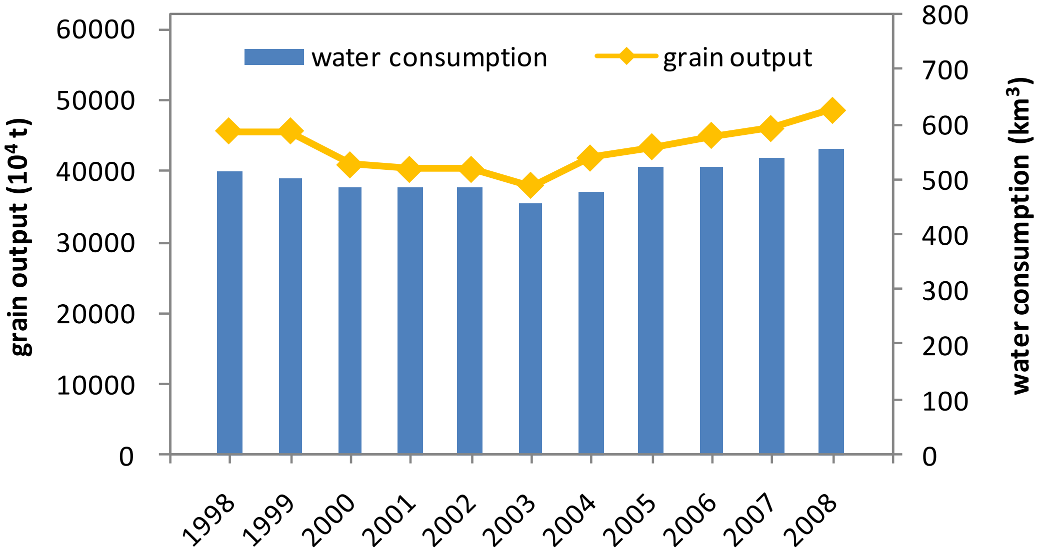

Figure 1. Grain output and associated total water consumption over 1998-2008

Agricultural intensification leads to change in soil organic carbon food security, and the negative effects such as groundwater depletion. Here, we take HHH (Huang, Huai and Hai) region as the case study to show the positive and negative effects by agricultural intensification.

Study Area

The HHH plains, located in the east of China, are formed by alluvial sedimentation of the three eastward flowing rivers, i.e., the Huang River (Yellow River), Huai River, and Hai River (Fig.2.). It is the largest plain and an important agricultural region in China, covering 350,000 km^2, with 18.67 million ha of farmland and a population of 200 million (Liu, et al.,2004). The winter wheat and summer maize has been the most popular cropping systems in the HHH region.

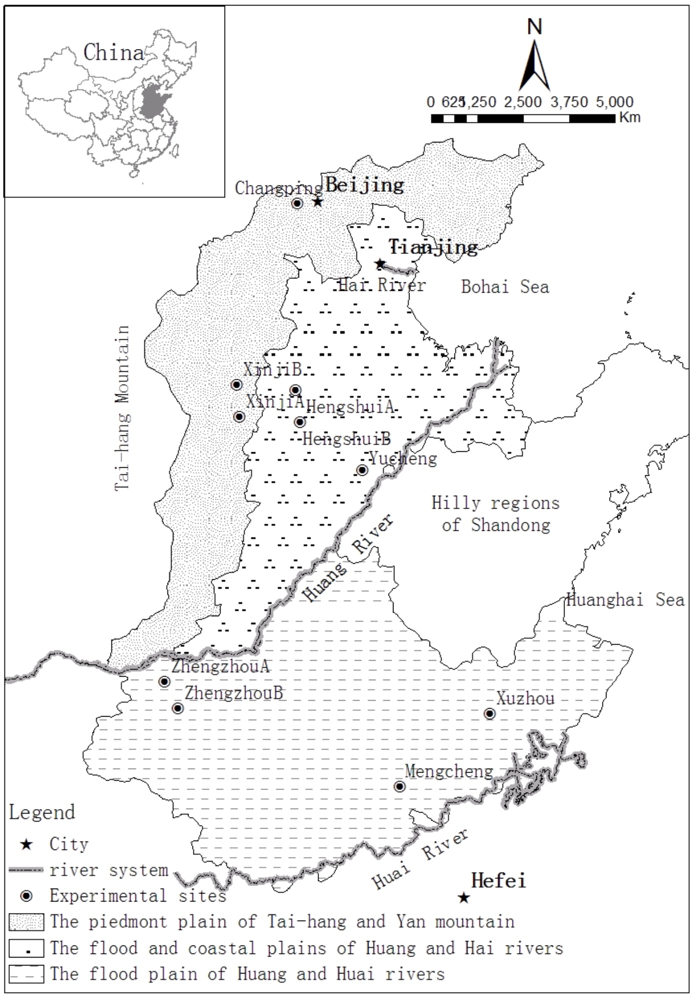

Figure 2. The HHH region in China

The HHH plains, located in northern China, are formed by alluvial sediments deposited by three rivers (i.e., the Huang River or Yellow River, Huai River, and Hai River) (Fig.2). These are the largest plain and constituting an important agricultural region in China, covering 320,000 km2, with 18.67 million ha (M ha) of farmland and a population of 200 million (Liu et al.,2010). The region is characterized by intensive use of irrigation and chemical fertilizers, and the predominant cropping system in the region is double-cropping of winter wheat and summer maize. The SOC concentration was measured for soils from different long-term experimental sites in the HHH (Fig.2). The groundwater decline was got from the statistics yearbook in China (http://www.cws.net.cn/).

SOC data were collected from eleven long-term experimental sites between 1980 and 2005 across the HHH region (Table 1.) These studies include a total of four fertilizer treatments including: (ⅰ) no chemical fertilizer or organic manure as control treatment (CK); (ⅱ) chemical nitrogen(N) fertilizers applied without organic manure (UF); (ⅲ) combined application of chemical fertilizer N,P and K without organic manure (CF); and (ⅳ) integrated nutrients management of applying manure/straw along with combined application of chemical fertilizer N,P and K (INM).

Results

Increase in crop production by increasing in fertilizer input

As in other countries in the world **(**Rodell,et al.,2009)**,** China's success in food security lies in agricultural intensification fueled by the "green revolution". Agricultural intensification in China has dramatically increased maize and wheat production by 150% and 240% over the last four decades**(**Piao, et al. 2010), by use of 40% of total world fertilizer **,** and 7.0% of total world fresh water.

The HHH region, producing 60-80% of China's total wheat and 35-40% maize production (Fig.4), has become the region of the highest agricultural intensification in China. HHH region has increased average wheat and maize yield (Mg ha^{-1}) from 1582 and 4492 in 1985 to 5860 and 5610 in 2009, about 1.25 and 1.07 times of China's average yield for wheat and maize.

The massive increase in crop yields and production in the HHH region is fuelled largely by an increase in agricultural intensification through increase in consumption of water for irrigation use, and increase in rates of application of N,P and K to about 1.66 , 4.43 and 1.46 times of the average China (Fig.4), which began in the1960s (Guo,et al.,2010)**.**

Table 1. Soil and Climate environments of the 11 long-term experimental sites in HHH region

Sites	Location			Annual rainfall	Annual accumulative temp.	Annual average temp.	Experiment duration	Soil Properties			
								pH	Soil texture	Bulk density	Soil subgroup in China
County	Province	Latitude	Longitude	mm yr^{-1}	degree days	℃	year			Mg m^{-3}	
Changping A	Beijing	40°02′	116°10′	574.1	4874.0	12.8	1984-1997	8.6	Silty clay loam	1.45	Shajing-endorustiUdicCambosols /Inceptisols
Changping B	Beijing	40°10′	116°13′	574.1	4874.0	12.8	1991-2005	8.8	clay loam	1.3	Motti-argicendorusticUdicCambosols /Inceptisols
Xinji A	Hebei	37°54′	115°13′	461.9	5015.7	13.2	1979-1999	8.3	silt loam	1.4	Calic-endorustiAquicCambosols /Inceptisols
Xinji B	Hebei	37°55′	115°14′	461.9	5015.7	13.2	1979-1999	8.2	silt loam	1.4	Mottli-endorustiAquicCambosols /Inceptisols
Henshui A	Hebei	37°42′	115°42′	478.1	4996.3	13.2	1979-2002	8.3	loam	1.4	Mottli-endorusticAquicCambosols /Inceptisols
Henshui B	Hebei	37°43′	115°43′	478.1	4996.3	13.2	1979-2002	8.2	loam	1.5	Mottli-argicAquicCambosols / Inceptisols
Yucheng	Shandong	36°50′	116°34′	582	4951	13.4	1987-2005	8.3	loam	1.3	Mottli-Salic AquicCambosols / Inceptisols
Zhenzhou A	Henan	34°46′	113°40′	623.2	5334.0	14.4	1980-2000	8.1	loam	1.5	Mottli-endorusticAquicCambosols /Inceptisols
Zhenzhou B	Henan	34°47′	113°41′	623.2	5334.0	14.4	1990-1999	8.3	loam	1.5	Mottli-argicAquicCambosols / Inceptisols
Xuzhou	Jiangsu	33°54′	117°57′	837.3	5368.2	14.6	1980-2005	8.3	sand loam	1.4	Xanthic-enorusticAquicCambosols /Inceptisols
Mengchen	Anhui	33°52′	115°16′	790.1	5436.8	14.7	1994-2001	6.3	clay	1.6	Shajiang-ClaypanicAquicCambosols /Inceptisols

Soil classification is according Chinese soil classification

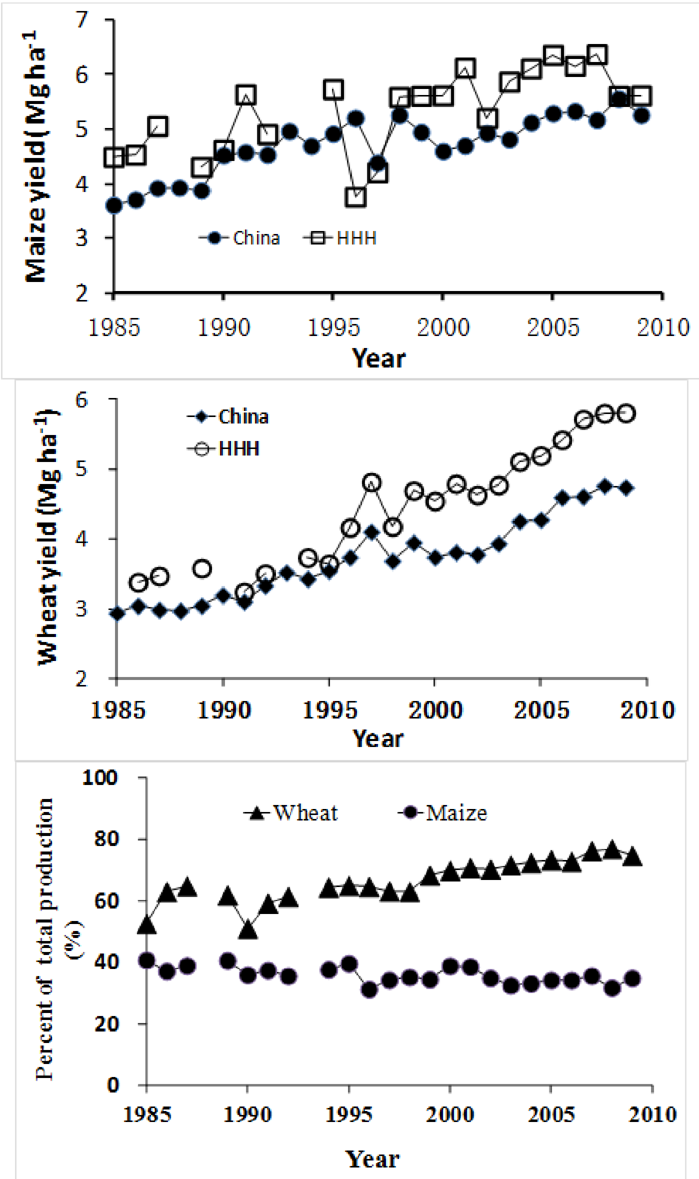

Figure 3. Observed variations in crop yields and production in the HHH region during the period 1985-2010.

a) *Changes in maize yield during 1985-2010, expressed as mean maize yield per unit area for the HHH region and China. The black line is fit to the data: for HHH region is $y1=68.33x-131163$ ($R^2=0.47, P<0.001$); for China is $y2=63.69x-122467$($R^2=, P<0.001$). The data come from China's agricultural statistics (2010).*

b) *Changes in wheat yield during 1985-2010, expressed as mean maize yield per unit area for the HHH region and China. The black line is fit to the data: for HHH region is $y1=115.72x-226789$($R^2=0.91, P<0.001$); for China is $y2=75.97x-147997$($R^2=0.92, P<0.001$). The data come from China's agricultural statistics (China Statistics press, 2010).*

c) *Changes in percent of total China's production for wheat and maize during 1985-2010, expressed as percent (%) for the whole HHH region. The black line is fit to the data: for wheat yield is $y1=0.82x-1579.2$($R^2=0.78, P<0.001$);for maize yield is $y2=-0.23+495.38$($R^2=0.39, P<0.001$)*

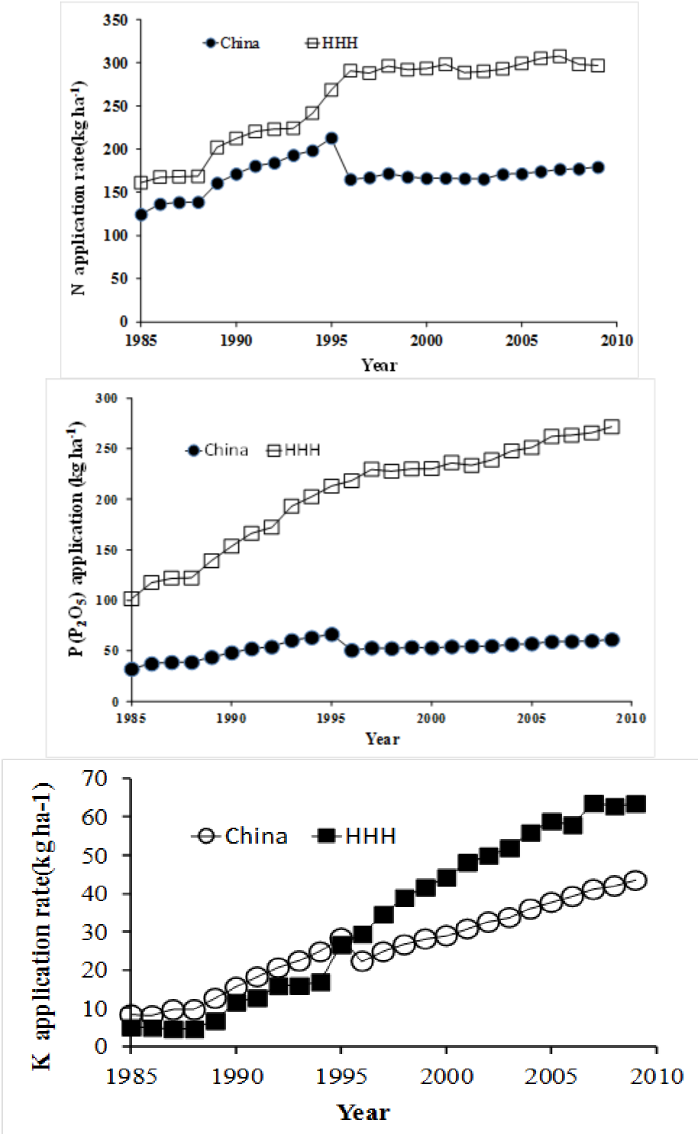

Figure 4. Observed variations in rate of chemical fertilizer of N,P,K application in HHH region compared with China national doses

a) *Observed variation in rate of chemical N during 1985-2010, expressed as rate per unit area for the HHH region and China. The black line is fit to the data: for HHH region is y1=6.36x-12455(R^2=0.84,P<0.001), for China is y2=1.09-2015.4(R^2=0.17,P<0.05). The data come from China's agricultural statistics (China Statistics press, 2010).*

b) *Variations in rate of chemical P during 1985-2010, expressed as rate per unit area for the HHH region and China. The black line is fit to the data: for HHH region is y1= 6.88x-13530 (R^2=0.93,P<0.001); for China is y2=0.84x-1628.3 (R^2=0.52,P<0.001). The data come from China's agricultural statistics (China Statistics press, 2010).*

c) *Variations in rate of chemical K during 1985-2010, expressed as rate per unit area for the HHH region and China. The black line is fit to the data: for HHH region is y1=2.92x-5792.6(R^2=0.98,P<0.001); for China is y2=1.48x-2925.7(R^2=0.97,P<0.001). The data come from China's agricultural statistics .*

Increase in Soil Organic Carbon

Mean SOC stock in different sites from 1980 to 2005 are shown Fig. 5. On the whole, the ranges of change in SOC stock were in the order of INM>CF>UF>CK. The mean SOC stock for INM treatment shows significant differences with CK for most soil subgroups, except for Motti-argicendorusticUdicCambosols. However, there were no significant differences for UF treatment compared with CK treatment for four different soil types.

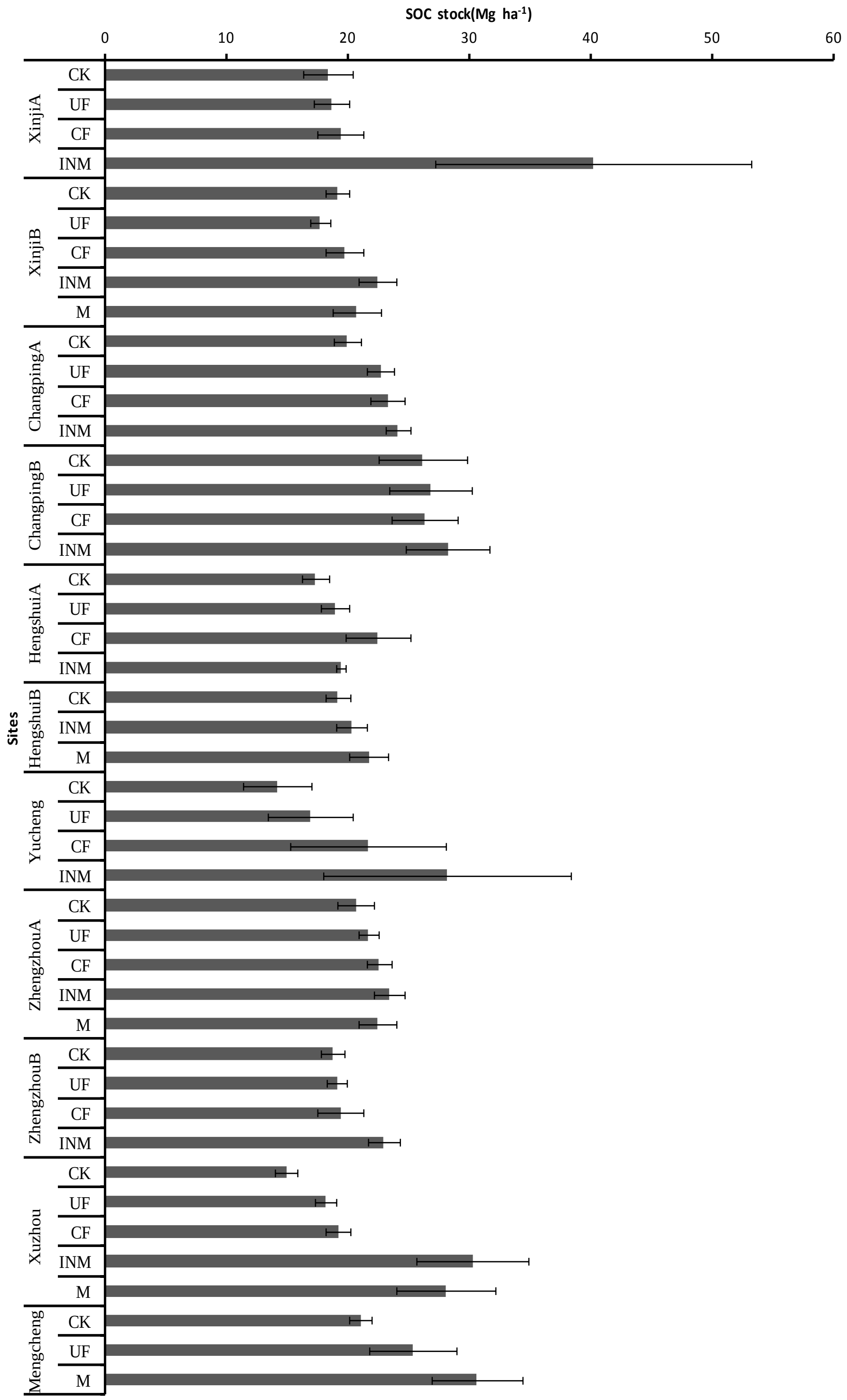

Figure 5. SOC stock for different fertilizer management across the HHH region

The mean SOC stock in CK treatments ranged from 14.19 in soil subgroup Mottli-Salic AquicCambosols to 26.17 Mg ha^{-1} in soil subgroup Motti-argicendorusticUdicCambosols. The mean SOC stock for UF treatmenst ranged from 17.71 in soil subgroup Mottli-endorustiAquicCambosols to 25.34 Mg ha^{-1} in soil subgroup Shajiang-ClaypanicAquicC ambosols. The mean SOC stock for CF treatments ranged from 19.38 Mg ha^{-1} in soil subgroup Calic-endorusti Aquic Cambosols to 26.29 Mg ha^{-1} in soil subgroup Motti-argicendorustic Udic Cambosols. The mean SOC stock for INM treatments ranged from 19.4 in soil subgroup Mottli-endorustic Aquic Cambosols to 40.25 Mg ha^{-1} in soil subgroup Calic-endorustiAquicCambosols.

As to the order of treatment effects for different soil subgroups, there are similar trends of INM>CF>UF>CK except for the soil subgroup Calic-endorustiAquicCambosols, Mottli-endorusticAquicCambosols, and Motti-argicendorusticUdicCambosols. The INM treatments appeared to be the best way to increase SOC stocks. However, the range of increases for the same fertilizer management varied with different soil subgroups (Table 2). Compared with CK treatment, the INM treatments show the greatest increase in SOC stock for soil subgroups Calic-endorustiAquicCambosols and Mottli-Salic AquicCambosols.

Exploitation of groundwater

One of the costs of the increase in crop production and SOC is the excessive withdrawal of groundwater in the HHH region. Over exploitation of groundwater for irrigation has led to an increase in the depth of the groundwater table. Over the western part of the plain, the groundwater table has been falling at an accelerating rate. The decline of the shallow groundwater table observed along the Beijing–Guangzhou railway line in North China is shown in Fig 6. The shallow groundwater table fell from a depth below ground of 3 to 4 m in the 1950s to more than 20 m in the 1980s and to about 30 m in the 1990s. The fall in groundwater levels shows a negative relationship with the increase in SOC.

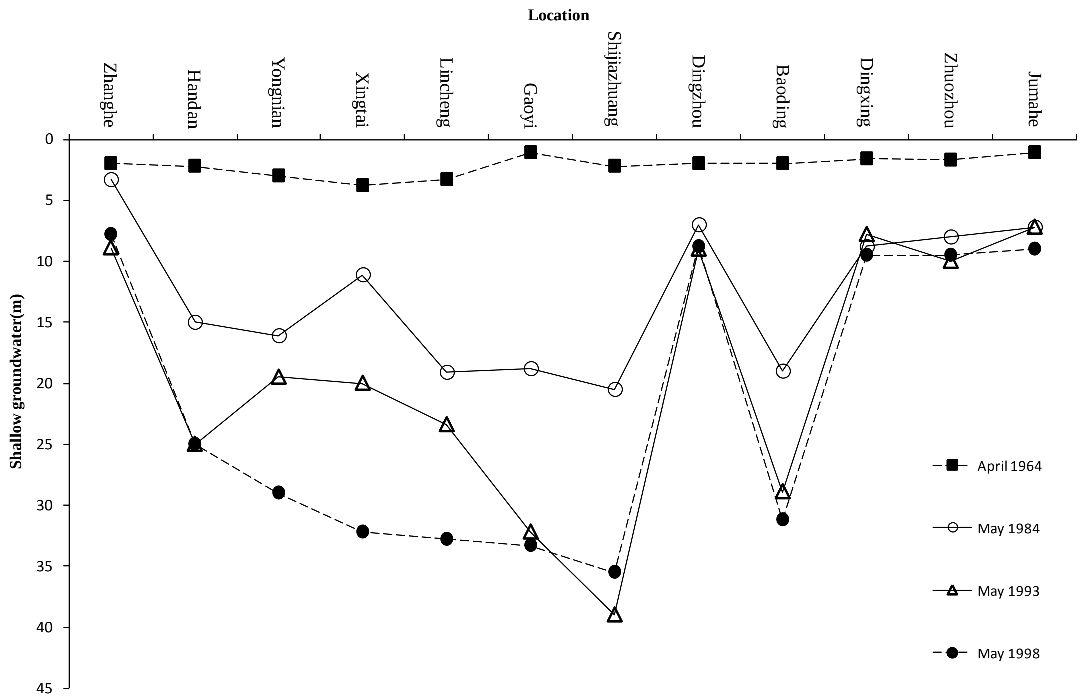

Figure 6. Shallow groundwater change from south to north in the HHH region

Conclusion

The HHH plains have become the critical region to ensure China's food security. The results here show that the increase in crop yields and SOC stocks, and the decline in groundwater levels as a result of agricultural intensification factors such as the increase in the amount of irrigation and the fertilizer application rate. There has during this intensification period been an increase in the SOC stocks. The increases in the SOC stocks has been achieved by high rates of fertilizer application and the introduction of the two cropping system of winter wheat and summer maize with its increased use of irrigation. Thus, the increase in SOC stocks is at the cost of the marked fall in groundwater levels.

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5.3.2. Changing of organic matter content of soil in long term field experiments in Hungary

Tamás Kismányoky

Introduction

Soil organic matter (SOM) is the vast array of carbon compounds in soil. Originally created by plants, microbes and other organisms, these compounds play a variety of roles in nutrient, water and biological cycles. For simplicity, organic matter can be divided into two major categories: stabilized organic matter which is highly decomposed and stable, and the active fraction which is being actively used and transformed by living plants, animals and microbes. Two other categories of organic materials are living organisms and fresh organic residue. These may or may not be included in some definitions of soil organic matter.

Many soil organisms decompose plant and animal tissues and transform these organic materials into new compounds. After years or decades of these transformations, what remains in the soil are large, complex compounds that few microbes can degrade. Other compounds become bound inside soil aggregates an are not accessible to microbes. These difficult-to decompose, or stabilized substances make up a third to a half of soil organic matter. Some of these decomposed compounds are bound to clay, and are important in 'gluing together' micro-aggregates of soil particles. Stabilized organic matter acts like a sponge and can absorb six times its weight in water. In sandy soils, water held by organic matter will frequently make the difference between crop failure or success during a dry year. Both organic and clay particles can hold on to nutrients electrochemically-like a magnet holds on to iron filings. The amount of cations that the organic compounds and clay could carry and make available to plants is called the soil's cation exchange capacity (CEC).

Up to 15% of soil organic matter is fresh organic material and living organisms. Another third to one half is partially and slowly decomposing material that may last decades. This decomposing material is the active fraction of soil organic matter.

The active organic matter and the microbes that feed on it are central to nutrient cycles. Many of the nutrients used by plants are held in organic matter until soil organisms decompose the material and for example release ammonium and other plant-available nutrients. Organic matter is especially important in providing nitrogen, phosphorus, sulfur and iron. Organic matter also effects nutrient cycles by chelating (chemically holding on to) nutrients and preventing them from becoming insoluble and therefore unavailable to plants. For example, humic substances help make iron available to plants even in medium-to-high pH soils. Regular additions of organic matter important as food for microorganisms, insects, worms and other organisms and as habitat for some larger organisms.

A key question is: 'what does organic matter do in the soil on arable land?'

The SOM plays a very important role in the nutrient cycling, water dynamics, soil structure and many soil functions.

The amount of Organic Matter (OM) in soil is the result of two processes: the addition of organic matter (roots, surface residue, manure etc.) and the loss of OM through decomposition. Four main factors affect both additions and losses: (i) management (ii) soil structure (iii) landscape position, (iv) vegetation and (v) climate.

To build organic matter levels in topsoil, more OM must be added than is lost to decomposition and erosion. As with a person trying to lose or gain weight, increasing organic matter is about changing the balance between how much energy goes in and how much is burned off.

Intensive tillage aerates the soil and decomposition rate will increase with the increased aeration.. Decomposition is desirable because it releases nutrients and feeds soil organisms. But if decomposition is faster than the rate at which organic matter is added, SOM levels will decrease. To increase the levels of SOM the rate of decomposition can be reduced or the additions of organic material increased. In agricultural systems the additions to the soil may be from plants and animals grown in the soil or by importing organic materials.

Building organic matter is slow process. When the rate of addition exceeds the rate of decomposition, first, the amount of residue and active OM will increase. Gradually, the species and diversity of organisms in the soil will change, and amount of stabilized organic matter will rise. It may take a decade or more for total OM levels to significantly increase after a management change to increase organic matter levels. Fortunately, the beneficial effect of these changes often appears before there is a perceptible rise in SOM levels. These improvements, however can be reversed in a year or two if the practices are not continued.

In examining data on the OM content of representative mineral soils , it is clear that there are differences between soils of different provinces ,but also within particular localities.

Climatic conditions, especially temperature and rainfall, exert a dominant influence on the amounts of OM found in soils. When moving from a warmer to a cooler climate ,the OM content of comparable soils under similar management tends to increase. This is because the overall trend in the decomposition of OM is accelerated in warm climates, while a lower rate of decomposition is the case for cool regions. Within belts of uniform moisture conditions and comparable vegetation, the average total SOM contents increases from two to three times for each 10 degree C fall in mean annual temperature (Soil Atlas of Europe, 2005). Under comparable conditions, OM content increases as the moisture becomes greater.

From the map of the distribution percentage of the organic matter content of Hungarian soils (Figure 2) it can be seen that in about 60% of Hungarian soils the organic matter content is between 1 and 3%. In sandy soils it is usually below 1 % (15 % of the area),/ whilst in clay loams it is between 3 and 4 % (also 15 % of the total area). The SOM content is over 4% on about 5% of the territory. The territorial distribution shows that sandy soils with low original OM contents are situated in south-western , central and n the eastern parts of Hungary, whilst those with the highest OM content are found in the south-eastern part.

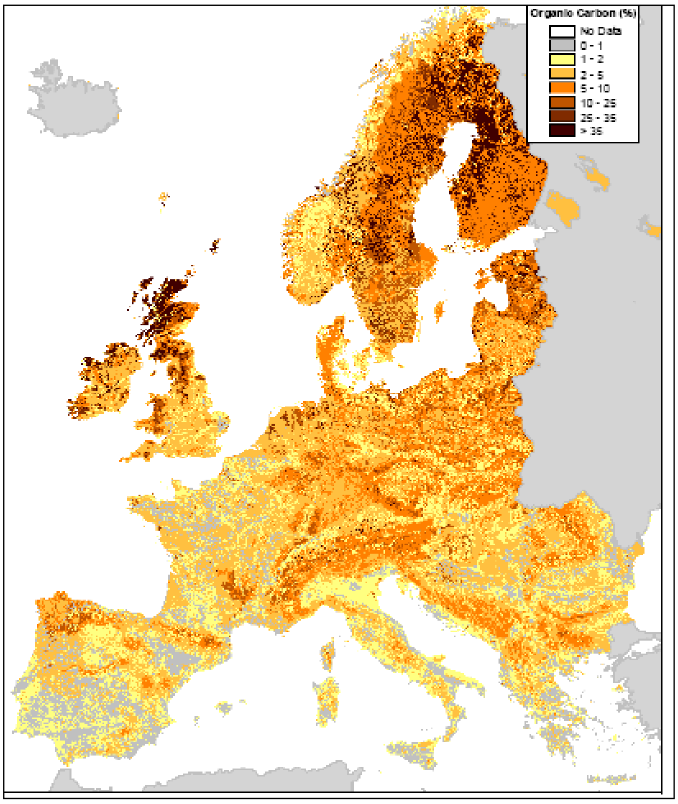

Figure 1. Organic carbon content % in the surface horizon of soils in Europe (Jones et al., 2005)

Building soil organic matter is a slow process, and this process can be studied reliably only in long-term field experiments.

Long term field experiments play a significant role in agronomy research, since they are sources of information from which we can learn a lot about the factors that influence soil fertility and its sustainability. In most cases, effects and interactions of experimental factors and treatments can be understood only from long-term data across different soil and climatic conditions (Kismanyoky-Toth, 2007).

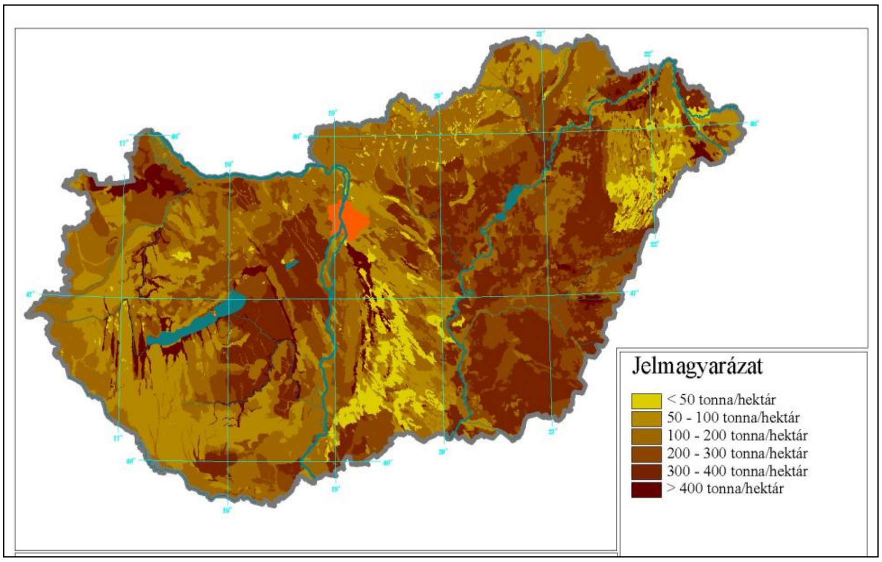

Figure 2. Soil organic matter content in Hungary (RISSAC 208)

The results of long-term field experiments are valid for a given territorial unit and a given time interval but we want to use this information as the scientific basis for general recommendations over a larger area and for a longer period (Várallyay, 2009).

Guidance on many of our current agronomic problems can be provided from the results of long term experiments (Körschens, 2005).

The international working group for soil fertility (International Working Group of Long-term Experiments-IOSDV/ILTE) within the International Soil Science Society /(ISSS) under leadership of Prof. Boguslawski formed the IOSDV network with 10 participating European countries in 1984.In this paper some result of the international mineral and organic N fertilization trial located in Keszthely (/Hungary) are reported. The long-term field experiment testing mineral fertilizer in combination with different forms of organic manure has provided specific results concerning the interactions of fertilizer manure treatments on cereal production and SOM content of soil.

This case study was written after the paper of Kismányoky and Tóth, Z. (2012.).

Materials and methods

A study was conducted in the international mineral and organic nitrogen fertilization trial (IOSDV) located in Keszthely in the western part of Hungary (46°44' N, 17°13' E, 112 m above sea level). The experiment was set up in the autumn of 1983 and the first harvest year was 1984.

The soil class at the study site was a Ramann-type brown forest soil (Eutric Cambisol, WRB) containing 410 g kg^{-1} sand, 320 g kg^{-1} silt, and 270 g kg^{-1} clay. The naturally available phosphorus (P) content of this sandy and loam soil was low (ammonium-lactate soluble [AL] P_2O_5: 60-80 mg kg^{-1}), the potassium (K) content medium (AL-K_2O: 140-160 mg kg^{-1}) and the humus (H, SOM) content fairly low (16-17 g kg^{-1}), with a pH_{KCl} value of 7.1. The bulk density of the undisturbed soil was 1.53 g cm^{-3}. The 100 year average annual precipitation was 683 mm, but the distribution was often unequal (most rainfall occurs in June – 79.0 mm - and low rainfall can be observed in January – 34.5 mm). The long-term annual mean temperature was 10.8 ^oC.

The factorial experiment had a strip-plot design with three replications. The size of the subplots was 48 m^2. The factorial treatments were mineral N fertilization (5 rates) combined with organic fertilizers (3 variants). Treatments were applied in a field with a three-year cereal crop rotation (maize, winter wheat, winter barley) system. The mineral N fertilizer rates were apllied 0, 70, 140, 210 and 280 kg ha^{-1} N in the case of maize, 0, 50, 100, 150 and 200 kg ha^{-1} N for winter wheat and 0, 40, 80, 120, 160 kg ha^{-1} N for winter barley. N rates are referred to in the text as N0, N1, N2, N3 and N4. Supplemental P and K fertilizers at rates of 100 kg ha^{-1} P_2O_5 and K_2O were applied on all of the experimental plots (even on the N control plots). The organic fertilizer treatments were applied as a complementary fertilization with the mineral NPK fertilizers having 3 different variants: (I) no organic fertilizer application (control), (II) organic manure (OM) application (35 t ha^{-1}, in every third years before maize), (III) straw (St) incorporation (completed with 10 kg mineral N for each t straw ha^{-1}). The total amount of residue yield of all the three crops that were produced on each plots were measured and incorporated into the soil. In addition after winter barley on the "St" plots an extra green manure (GM) was applied (*Raphanus sativus* var. Oleiformis) as a 2nd crop sowing into the barley stubble. The average N content of OM was 4 g kg^{-1}.

In the text the following abbreviations are used:

N0PK: no organic fertilizer application (without N fertilizer)

NPK: no organic fertilizer (averaged over the N2, N3, N4 variants without residues)

OM: with organic manure (farmyard manure)

SM: with straw/stalk manure (residues)

Soil tillage and all soil and pest managements were applied as usual in conventional farming systems. The soil C_{org} and humus (H, SOM) content was determined by Tyurin's method. The statistical significance of the experimental factors and treatments (increasing rates of N fertilizer, organic fertilizer, and the mineral fertilizer × organic fertilizer interactions) was tested by regression analysis and analysis of variance as two factorial experiment on a $p<0.05$ level. SPSS statistical software was used for the tests.

In this paper the last 12 years (1999-2010) of the long-term field experiment (established 1983) is evaluated. The yield measurement are done annually, while the soil samples for C_{org} analyses were taken in every third year (crop rotation 6th, 7th, 8th, and 9th) in 2000, 2003, 2006, and 2010.

Results and discussion

Yields of crops in the crop rotation as a function of different rates and forms of fertilizers (1999-2010)

The relationship between N fertilization and crop yield can be described by a quadratic equation. It is well known that with increasing N rates the crop yield will increase to a certain maximum level above this the yield will remain at the same level or may even decline. When the inorganic N fertilizer treatments are supplemented with different organic manures the combined effect produces the same curvilinear shape but on a higher level.

The yield of winter wheat (Figure 3) varied between 2 and 6 t ha^{-1} depending on the different manure treatments when averaged over the rotation cycles. The maximum grain yield was obtained when 150-200 kg ha^{-1} N was applied. The yield was lower when plots received mineral NPK fertilizers alone (no organic fertilizer) compared to plots that received OM or SM applied to complement the mineral fertilizer inputs. The positive effect of OM+mineral fertilizer application on crop yield were also reported by Kuldkepp (1997), as well as Pfefferkorn and Körschens (1995) in similar long-term field experiments, in IOSDV Tartu, Estonia and IOSDV Bad Lauchstadt, Germany.

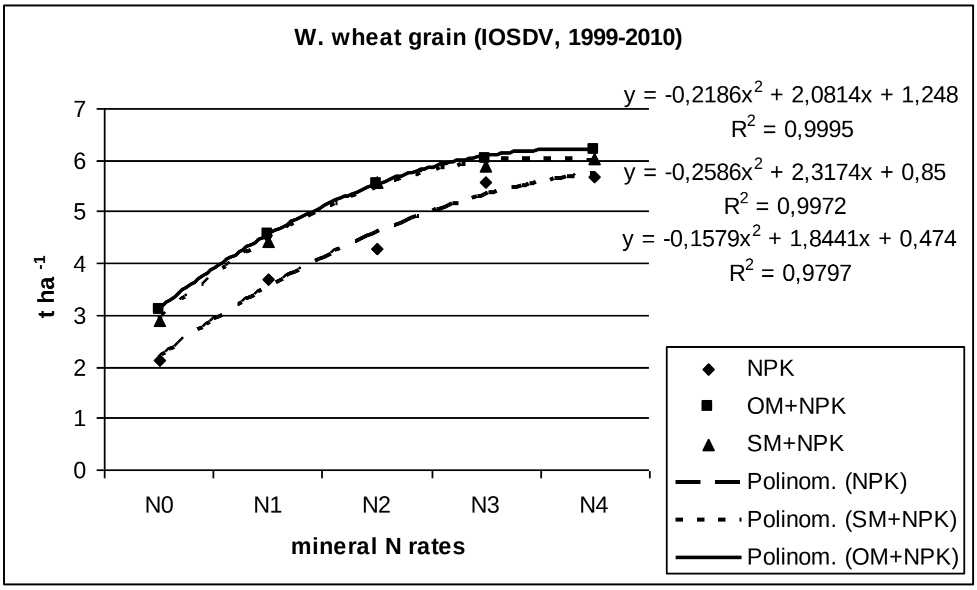

Figure 3. Grain yield of winter wheat as a function of increasing rates of N fertilizer and N fertilizer plus organic manures when averaged over the 6.-9. rotations (1999-2010) in the long term IOSDV trial Keszthely, Hungary.

The N0 treatments yielded about 2 t ha^{-1} when averaged over the decade, whereas in plots with complementary organic fertilizer application N0 plots yielded 1 t ha^{-1} more, which is due to the additional nutrient content of OM extended over the whole crop rotation. The positive effect of organic fertilizer compared to the mineral NPK fertilizer alone was significant in all of the N fertilizer treatments.

The grain yield of maize varied between 4-9 t ha^{-1} depending on the different N fertilizer and manure treatments (Figure 4.).

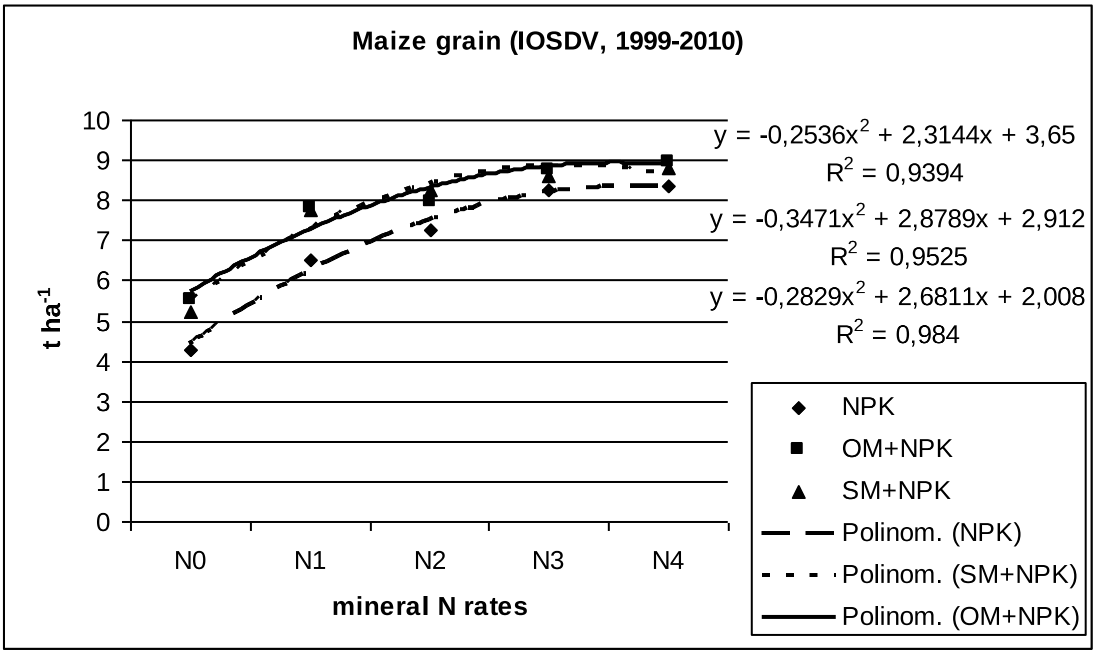

Figure 4. Grain yield of maize as a function of increasing rates of N fertilizer and N fertilizer plus organic manureswhen averaged over the 6-9. rotations (1999-2010) in the long term IOSDV trial Keszthely, Hungary.

The highest grain yield was obtained when 210-280 kg ha^{-1} N was applied, but the yield increase between application rates of 210 and 280 kg ha^{-1} was not statistically significant difference. The average yield level was significantly lower with mineral NPK fertilizer alone as compared with the application of organic fertilizer to complement the mineral fertilizers. On the N0 plots, the complementary organic fertilizer application resulted in 1.0-1.5. t ha^{-1} extra yield. No significant difference in yield was detected between the NPK+OM and the NPK+SM treatments.. The incremental yield increases tended to diminish with higher fertilizer rates and the interactive effect of mineral N × organic fertilizer application was also smaller at the high N rates.

The winter barley followed the winter wheat in the crop rotation. The effect of N fertilizers on barley was similar to those observed for wheat (Figure 5.).

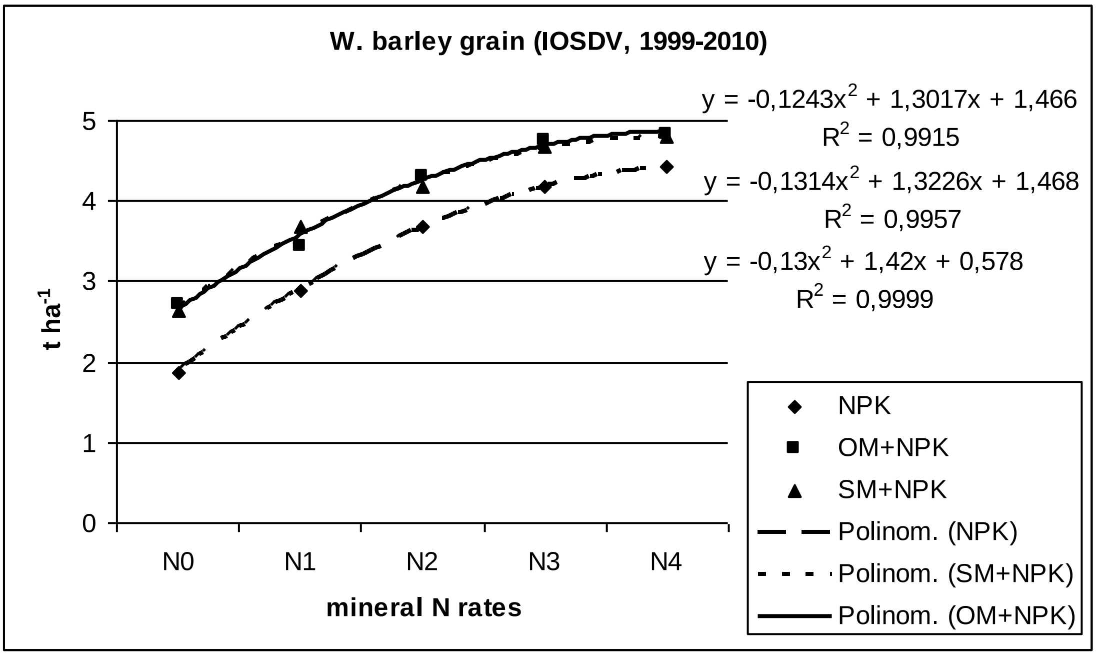

Figure 5. Grain yield of winter barley as a function of increasing rates of N fertilizer and N fertilizers plus organic manures when averaged over the 6-9 rotations (1999-2010) in the long term IOSDV trial Keszthely, Hungary.

The maximum grain yield was obtained when 120 and160 kg ha^{-1} N was applied but the increase in yield between applications of 120 and160 kg ha^{-1} N was not significantly different. The effect of manures in the crop rotation resulted in about 1 t ha^{-1} extra yield increase compared to the N0 plots. SM with complementary N application resulted in the same yield increase as achieved with OM. This positive effect of organic matters was also measured at higher N rates.

Organic fertilizers and yield

In this study the following questions were posed: (I) how much yield can be achieved with the joint application of inorganic and organic fertilizers, (II) what is the adequate C_{org} level for the given soil type and region, (III) how much manure input is required in the crop rotation in the long run?

In Table 1. the yield data of the N0PK, NPK (averaging over three levels of N takes out some interesting data worthy of analyses, N2, N3 and N4) treatments as well as the maximum yield (one of the treatments) are arranged according to the organic and inorganic fertilizers and the rotations (1999-2001, 2002-2004, 2005-2007, 2008-2010 years – 6th, 7th, 8th, and 9th rotations).

The relatively large differences in annual crop yield levels between the years, even with the annual treatments of the soil, are due largely to the varying annual precipitation levels. In the control plots the annual variation in yield was essentially higher than in the fertilized treatments. To evaluate the long-term effect of climatic conditions will require further investigations.

The effect of the application of organic manure (N0PK+OM) is an increase in crop yield of 40-45% in case of barley and wheat, and 24% in maize as compared with N0PK treatments only. The positive effect of the SM is somewhat less in the range of 37-38% and 18% in the same order as above. The yield increase in these cases is attributable to the NPK nutrient content of the additional organic manures. The extra yield of maize is less in percentage than the others but it is higher in absolute weight because of the higher yield level.

The additional OM fertilization (NPK+OM) resulted in increasing average yield in case of wheat 8%, barley 13%, maize 7% compared to the NPK inorganic treatments (when averaged over the N2, N3, N4 variants). In the case of the SM (NPK+SM) the increases are 6, 10 and 7%, respectively in the same order.

The extra yield is explainable by the fact that the higher advantage of OM comes not from the nutrient content but from other properties like the effect on soil physical and biological processes.

It is worth mentioning that the least positive effect of manuring was obtained in the 1st year of manuring in the crop rotation (for maize), at the same time the 3rd year post effect of manure was the highest for barley.

At the maximum yields the positive OM effect was 9, 10 and 7% in this order for wheat, barley, and maize, and in case of SM 7, 10 and 5%, respectively. It is evident that even with intensive NPK fertilization the positive effect of organic manure of 5-10% can be expected.

If we take into consideration the average of all the crop rotations, which is the average of crop yields, the OM and SM resulted in 33% (900 kg ha^{-1}) and 27% (700 $kgha^{-1}$) additional grain yield as compared to the N0 plots. In case of the maximum yield this represents 8-6%, which equates to about 500 kg ha^{-1} extra yield in absolute measurement terms.

Table 1. Grain yield of cereals as a function of fertilization (t ha^{-1}) when averaged over the 6.-9. rotations (1999-2010) in the long term IOSDV trial Keszthely, Hungary.

Crops	Winter wheat					Winter barley					Maize				
Rotations / Variants	6	7	8	9	Mean	6	7	8	9	Mean	6	7	8	9	Mean
N0PK	2.38	2.25	1.72	1.95	2.07	2.31	1.69	1.95	1.34	1.82	4.32	3.24	5.08	5.95	4.65
NPK	5.47	5.57	5.22	5.07	5.33	4.23	3.83	4.96	2.76	3.94	7.25	7.10	8.77	9.27	8.10
Maximum yield	5.86	5.88	5.45	5.43	5.65	4.72	4.08	5.22	3.32	4.33	7.57	7.50	9.23	10.18	8.62
N0PK+OM	2.65	3.84	2.56	2.99	3.01	2.48	2.58	3.23	1.97	2.56	5.03	4.50	6.66	6.92	5.78
NPK+OM	5.70	6.19	5.55	5.74	5.79	4.65	4.28	5.34	3.62	4.47	7.41	7.60	9.48	10.24	8.68
Maximum yield	6.15	6.37	5.72	6.52	6.19	4.96	4.56	5.49	4.08	4.77	7.82	8.08	10.00	10.91	9.20
N0PK+SM	2.13	3.37	2.80	2.93	2.81	2.66	2.41	3.12	1.80	2.50	5.00	4.38	6.14	6.54	5.51
NPK+SM	5.68	5.80	5.44	5.77	5.67	4.81	4.16	5.26	3.18	4.35	7.44	7.56	9.19	10.47	8.66
Maximum yield	6.10	5.99	5.69	6.36	6.03	5.32	4.36	5.50	3.46	4.66	7.81	7.92	9.45	11.02	9.05
LSD 5%	0.87	0.49	0.56	0.78	0.39	1.41	0.48	0.41	0.75	0.48	0.44	1.89	1.82	2.40	0.92

OM=FYM (farmyard manure)

Organic Carbon status of soil in the different treatments of crop rotation

(6-7-8-9 rotations, 1999-2010)

Soil samples were taken from the 0-30 cm soil layer of all plots after harvest. Sampling was performed every 3rd year during the 10 years period such that the organic status of every rotation was represented. The analysis of variance (ANOVA) was undertaken for n=540 plots for the C_{org}% investigations (years × variants × replications). The calculations were mostly significant. The positive effect of organic fertilizers upon the inorganic fertilizers was more than the $LSD_{5\%}$ minimum in 58% of the cases.

During the 10 years the annual variation ranged from 1.00-1.36 C_{org} % in certain rotations, which indicates the importance of the annually changing climatic conditions. In Hungary, in a 40 year long-term field experiment strong correlation was found between the soil C_{org} and the summer half-year precipitation (Marton at al., 2011). The data in Table 2. seem to indicate that the difference of C_{org} between the inorganic and organic combinations was regularly within 0.10-0.20 C_{org}% for certain years.

The C_{org} content of the soil is variable in the N0PK treatments annually but its mean value for all years is nearly the same for every crop (1.06-1.07 C_{org} %). In the NPK inorganic fertilized plots the soil C_{org} content was about the same as for the N0PK treatments. This proves that inorganic fertilization alone does not increase the C_{org} content of soil or that its effect is rather insignificant. The values of C_{org} in N0PK and NPK inorganic treatments for wheat was 1.08%, for barley 1.07%, and for maize 1.08%. In contrast Zimmer et al. (2005) reported that on a sandy soil mineral N fertilization reduced C_{org} content of soil, while with the application of SM+mineral N fertilizer soil C_{org} content was sustained, but the separate application of SM+GM without mineral N had negative effect on C_{org} content of soil.

The addition of organic manure raised the C_{org} level in the soil as follows: for wheat 1.24%, for barley 1.27%, and for maize 1.23%, as the average of all rotations. There was no additional significant effect of the inorganic N fertilizer rates.

The straw manure application increased the soil C_{org} content to 1.18% for wheat, 1.17%, for barley, and 1.21% for maize fields. The C_{org} content of soil was almost the same in the organic manure and the straw manure treatments alike.

In regard to all field experiments and plots, the extreme values of C_{org} % were found to be 0.9-1.5 (H%=1.35-2.60), that corresponds to the lower and the upper limit of the humus dynamic on this soil type and ecological region. Taking into consideration the mean figures of the treatments and crops there is only a rather small range (0.15-0.20 C_{org}%) to improve the soil fertility by means of organic fertilization. Kolbe (2005) and Körschens (2010) found similar results in other long-term field experiments in Germany.

Conclusions

In the two-factorial field experiment the increasing rates of the N fertilizer increased the grain yield significantly as compared to the N0 plots. The relationships between the N treatments and the yield of winter wheat, winter barley, and maize can be described by a quadratic function. The maximumyields were reached between the 3rd-4th N treatments.

The organic amendments produced increasing yields in all cases and its curvilinear function remained broadly parallel with the inorganic curvilinear variant but provided a higher value. On average, the results of the organic amendment treatments over the experiment produced additional crop yields of 16% for wheat, 17% for barley, and 12% for maize, with manure applications and additional crop yields of 13% for wheat 13%, 17% for barley 17% and 11% for maize with straw residue application.

The positive effect of organic fertilizers was marked at lower levels of inorganic N fertilizer supply and N0 control, while the extra yield of with organic amendments was moderate at higher amounts of inorganic N fertilizer treatments. In case of N treatments (N2, N3, N4) the effect of OM and SM can be measured objectively as compared with the inorganic variant. Accordingly, the increased yields derived from the OM and SM were 8 and 6% for wheat, 13 and-10% for barley, and 7 and 7% for maize, respectively. At maximum yields the above mentioned figures were 9 and7%, 10 and 8% and 7 and 5%, respectively in the previous order.

There is no significant difference between the effects of OM and SM on increasing crop yield. At maize the effect of the two forms of organic matters were identical.

The ANOVA for n=540 plots was undertaken for the investigation of C_{org}% (years×variants×replications). The calculations were mostly significant. The positive effect of organic fertilizers upon the inorganic fertilizers was more than the $LSD_{5\%}$ minimum in 58% of the cases.

The range of soil C_{org}% values in all the plots were 0.9-1.5%. In certain years the average level of C_{org} was within the limits of 1.00-1.36%.

The average values of soil C_{org} in N0PK and NPK inorganic treatments in case of wheat was 1.08%, 1.07% for barley and 1.08% for maize 1.08%. Treatment with OM resulted in higher C_{org} levels in the soil as follows: wheat 1.24%, barley 1.27% and maize 1.23%. SM application increased the soil C_{org} to 1.18% for wheat, 1.17% for barley, and 1.21% for maize fields.

The annual fluctuations of the difference of soil C_{org} between the inorganic and organic combinations were 0.10-0.20 C_{org} % within the year.

The results of this paper give useful information for managing soil to ensure productivity, profitability, as well as, to enable sustainable natural resources as organic carbon status of soil. Due to the increasing price of energy – required for industrial N fixation – as well as decline in the availability of sources of rock P the importance of ecological cycles – among those OM application - in sustainable agriculture will increase in the future.

Table 2. Organic carbon content (C_{org} %) in the 0-30-cm soil layer when averaged over the 6.-9. rotations (1999-2010) in the long term IOSDV trial Keszthely, Hungary.

Crops	Winter wheat					Winter barley					Maize				
Rotations	6	7	8	9	Mean	6	7	8	9	Mean	6	7	8	9	Mean
Variants	2000	2003	2006	2010		2000	2003	2006	2010		2000	2003	2006	2010	
N0PK	1.03	1.13	1.13	1.09	1.07	1.00	1.03	1.11	1.13	1.06	0.92	1.18	1.05	1.12	1.07
NPK	1.05	1.10	1.15	1.07	1.09	1.04	1.04	1.10	1.17	1.08	0.90	1.17	1.05	1.25	1.09
N0PK+OM	1.09	1.45	1.38	1.10	1.23	1.21	1.27	1.31	1.26	1.26	0.94	1.43	1.23	1.32	1.23
NPK+OM	1.20	1.40	1.35	1.14	1.27	1.22	1.32	1.33	1.28	1.29	0.96	1.43	1.22	1.37	1.24
N0PK+SM	0.91	1.29	1.33	1.20	1.18	1.05	1.07	1.30	1.19	1.15	1.04	1.48	1.15	1.10	1.19
NPK+SM	1.00	1.22	1.30	1.21	1.18	1.10	1.13	1.30	1.24	1.19	1.04	1.49	1.15	1.15	1.21
Mean	1.05	1.26	1.27	1.13	1.17	1.10	1.14	1.24	1.21	1.17	0.97	1.36	1.14	1.22	1.17
LSD 5%	0.46	0.10	0.11	ns	-	0.62	0.13	0.10	0.03	-	0.50	0.54	0.10	0.07	-
P%	*	**	**	*ns*	-	*	***	*	*	-	*	***	*	*	-

Notes: ns, non-significant; *, P≤0.05; **, P≤0.01; ***, P≤0.001.

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5.4. Similarities and differences between China and the EU

A comparative assessment was performed using the DPSIR analytical framework (see Chapter 3 for details of the methodology) to explore cause-effect relationships related to agricultural intensification, water use and land resources degradation in China and the European Union.

The direct driver of soil resource degradation related to agricultural intensification and associated water use is, in both cases, the effort to maximise resource utilization in economic terms. Underlying social demands, however, are different. The intensification in China is driven by the increasing demand for food and fiber - associated with population growth and dietary change. In Europe a competition for land from bioenergy crops is a new recent element, however the consequences of this on the state of land resource and global food security are not yet known in detail.

Increasing levels of fertilizer and pesticide applications are among the main pressures arising from intensively used agricultural land that may lead to contaminated soil, while erosion and compaction are the main processes leading to degraded soil functions. These pressures are common to China and most parts of the EU, although none of the regions are similar in their magnitude. For example erosion due to deforestation occurs mostly in central regions of China; high fertilizer doses are characteristic in North-Western Europe.

Degradation processes not only undermine the productivity potential of soils on the long term but also have immediate negative impacts on the broader environment too (water resources, air). Impacts are broadly similar in China and the EU, but aquifer depletion affects larger areas in China than in the EU.

As a response to the above described processes and their negative impacts, both regions need to invest in research as well as in capacity building to develop and apply conservation and sustainable management measures. Further to knowledge generation, legal instruments and financial incentives need to be in place as well in order halt negative tendencies related to the intensification of agricultural land use.

Although biophysical conditions and agricultural traditions and technologies are different in China and in Europe, our comparative assessment highlighted that drivers and effects associated with agricultural intensification show high degrees of similarities between the two regions.

Table 1. Results of the DPSIR assessment:
threats from agricultural intensification and water use to land resources

	China	European Union
Driving forces	D: maximizing resource utilization ID: Increasing demands for food and fiber, diet change (economic growth, population increase)	D: maximizing resource utilization ID: Increasing demands for bioenergy (fuel, wood)
Pressures	Increased fertilizer and pesticide application (expansion of horticulture), compaction, erosion (deforestation; soil management)	Intensive use of fertilizers, pesticides, compaction, erosion (soil management)
State	eroded and degraded soils soil contamination; soil eutrophication,	eroded and degraded soils
Impacts	river, lake and ground water pollution; salinization aquifer depletion, contaminated food, air and water pollution, productivity decline on a long term (erosion)	contaminated food, air and water pollution, productivity decline on a long term (erosion)
Responses	research , capacity building, incentives legal regulations, increased investment in integrated land management (including lake and river pollution control),	research, capacity building, incentives

6. Soil degradation

6.1. Introduction

Gergely Tóth

Descriptions of soil (and land) quality through the multifunctional nature of soils (and land) appeared in the second half of the 20th century worldwide, giving frame for possible common scientific recognition of soil and land with regards to services provided to ecosystems and humans. One of the first widely accepted definitions was published by FAO (1976) describing land quality as „a complex attribute of land which acts in a distinct manner in its influence on the suitability of land for a specific kind of use". As one replaces the word "land" with "soil" in this statement, an acceptable broad definition for soil quality appears. Degradation deteriorates soil quality by partially or entirely damaging one or more of its functions (Blum 1988).

Alteration of soil characteristics by anthropogenic impact is – apart from climate – one of the main driver that changes the quality of the soil. Long-term human impact (eg. forestation), as well as seasonal soil management (drainage, cultivation, irrigation, nutrient management etc.) modifies material and energy flows, that result transformation of the soil processes to smaller or greater extent. When these processes are traceable, controllable, soil-use and soil quality remains sustainable on the long run. However, soil uses in most cases do not consider all factors and practical options required to secure sustainability. Therefore soil degradation is widespread problem globally.

Risk of soil degradation depends on soil and terrain properties which make the soil inherently receptive of degradation. Van Camp et al. (2004) provide substantial knowledge towards identifying and describing hazards (threats) to soil. Eckelman et al. (2006) summarizes the risk assessment methodologies applicable for soil degradation studies and offers the concept of threats to represent the hazards endangering the functioning of soils. The Thematic Strategy for Soil Protection of the EU (EC 2006a) declares that for sustainable development, soils (soil functions) need to be protected from degradation, thus soil threats set the boundary condition for - sustainable - soil quality as well.

The main threats to soil functioning abilities are identified as (1) decline in organic matter, (2) soil erosion, (3) compaction, (4) salinization, (5) landslides, (6) floods, (7) contamination and (8) sealing.

Threats 1-5 are area (and soil) specific in their appearance, therefore, they require additional spatial consideration during soil conservation planning.

The current report provides and introduction to the main soil degradation problems present in China and Europe and makes a first attempt for a comparative analysis to explore similarities and differences in their causes, processes and impacts in these two major food producing regions of the world.

6.2. Main soil degradation threats in China

Ganlin Zhang and Renfang Sheng

China has diversified natural and socio-economic conditions. The climate varies from tropical and subtropical monsoon to the arid and semiarid continental type, landforms transit from the highest Tibet-Qinghai Plateau to the flat land in the Yangtze and the Yellow River delta, while land uses from intensive to extensive. The diversity of those conditions renders the country abundant soil resources, but also all kinds of potential soil degradation risks.

Soil degradations can result from unfriendly natural settings, such as hilly and mountainous landforms, strong rainfall and harsh desert environment. However, with the continuing pressure from intensive land uses, rapid shfit of land use types, as well as the development of urbanization and industrialization, soil resources of China are also under severe human-induced degradation risks.

Soil erosion

Soil water erosion is the most serious soil degradation in China. About one sixth the total land is under soil water erosion risk, i,e., 1.7×10^8 ha, among which 4.54×10^7 ha belongs to farmland. The Yellow River basin is the most vulnerable region in which two thirds are under erosion. According to a study, the annual soil erosion of the Loess Plateau amounted to 1.630×10^9 t, which equals to 3.17×10^6 t of chemical nitrogen, phosphorus and potassium. Following the Loess Plateau, the hilly areas of the south China and the gentlly undulated plain in the northeast China rank the second and third largest regions affected by soil erosion. In the hilly areas of south China, the total area under soil erosion amounts to 5.6×10^5 km^2 while in the northeast China plain more than 35% of land surface is subject to water and wind erosion which seriously reduces the fertile surface mollic layer of the vast farmland.

Fig.1 shows the general pattern of soil erosion, in water, wind and frozen-thawing forms abd their severity in China. Besides water erosion mentioned abpve, wind erosion occurs mainly in the northwest China and the freezing-thawing erosion appears mainly in the Qinghai-Tibet Plateau deu to its frigid alpin climate condition.

It should be pointed out that over the last 10 years, soil erosion in several typical regions like the Loess Plateau, northeast China and southwest China has got a control due to the nation-wide “Grain for Green” project. In addition, the change of life style of many farmers in southeast China over the last 20 years or so has contributed also to the afforestation of the hilly regions thus a reduction of soil water erosion.

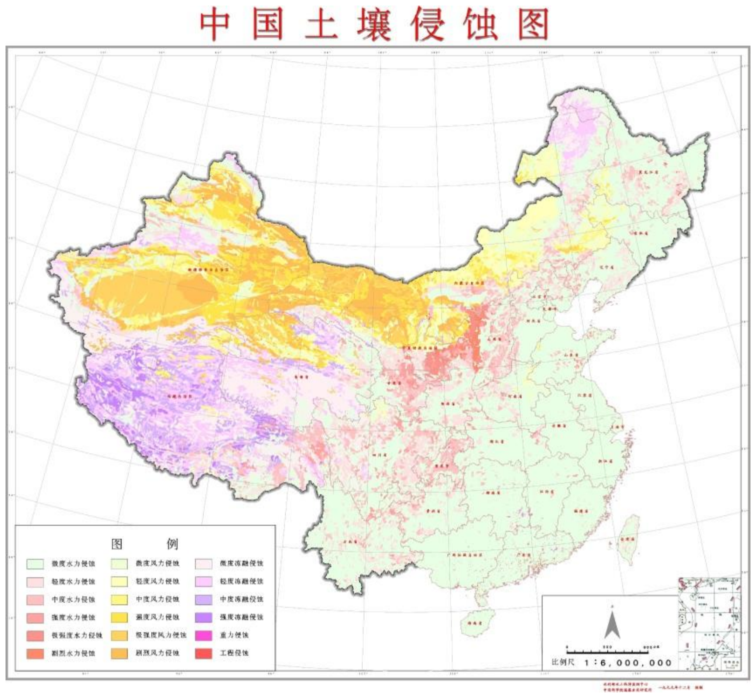

Figure 1. Map of soil erosion types and degrees of China (by Soil and Water Conservation Monitoring Center, the Ministry of Water Resources, unpublished)

Desertification

Desertification is partly overlaped with soil erosion but here mainly refers to the overall soil (land) degradation processes including soil erosion (by wind and water), vegetation destruction, soil salinization in aird and semi-arid regions.

According to a recent statistics, the total potential area subject to desertification amounts to 3.32×10^{8} ha, among which 79% are desertified, i.e., 2.62×10^{8} ha, a number equals twice of total arable land in China. There are various types of desertification ways in China, such as by wind erosion, water ersoin, freezing-thawing, and by salinization. Desertification by winderosion has the largest extent in China, with total area of more than 1.8×10^{8} ha, square kilometers, followed by water erosion and freezing-thawing type, with area of about 2.6×10^{7} ha and 3.6×10^{7} ha.

If classified according to severity, the most serious type amounts to 9.51×10^{7}ha, the moderate type amounts to 6.41×10^{7}ha and the slight type amounts to 10.03×10^{7} ha. Due to climate change and intensive human activities, the annual desertification rate in China is about 2.4×10^{5} ha, which is about a medium-sized county in China.

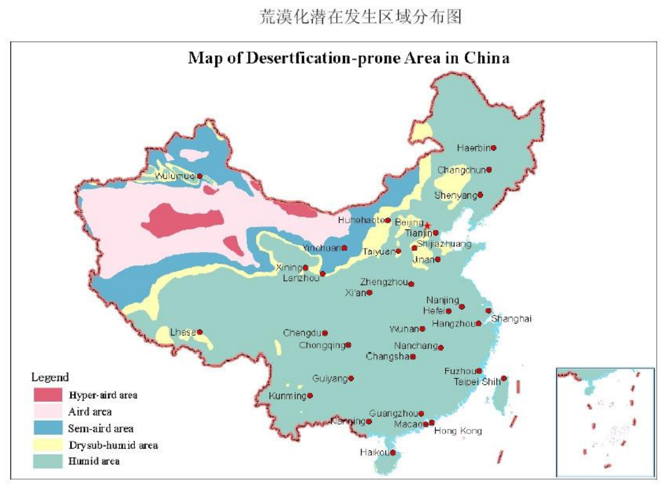

Figure 2. The desertification-prone areas in China

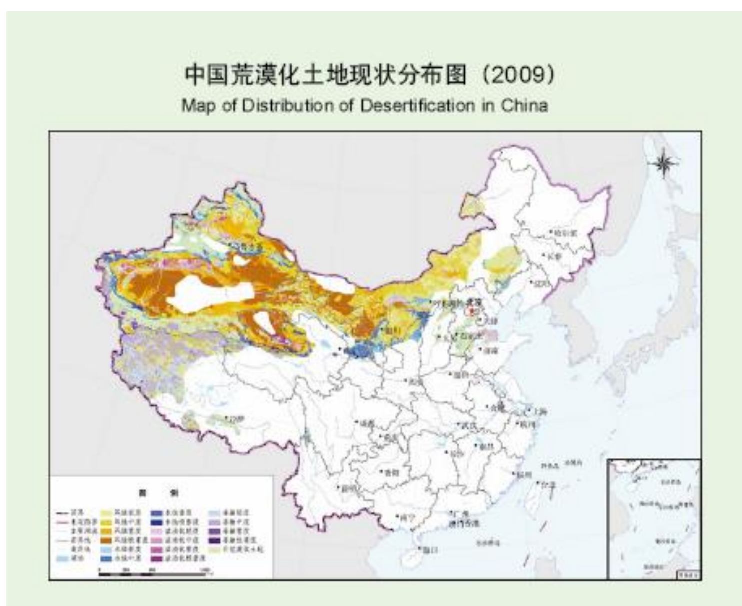

Figure 3. The actual distribution of desertification in China

The driving forces of desertification in China are mainly:

1. Vulnerability of arid and semi-arid grassland ecosystems in China against climate change and human activities.

2. The over use of the biological resources of grassland.

3. Shif of grassland to arable land in the marginal areas.

4. Deforestation.

Soil salinization and alkalinzation

Soil salinization and alkalinization refer to the secondary salt accumulation in soils. In China saline and alkaline soils sum to about 3.69×10^7 ha, among which the arable land amounts to 6.24×10^6 ha and mainly appears in the Huang-Huai-Hai Plain, the western part of the northeast China, the irrigated area of the Yellow River, the inland in the northwest China and the coastal area in the east part.

Although saline and alkaline soils in the Huang-Huai-Hai Plain largely gets controlled, due to improved irrigation engineering and biological countermeasures, salinization/alkalinization in the northwest China, namely Xinjiang, Gansu and Ningxia becomes even more serious. About 35% of the arable land in Xinjiang, Gansu and Ningxia is under the threats of salinzaition, while in the Inner Mongolia it is about 50%, substantially increased compared to that in 1950s.

Due to the shortage of irrigation water in the arid and semi-arid regions, the improvement of irrigation methods is becoming the top demand for agricultural development. However, soil salinization/alkalinzation risk exists largely unchanged. As important potential arable land, the amelioration of saline soils will be a long-term task in China. In addition to those regional problems, soil salinization of greenhouse soils has become an increasingly serious problem dur to the exceesive use of chemical fertilizers and improper irrigation.

Soil contamination

The rapid devlopment of urban, industrial, traffic and mining activities in China has caused unprecedent increase of contaimnatde land in China. Soil contamination has become a serious challenge. It is estimated that about 10% of the total arable land has exceeded the thresholds and has potential risk for food safety.

Soil contamination in China mainly appears in the east and southeast parts, where industrial activities are more intensive besides the urbanization process. However, mining may be the top driving force of soil pollution in the less developed regions.

Other soil degradation threats

Besides the above-mentioned major types of soil degradation, soil acidification, which is mainly caused by long-term use of chemical nitrogen fertilizers, is also emerging as a problem. Soil compaction, with the introduction of heavy field machines, will be projected as a new type of soil degaradation. Soil fertility decline mainly appears in remote regions where chemical fertilizers are not adequately used. However, unbalanced use of chemical fertilizers seems to be a more urgent problem as it not only lowers the use efficiency of nutrients but also causes serious environmental problems.

6.3. Main soil degradation threats in Europe[4]

Arwyn Jones

Widespread soil degradation, leading to a decline in the ability of soil to carry out its ecosystem services, is caused largely by non-sustainable uses of the land. This has also marked local, regional, European and global impacts. Soil degradation contributes to food shortages, higher commodity prices, desertification and ecosystem destruction. Society has a duty to ensure that the soil resources within their territories are managed appropriately and sustainably. The character of the major threats to soil has not changed significantly since the last SOER assessment in 2005 (EEA, 2005a). The following sections outline the state and trends of the main soil degradation processes in Europe and show that, while the situation is variable, many soil degradation processes are accelerating in many parts of Europe (EEA, 2005b), often exacerbated by inappropriate human activities and widely varying approaches to tackling degradation processes.

Organic matter content

- **State of soil organic carbon levels**: Around 45% of the mineral soils in Europe have low or very low organic carbon content (0–2%) and 45% have a medium content (2–6%) (Rusco *et al*., 2001). Low levels are particularly evident in the southern countries of Europe: 74% of the land in southern Europe is covered by soils that have less than 2% of organic carbon in the topsoil (0–30cm) (Zdruli *et al*., 2004). However, low levels of organic matter are not restricted to southern Europe as areas of low soil organic matter can be found almost everywhere, including in some parts of more northern countries such as France, the United Kingdom, Germany, Norway and Belgium.

  Excess nitrogen in the soil from high fertiliser application rates and/or low plant uptake can cause an increase in mineralisation of organic carbon which, in turn, leads to an increased loss of carbon from soils. Maximum nitrogen values are reached in areas with high livestock populations, intensive fruit and vegetable cropping, or cereal production with imbalanced fertilisation practices. While in extreme situations, the surplus soil nitrogen can be as high as 300 kg N ha^{-1} (EC, 2002)¸ estimates show that 15% of land in the EU-27 exhibits a surplus in excess of 40 kg N ha^{-1}. For reference, while rates vary from crop to crop, the IRENA Mineral Fertiliser Consumption indicator (EEA, 2005a) estimates that average application rates of nitrogen fertiliser for EU-15 in 2000 ranged from 8–179 kg N ha^{-1}.

  There is growing realisation of the role of soil, in particular peat, as a store of carbon and its role in managing terrestrial fluxes of atmospheric carbon dioxide (CO_2). Other than in tropical ecosystems, soil contains about twice as much organic carbon as above-ground vegetation. Soil organic carbon stocks in the EU-27 are estimated to be between 73 to 79 billion tonnes, of which about 50% is to be

[4] This chapter is an extract from: Jones, A. et al. 2012. The State of Soil in Europe. Publications Office of the European Union. Luxembourg 78pp. See the original source for details and references.

found in the peatlands and forest soils of Sweden, Finland and the United Kingdom (Schils *et al*., 2008).

Peat soils contain the highest concentration of organic matter in all soils [5]. Peatlands are currently under threat from unsustainable practices such as drainage, clearance for agriculture, fires, climate change and extraction. The current area of peatland in the EU is estimated at more than 318 000 km^2, mainly in the northern latitudes. While there is no harmonised exhaustive inventory of peat stocks in Europe, the CLIMSOIL report (Schils *et al*., 2008) estimated that more than 20% (65 000 km^2) of all peatlands have been drained for agriculture, 28% (almost 90 000 km^2) for forestry and 0.7% (2 273 km^2) for peat extraction.

The EU funded Carbon - Nitrogen Interactions in Forest Ecosystems (CNTER) project assessed carbon fluxes and pools for 400 European forest sites and found that sequestration rates in the soils of central European forests were around 190 kg C ha^{-1} yr^{-1}, which converted to a European scale would be equivalent to around 13 million tonnes C yr^{-1} (Gundersen *et al*., 2006).

- **Trends in soil organic carbon levels:** In general, soils lose carbon through cultivation and disturbance. Changes in soil organic carbon (SOC) content are expected to be faster in topsoil (0–30 cm) than in deeper soil. An assessment of carbon stocks is a reliable approach to provide an indication of changes in organic matter. Comparisons of carbon stocks should always take into consideration the soil type and land management practices.

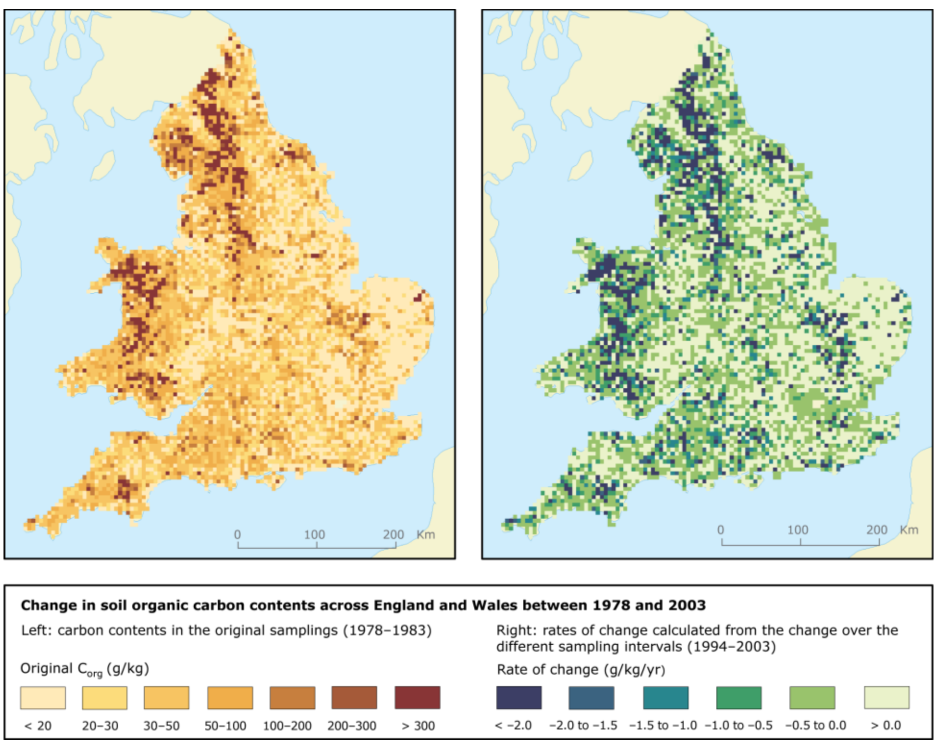

Figure 1. Changes in soil organic carbon content across England and Wales between 1978 and 2003. Source: Bellamy et al., 2005.

Except for the rapid removal of SOC by erosion and landslides, changes in SOC levels as a result of the intensification of agriculture, deforestation or conversion of grassland to arable land are slow processes. This makes changes difficult to assess. Some recent studies suggest that SOC in European agricultural land is decreasing (Vleeshouwers and Verhagen, 2002; Sleutel *et al*., 2003). Bellamy *et al*. (2005) used data from the National Soil Inventory of England and Wales obtained between 1978 and 2003 to show that an average of 0.6% of the organic carbon content was lost per year from soils across England and Wales over that period, with some soils loosing up to 2 g kg^{-1} yr^{-1}. Similar trends were observed in France, Belgium and Sweden (Saby *et al*., 2008; Goidts *et al*., 2009). The rate of change appears to be proportional to the initial soil organic carbon content. Soil organic matter (SOM) decline is also of particular concern in the Mediterranean region (Jones *et al*., 2005) where high temperatures and droughts can accelerate the decomposition of SOM.

Several factors are responsible for a decline in SOM and many of them relate to human activity: conversion of grassland, forests and natural vegetation to arable land; deep ploughing of arable soils; drainage, fertiliser use; tillage of peat soils; crop rotations with reduced proportion of grasses; soil erosion; and wild fires (Kibblewhite *et al*., 2005). High soil temperatures and moist conditions accelerate soil respiration and thus increase CO_2 emissions (Brito *et al*., 2005).

Comparisons of results from the Biosoils project, carried out under the Forest Focus Regulation, with previous pan-European forest surveys provided new information on trends in soil organic carbon levels in European forests (Hiederer, et al., 2011). While analysis is complicated by differences in sampling and laboratory practices, several sites show a slight increase in the organic carbon stocks of forest soils over a 10 year interval.

Erosion

Erosion is the wearing away of the land surface by water [6] and wind [7], primarily due to inappropriate land management, deforestation, overgrazing, forest fires and construction activities. Erosion rates are very sensitive to climate, land use, soil texture, slope, vegetation cover and rainfall patterns as well as to detailed conservation practices at field level. With the very slow rate of soil formation, any soil loss of more than 1 tonne per hectare per year (t ha^{-1} yr^{-1}) can be considered as irreversible within a time span of 50–100 years (Huber *et al*., 2008) [8]. However, the concept of variable tolerable rates of erosion should be noted and requires further definition (i.e. in some areas 1 t ha^{-1} yr^{-1} can be irreversible while in other regions, rates of 2-3 t ha^{-1} yr^{-1} can be sustained, given corresponding rates of soil formation).

- **State of soil erosion by water**

  Soil erosion by water is one of the most widespread forms of soil degradation in Europe [9] affecting an estimated 105 million ha, or 16% of Europe's total land area (excluding the Russian Federation; EEA, 2003). The Mediterranean region is particularly prone to water erosion because it is subject to long dry periods followed by heavy bursts of intense rainfall on steep slopes with fragile soils. In some parts of the Mediterranean region, erosion has reached a state of irreversibility and in some places erosion has practically ceased because there is no soil left. Soil erosion in northern Europe is less pronounced because of the reduced erosivity of the rain and higher vegetation cover. However, arable land in northern Europe is susceptible to erosion, especially loamy soils after ploughing

(Bielders *et al*., 2003). One consequence of soil erosion is the transfer of nutrients from agricultural land to water bodies, which can result in the formation of toxic algal blooms.

No harmonised measures of actual soil erosion rates exist for the European continent. Until recently, the only harmonised Europe-wide estimates of soil erosion by water were provided by the PESERA project (Gobin and Govers, 2003) [10]. However, issues with some input datasets gave rise to over- and under-estimates of erosion rates in certain conditions.

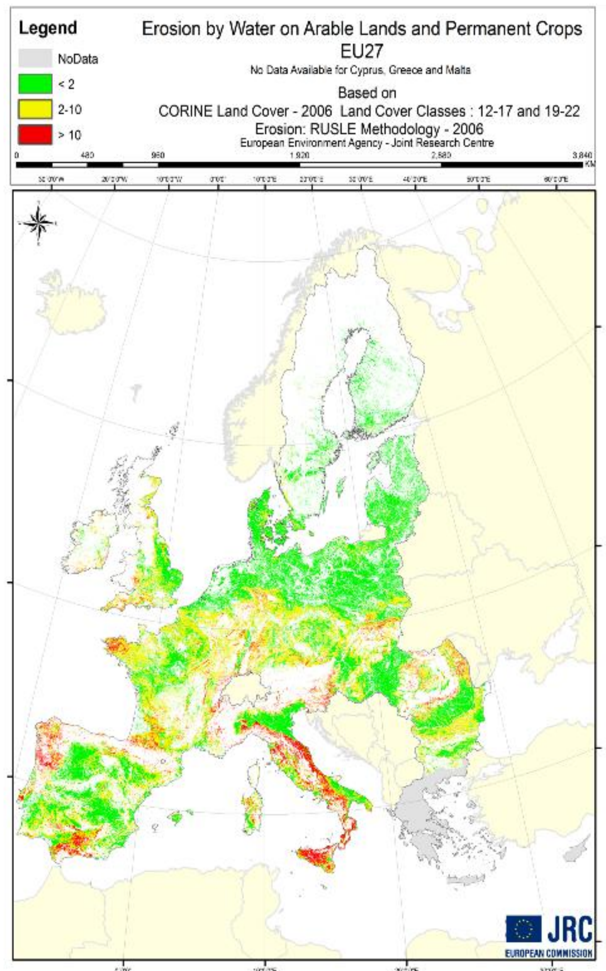

Figure 2. Estimation of soil erosion on cultivated land through rainsplash, sheetwash and rill erosion as calculated from the Revised Universal Soil Loss Equation (1 km grid cells) and CORINE 2006 Land Cover database. White areas are not considered as cultivated land in the Corine classification system. (Source: JRC/Bosco et al., 2012)

Recent studies by the JRC (Bosco *et al*., 2012) using the Revised Universal Soil Loss Equation (RUSLE) model and updated pan-European datasets indicated that mean rates of soil erosion by water in EU-27 were estimated to be 2.76 t ha^{-1} yr^{-1}; rates were higher in the EU-15 (3.1 t ha^{-1} yr^{-1}) than in the EU-12 (1.7 t ha^{-1} yr^{-1}) probably as EU-15 includes the Mediterranean area where overall erosion rates are higher. Several countries in the southern part of the EU show mean erosion rates that are significantly higher than the mean value for the EU. In addition, just over 7% of cultivated land (arable and permanent cropland) in EU-24 (excluding Cyprus, Greece and Malta) is estimated to suffer from moderate to severe erosion (i.e. OECD definition of > 11 t ha^{-1} yr^{-1}). This equates to 115,410 km² or approximately the entire surface area of Bulgaria (Fig. 8). In comparison, only 2% of permanent grasslands and pasture in EU-24 (excluding Cyprus, Greece and Malta) is estimated to suffer from moderate to severe erosion. This demonstrates the importance of maintaining permanent vegetation cover as a mechanism to combat soil erosion. Several researchers have reported soil erosion rates in Europe in excess of a critical 1 t ha^{-1} yr^{-1}. Arden-Clarke and Evans (1993) noted that water erosion rates in the United Kingdom varied from 1–20 t ha^{-1} yr^{-1} with the higher rates being rare events. Other researchers frequently found rates between 10 and 20 t ha^{-1} yr^{-1} in mainland Europe (Lal, 1989; Richter, 1983). Losses of 20 to 40 t ha^{-1} yr^{-1}in individual storms, which may happen once every two or three years, are measured regularly in Europe, with losses of more than 100 t ha^{-1} yr^{-1} occurring in extreme events.

- **State of soil erosion by wind**

  Wind erosion is a serious problem in many parts of northern Germany, eastern Netherlands, eastern England and the Iberian Peninsula. Estimates of the extent of wind erosion range from 10 to 42 million ha of Europe's total land area, with around 1 million ha being categorised as severely affected (EEA, 2003; Lal, 1994). Recent work in eastern England reported mean wind erosion rates of 0.1–2.0 t ha^{-1} yr^{-1} (Chappell and Warren, 2003), though severe events are known to erode much more than 10 t ha^{-1} yr^{-1} (Böhner *et al*., 2003). In a similar study, Goossens *et al*. (2001) found values of around 9.5 t ha^{-1} yr^{-1} for arable fields in Lower Saxony, Germany. Breshears *et al*. (2003) researched the relative importance of soil erosion by wind and by water in a Mediterranean ecosystem and found that wind erosion exceeded water erosion in shrubland (around 55 t ha^{-1} yr^{-1}) and forest (0.62 t ha^{-1} yr^{-1}) sites but not on grasslands (5.5 t ha^{-1} yr^{-1}).

- **Trends in erosion:** Assessing trends in soil erosion rates across Europe is difficult due to a lack of systematic approaches and data. However, a number of assumptions can be made. Given the close link with meteorological events and land cover, erosion rates and extent are expected to reflect changing patterns of land use and climate change. The SOER 2010 Assessment on Land Use (EEA, 2010b) presents statistics on trends in land-use patterns obtained from analysing changes in the Corine land cover datasets. The marked conversion of permanent pasture to arable crops and increasing demands for bioenergy, mostly from maize and other crops, are expected to lead to an increase in the risk and rates of soil erosion. As a result of climate change, variations in rainfall patterns and intensity may well result in increased erosion as droughts may remove protective plant cover while more intense rainfall events will lead to the physical displacement of soil particles.

Compaction

Soil compaction is a form of physical degradation due to the reorganisation of soil micro and macro aggregates, which are deformed or even destroyed under pressure. Compaction leads to a reduction in biological activity, porosity and permeability. Compaction can affect water infiltration capacity and increase erosion risk by accelerating run-off. A feature of compacted soils is the formation of a pan-layer that is less permeable for roots, water and oxygen than the soil below and is a bottleneck for the function of the subsoil. Topsoil compaction occurs when soil is subjected to pressure from the passage of heavy machinery or by repeated trampling of grazing animals, especially under wet conditions [11]. In arable land with annual cultivation, subsoil compaction is also possible by tractors driving directly on the subsoil during ploughing. Unlike topsoil, the subsoil is not loosened annually, and compaction becomes cumulative. As it occurs below the ground, soil compaction is very much a hidden problem.

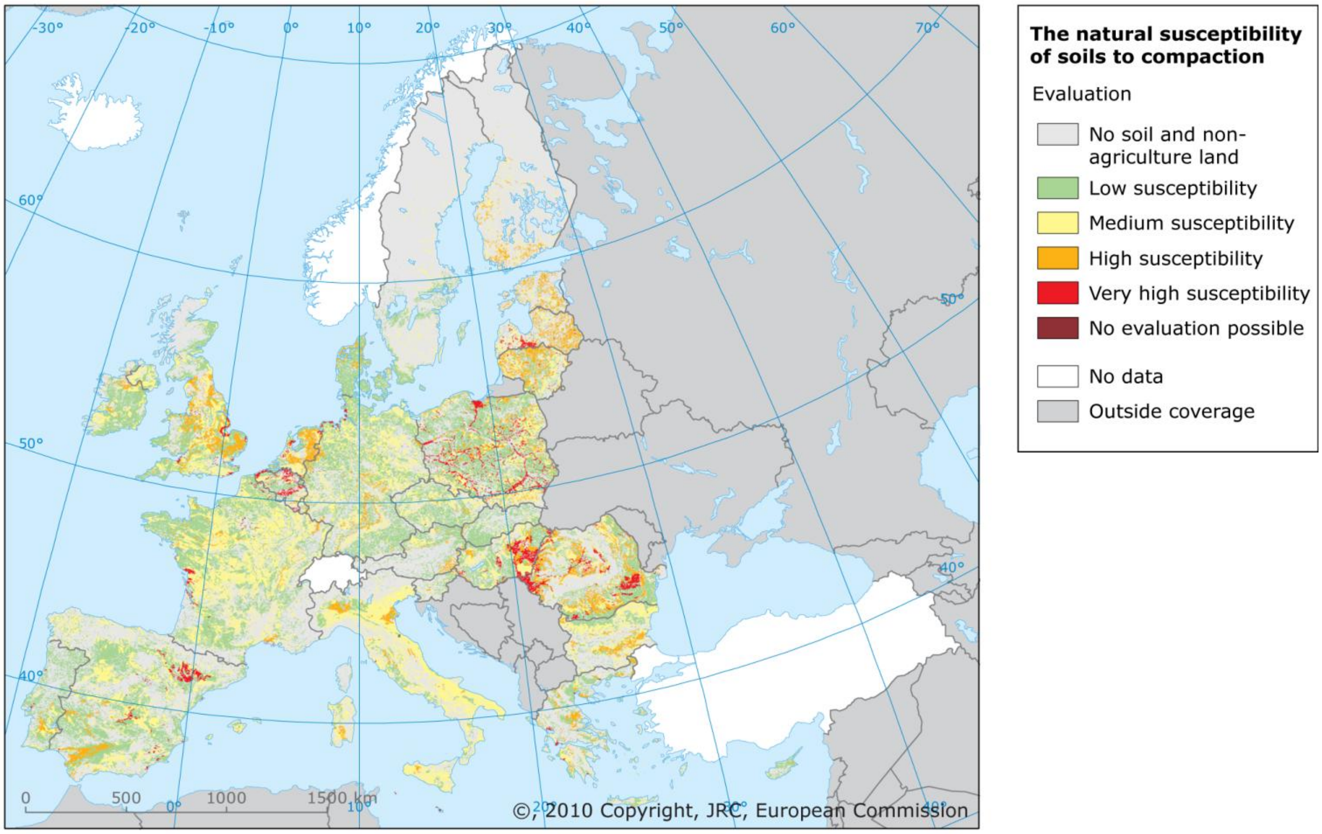

Figure 3. The natural susceptibility of soils to compaction. Susceptibility is the likelihood of compaction occurring if subjected to factors that are known to cause compaction. It does not mean that a soil is compacted.

Source: JRC/ESDAC

- **State of soil compaction:** Estimates of the area at risk of soil compaction vary. The sensitivity of soils to compaction depends on soil properties, such as texture and moisture, organic carbon content, and on several external factors such as climate and land use. Some researchers classify around 36% of European subsoils as having high or very high susceptibility to compaction (Van Camp et al., 2004). Other sources report that 32% of soils are highly vulnerable and 18% moderately affected by compaction (Crescimanno *et al.*, 2004). Again other sources estimate 33 million hectares being affected in total, corresponding to 4% of the European land surface (Van Ouwerkerk and Soane, 1995).

- **Trends in compaction:** Since the 1960s, the mechanisation of agriculture using heavy machinery has caused high stresses in the soil, even causing compaction deep in the subsoil below the plough layer

(Van den Akker, 2004; Van den Akker & Schjønning, 2004). In recent years, arable farming techniques have improved (e.g. twin tyres, lower tyre pressures) in an attempt to minimize compaction, but overall the problem remains.

Soil sealing

Sealed soils can be defined as the destruction or covering of soils by buildings, constructions and layers of completely or partly impermeable artificial material (asphalt, concrete, etc.). It is the most intense form of land take and is essentially an irreversible process. Sealing also occurs within existing urban areas through construction on residual inner-city green zones.

- **State of soil sealing**: On average, built-up and other manmade areas account for around 4% of the total area in EEA countries (data exclude Greece, Switzerland and United Kingdom), but not all of this is actually sealed (EEA, 2009). Member States with high sealing rates exceeding 5 % of the national territory are Malta, the Netherlands, Belgium, Germany and Luxembourg (Prokop *et al.*, 2011).The EEA has produced a high resolution soil sealing layer map for the whole of Europe for the year 2006 based on the analysis of satellite images. Much more detail can be found in the SOER Assessments on the Urban Environment (EEA, 2010a) and Land Use (EEA, 2010b) , as well as in Prokop *et al.* (2011).

- **Trends in soil sealing**: Productive soil continues to be lost to urban sprawl and transport infrastructures. Between 1990 and 2000, the sealed area in the EU-15 increased by 6% (see Fig. 12) and at least 275 hectares of soil were lost per day in the EU, amounting to 1,000 km² / year (Prokop *et al.*, 2011). Between 2000 and 2006, the EU average loss increased by 3%, but by 14% in Ireland and Cyprus, and by 15% in Spain year (Prokop *et al.*, 2011). Huber *et al*. (2008) provides an interesting insight into the development of baselines and thresholds to monitor soil sealing. See also the SOER 2010 Assessment on Land Use (EEA; 2010b) for additional details on urbanisation.

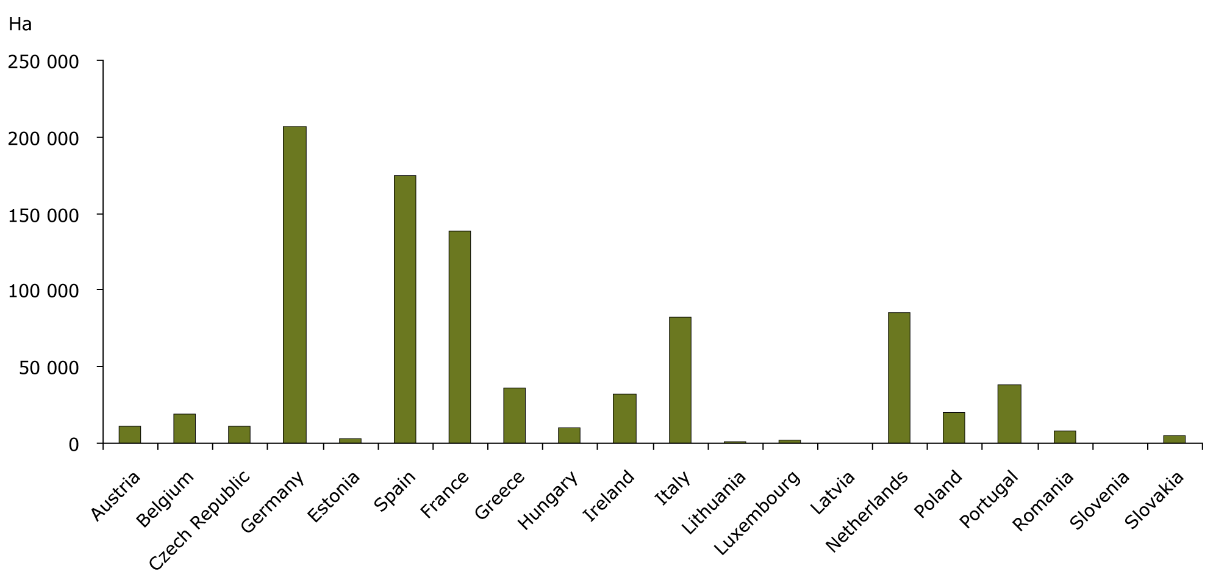

Figure 4a. Losses of agricultural areas to urbanisation (ha). Comparison of CORINE land cover data

for 1990 and 2000 shows an estimated loss of 970 000 ha of agricultural land due to urbanisation for 20 EU Member States in this ten year period. The rate of change is not the same across all countries. It should be noted that non-agricultural land is also consumed by urbanisation. These trends continue in the period 2000–2006 as shown in the SOER 2010 Assessment on Land Use (EEA, 2010b).

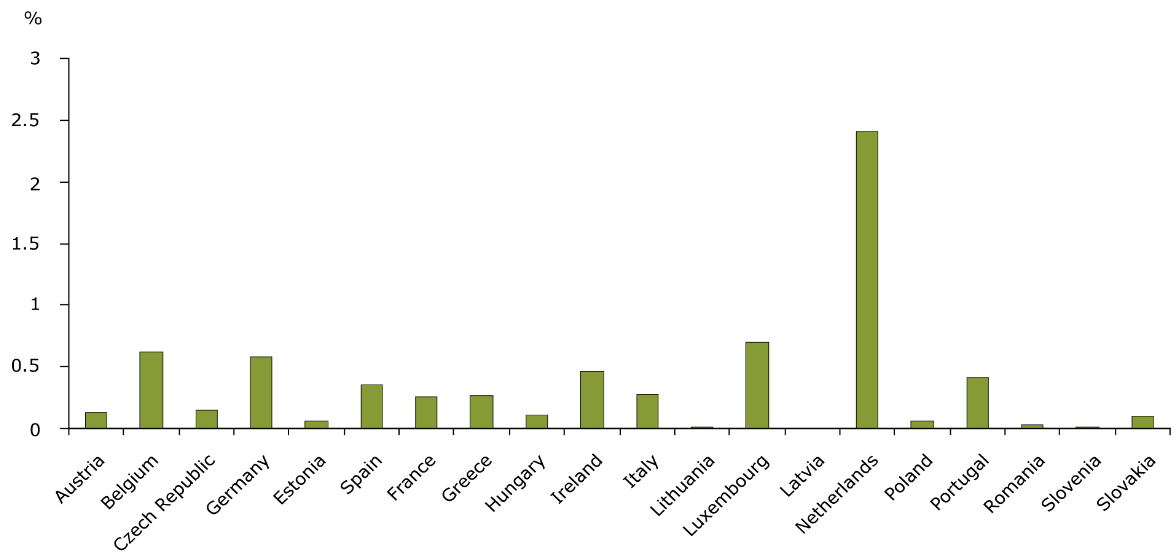

Figure 4b. Relative losses of agricultural areas to urbanisation (%) based on a comparison of CORINE land cover data for 1990 and 2000. The change in the Netherlands is dramatic, probably reflecting the intense demand on space and economic growth during the period in question. Source: JRC/Gardi et al., 2009b

Salinisation

The accumulation of salt in soil is commonly referred to as salinisation. While naturally saline soils exist in certain parts of Europe, the main concern is the increase in salt content in soils resulting from human interventions such as inappropriate irrigation practices, use of salt-rich irrigation water and/or poor drainage conditions. Locally, the use of salt for de-icing can be a contributing factor. The primary method of controlling soil salinity is to use excess water to flush the salts from the soil (in most cases where salinisation is a problem, this must inevitably be done with high quality irrigation water) [12].

- **State of salinisation:** Thresholds to define saline soils are highly specific and depend on the type of salt and land use practices (Huber *et al*., 2008). Excess levels of salts are believed to affect around 3.8 million ha in Europe (EEA, 1995). While naturally saline soils occur in Spain, Hungary, Greece and Bulgaria, artificially induced salinisation is affecting significant parts of Sicily and the Ebro Valley in Spain and more locally in other parts of Italy, Hungary, Greece, Portugal, France and Slovakia.
- **Trends in salinisation:** While several studies show that salinisation levels in soils in countries such as Spain, Greece and Hungary are increasing (De Paz *et al*., 2004), systematic data on trends across Europe are not available.

Acidification

Acidification describes the loss of base cations (e.g. calcium, magnesium, potassium, sodium) through leaching and replacement by acidic elements, mainly soluble aluminium and iron complexes [13]. Acidification is always accompanied by a decrease in a soil's capacity to neutralise acid, a process which is naturally irreversible when compared to human lifespans. In addition, the geochemical reaction rates of buffering substances in the soil are a crucial factor determining how much of the acidifying compounds are neutralized over a certain period. Acidifying substances in the atmosphere can have natural sources such as volcanism. However, the most significant ones in the context of this assessment are those that are due to anthropogenic emissions, mainly the result of fossil fuel combustion (e.g. in power plants, industry and traffic) and due to intensive agricultural activities (emissions of ammonia, NH_3). Emissions of sulphur dioxide (SO_2) and nitrogen oxides (NO_X) to the atmosphere increase the natural acidity of rainwater, snow or hail. This is due to the formation of sulphuric and nitric acid (H_2SO_4, HNO_3), both being strong acids. Ammonia contributes to the formation of particulate matter in the air, including ammonium (NH_4). After deposition to ecosystems, the conversion of NH_4 to either amino acids or nitrate (NO_3) is an acidification process. Furthermore, forestry and agriculture (due to biomass harvest) can lead to ecosystem acidification processes in soils. Such conditions can be found in the heathlands of north-western Europe where land management practices over centuries have led to soil acidification and erosion.

- **State of soil acidification:** While a number of studies have produced reports of soil pH across Europe (Salminen *et al*.,2005; JRC 2008), the systematic monitoring of soil acidification across Europe is generally lacking for non-forested soils. The EU Environmental Action Plans have a long-term objective of not exceeding critical loads of acidity in order to protect Europe's ecosystems from soil and water acidification. Though the interim environmental objective for the year 2010 has strictly speaking not been met, the improvements are considerable (see the SOER 2010 Assessment on Air Pollution (EEA, 2010c)). Soil acidification is closely linked to water acidification and indicators of critical loads [14] can be used to show the exposure of soils to acidification. Assuming full implementation of current policies in 2010, critical load models show that 84% of European grid cells which had exceedances in 1990 show a decline in exceeded area of more than 50% in 2010 (EEA, 2010a). However, a recent assessment of 160 intensive forest monitoring plots showed that critical limits for soil acidification were substantially exceeded in a quarter of the samples (Fischer *et al*., 2010).

- **Trends in acidification:** As a result of regulation and improved practices, emissions of acidifying pollutants, particularly of SO_2, have fallen in recent years (see the SOER 2010 Assessment on Air Pollution, EEA, 2010c). A number of local and regional studies have shown that the impact of emissions reduction schemes in many parts of the United Kingdom, Germany and Scandinavia is particularly evident with acid levels declining, rapidly in some parts, or at least stabilising (Ruoho-Airola *et al*., 1998; Fowler *et al*., 2007; Kowalik *et al*., 2007; Carey *et al*., 2008, EEA 2010). However, a recent assessment of 160 ICP-Forest intensive forest monitoring plots showed that between 2000 and 2006 there was little change in soil acidification on the plots studied (Fischer *et al*., 2010). In many areas, NO_X and NH_3 are now identified as the main acidifying agents.

Soil biodiversity

Soil biodiversity reflects the mix of living organisms in the soil. These organisms interact with one another and with plants and small animals forming a web of biological activity. Soil is by far the most biologically diverse part of Earth. Soil biota play many fundamental roles in delivering key ecosystem goods and services, such as releasing nutrients from SOM, forming and maintaining soil structure and contributing to soil water entry, storage and transfer (Lavelle and Spain, 2001). Soil biodiversity is defined by the variation in soil life, from genes to communities, and the variation in soil habitats, from micro-aggregates to entire landscapes (UN, 1992; EEA, 2010f). Hence, soil degradation by erosion, contamination, salinisation and sealing all threaten soil biodiversity by compromising or destroying the habitat of the soil biota. Management practices that reduce the deposition or persistence of organic matter in soils, or bypass biologically-mediated nutrient cycling also tend to reduce the size and complexity of soil communities. It is however notable that even polluted or severely disturbed soils still support relatively some level of microbial diversity. Specific groups may be more susceptible to certain pollutants or stresses than others, for example nitrogen fixing bacteria that are symbiotic to legumes are particularly sensitive to copper; colonial ants tend not to prevail in frequently-tilled soils due to the repeated disruption of their nests; soil mites are a generally very robust group.

- **State and trends of soil biodiversity**: Little is known about how soil life reacts to human activities but there is evidence that soil organisms are affected by SOM content, the chemical characteristics of soils (e.g. pH, the amount of soil contaminants or salts) and the physical properties of soils such as porosity and bulk density, both of which are affected by compaction or sealing. However in the last years, several studies on soil biodiversity have been started, allowing a better comprehension of the biogeography of soil organisms (Dequiedet *et al*., 2009; Griffiths *et al*., 2011, Cluzeau *et al*., 2009). Other recent research has targeted the investigation of the relationships between soil parameters, land management practices and soil biodiversity patterns (Dequiedet *et al*., 2011; Keith *et al*., 2011; Bru *et al*., 2011; Gardi *et al*., 2008), while other investigations are more focused on the contribution of soil biota to the provision of ecosystem services (Mulder *et al*., 2011). Despite these individual initiatives, one of the major differences between above-ground and below-ground biodiversity is that a majority of soil organisms are still unknown (see Table 1). For instance, it has been estimated that the currently described fauna of nematoda, acari and protozoa represent less than 5 % of the total number of species (Wall *et al*., 2001).

  Monitoring programmes are essential for the understanding of trends in soil biodiversity; within the EU several initiatives are currently running at national (Countryside Report, UK; ECOMIC-RMQS, France; BISQ, the Netherlands; CreBeo, Ireland; etc.) or regional level. Some of the ongoing initiatives at European level have been described by Gardi *et al*. (2009a).

  A limited number of data concerning the dynamics of soil biodiversity are available, and these generally refer to a few groups of soil organisms. Mushrooms, for instance, are a group of soil organisms for which a relatively long history of records exists. From this type of dataset, it has been possible to show mushroom species decline in some European countries. For example, a 65% decrease in mushroom species over a 20-year period has been reported in the Netherlands, and the Swiss Federal Environment Office has published the first ever 'Red List' of mushrooms detailing 937 known species that face possible extinction in Switzerland (Swissinfo, 2007).

Desertification

Prolonged droughts and more irregular precipitation, combined with unsustainable use of water and agricultural practices, could lead to desertification, defined by the United Nations Convention to Combat Desertification (UNCCD) (UN, 1994) as 'land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities'. The most recent terminology adopted by the UNCCD includes 'Desertification, Land Degradation and Drought'. This reflects the widespread endorsement of the Convention also by countries that do not have drylands within their national territories. Within the EU, the following Member States consider themselves affected by desertification and are included in the Annex V of the UNCCD: Bulgaria, Cyprus, Greece, Hungary, Italy, Latvia, Malta, Portugal, Romania, Slovakia, Slovenia and Spain (UN, 2001).

- **State of desertification:** The DISMED assessment (Domingues and Fons-Esteve, 2008) has shown that sensitivity to desertification and drought is lower in Europe than in neighbouring regions. The situation is most serious in southern Portugal, much of Spain, Sicily, south-eastern Greece and the areas bordering the Black Sea in Bulgaria and Romania. In southern, central and eastern Europe 8% of the territory currently shows very high or high sensitivity to desertication, corresponding to about 14 million ha, and more than 40 million ha if moderate sensitivities are included [15].
- **Trends in desertification:** Many soil types in the Mediterranean region already exhibit many aspects of degradation (i.e. low SOC content, prone to erosion, low fertility) which, together with the hot, dry climate of the region, hampers the recognition of desertification. While qualitative evidence for desertification appears to be prevalent throughout the region (e.g. increasing aridity, declining ground water levels), some recent observations suggest that the western Mediterranean is showing signs of a slight warming and of drier conditions while eastern parts are experiencing cooler, wetter conditions. However, other studies report opposing trends (Safriel, 2009).

Landslides

Landslides are the gravitational movement of a mass of rock, earth or debris down a slope (Cruden, 1991) [16]. Landslides occur when the stability of a slope changes from a stable to an unstable condition. Such changes can be caused by a number of factors, acting together or alone. Natural causes of landslides include groundwater pressure, loss of vegetation cover (e.g. after a fire), erosion of the toe of a slope by rivers or ocean waves, saturation by snowmelt or heavy rains and earthquakes. Human causes include deforestation and removal of vegetation cover, cultivation, construction and changes to the shape of a slope. Landslides can be slow moving or very rapid.

- **State of landslides:** There are no data on the total area affected in Europe, although estimates have been made for Italy (7%), Portugal (1%), Slovakia (5%) and Switzerland (8%). The main landslide-prone regions include mountain ranges such as the Alps, Apennines, Pyrenees, Betics, Carpathians, and Balkans; hilly areas on landslide- sensitive geological formations for example in Belgium, Portugal and Ireland; coastal cliffs and steep slopes for example in the United Kingdom, France, Bulgaria, Norway and Denmark; and gentle slopes on quick clay in Scandinavia. Landslides are possibly the most serious environmental issue in Italy. [17: See dramatic films of major landslides in Calabria, Italy, and Cornwall, UK].

The development and harmonisation of national landslide inventories should be a priority to serve as a database for research into causes, susceptibility and risk zoning and potential remedial action. Many countries are creating comprehensive nationwide or regional landslide databases. So far European national databases contain more than 630 000 landslides but the true number of landslides in each country is certainly much higher, e.g. Italy (> 485 000), Austria (> 25 000), Slovakia (> 21 000), Norway (> 19 500), the United Kingdom (> 15 000), Czech Republic (> 14 000), Poland (> 12 000), France (> 10 000), Slovenia (> 6 600), Iceland (> 5 000), Greece (> 2 000) and Bosnia and Herzegovina (> 1 500) (Van Den Eeckhaut and Hervás, in press). However, neither landslide inventories nor landslide susceptibility or risk maps are harmonised among European countries, hampering comparison between different countries and implementation of consistent policies at the European level.

- **Trends in landslides:** While changes in land use, land cover and climate (higher and more intense rainfall patterns) will have an impact on landslides there are no pan-European data on trends in landslide distribution and impact. The national inventories described above will eventually provide the necessary spatio-temporal information to assess trends. Landslides continue to affect people, property and infrastructure.

Soil contamination

It is important to distinguish between local soil contamination (the result of intensive industrial activities or waste disposal [18]) and diffuse soil contamination covering large areas [19] (see also the SOER 2010 Assessment on Consumption and the Environment (EEA, 2010d)).

- **State of soil contamination**: It is difficult to quantify the real extent of local soil contamination as many European countries lack comprehensive inventories and there is a lack of EU legislation obliging Member States to identify contaminated sites (the Directive on the management of waste from extractive industries is an exception (EC, 2006a)). Estimates show that the number of sites in Europe where potentially polluting activities are occurring, or have taken place in the past, now stands at about 3 million (EEA, 2007). Some locations, depending on their use and the nature of the contaminant, may only require limited measures to stabilise the dispersion of the pollution or to protect vulnerable organisms from pollution. However, it should be noted that around 250 000 sites may need urgent remediation. The main causes of the contamination are past and present industrial or commercial activities and the disposal and treatment of waste (although these categories vary widely across Europe). The most common contaminants are heavy metals and mineral oil.

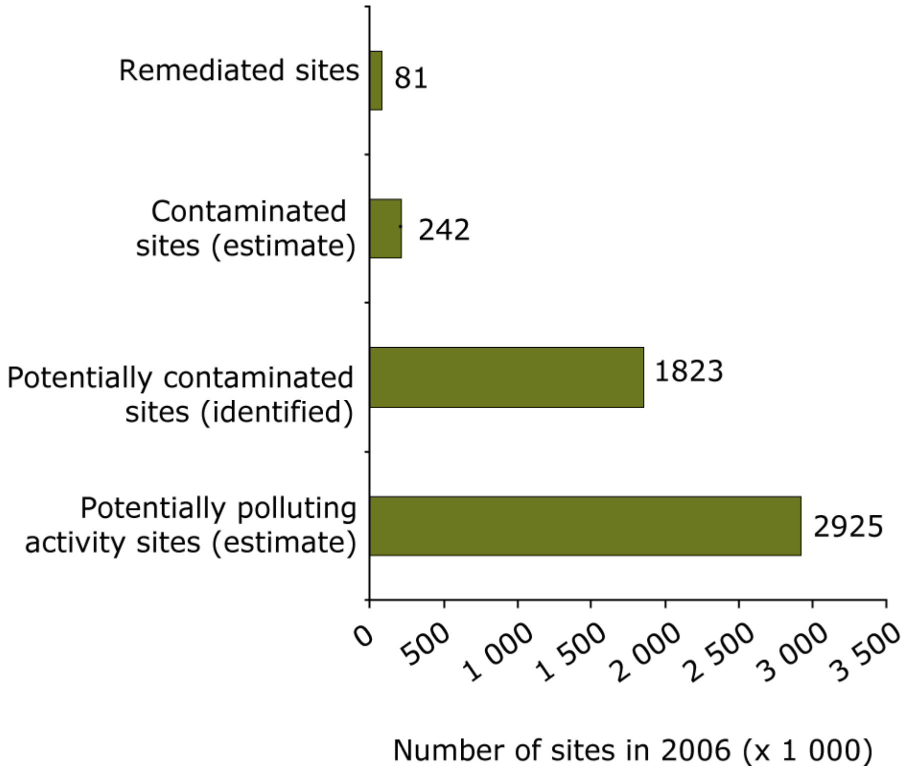

Figure 5. The graph shows the status of identification and clean-up of contaminated sites in Europe as reported to the European Environment Agency through the EIONET priority data flows on contaminated sites. While trends vary across Europe, it is clear that the remediation of contaminated sites is still a significant undertaking.

Source: EEA, 2007.

Data on diffuse contamination across Europe is even more limited than that for local contamination as there are no harmonised requirements to collect information. Rodriguez Lado *et al*. (2008) attempted to map the concentrations of eight heavy metals based on samples from the Forum of European Geological Surveys Geochemical database of 26 European countries, but noted mixed accuracies during the validation phase. Bouraoui *et al*. (2009) modelled fertiliser application rates across EU-25 and showed that approximately 15% of the land surface experienced soil nitrogen surpluses in excess of 40 kg N ha^{-1}. Proxy measurements such as the concentration of nitrates and phosphates in water bodies, including groundwater supplies, can be used as an indication of excessive nutrient application to soils.

- **Trends in soil contamination:** Due to improvements in data collection, the number of recorded polluted sites is expected to grow as investigations continue. If current trends continue and no changes in legislation are made, the numbers reported above are expected to increase by 50% by 2025 (EEA, 2007). There is some evidence of progress in remediation of contaminated sites, although the rate is slow (Figure 5). In recent years, around 80 000 sites have already been treated while many industrial plants have attempted to change their production processes to generate less waste. In addition, most countries now have legislation to control industrial wastes and prevent accidents. In theory, this should limit the introduction of pollutants into the environment. However, recent events such as the flooding of industrial sites in Germany during extreme weather events leading to the dispersal of organic pollutants and the collapse of a dam at an aluminium plant in Hungary in October 2010 shows that soil contamination can still occur from potentially polluting sites. Trends in the deposition of heavy metals from industrial emissions are discussed in the SOER 2010 Assessment on Air Pollution (EEA, 2010c).

While reports show that fertiliser sales have remained stable or fallen slightly in EU-15 countries, consumption in Europe as a whole has continued to grow steadily during recent years (Eurostat, 2010a; FAO, 2008). Although it is too early to detect any impact of the current economic crisis on fertiliser applications, a number of recent indicators (e.g. IRENA Gross Nitrogen Balance; EEA 2005a) and reports (EC, 2010a) have noted that nitrate levels in water bodies across Europe have fallen markedly (in 70% of monitored sites between 2004 and 2007). Given that the major source of nitrates in water bodies is runoff from agricultural land, one would expect to observe a similar situation in soil. If biofuel production becomes an important issue in the EU, this could lead to increased fertiliser applications and an increase in areas affected by diffuse contamination.

In EU-27, the total area under organic farming increased by 7.4% between 2007 and 2008 and accounted for 4.1% of the total utilised agricultural area (Eurostat, 2010b). Increased use of organic farming methods throughout Europe should result in an improvement of diffuse soil pollution from agro-chemicals. However, good agricultural practices should be followed to reduce the risk of pollution of water courses from manure applications.

6.4. Similarities and differences between China and the EU

Soil degradation is a global issue and one of the major causes of land productivity decline, and related social and environmental effects.

Main driving forces - as discussed in this report in detail – are urbanization and infrastructural development and inappropriate agricultural practices (Table 1) both in China and in the EU. Similar pressures can also be observed, that result in degraded soils. Soil sealing, contamination, erosion, salinization, loss of soil organic matter and biodiversity are common features of land resources of the EU and China. Degradation alters the capacity of soil to function, resulting in productivity decline and a series of off-site environmental problems, e.g. pollution of freshwater resources, eutrophication etc. Furthermore, degradation can indirectly affect food safety, thus social development globally.

In order to combat degradation and reduce degradation risk, targeted policy actions are needed, including incentives and legal regulations, both in China and Europe.

Table 1. Results of the DPSIR assessment: soil degradation threats and land resources

	China	European Union
Driving forces	D: urbanization and industrialization, agricultural intensification ID: economic growth with high resources and energy consumption lack of adequate legal instruments	D: urbanization and industrialization, soil management practices, ID: socioeconomic changes, need for biofuel lack of adequate legal instruments
Pressures	D: erosion, desertification, sealing, contamination, compaction, salinization, loss of soil organic matter and biodiversity , ID: industry/ energy mining; infrastructure construction	D: sealing, contamination, erosion, compaction, salinization, loss of soil organic matter and biodiversity, nutrient mining
State	loss of productive soils, altered functional capacities, degraded soils	loss of productive soils, altered functional capacities, degraded soils
Impacts	deforestation (loss of grassland; landslides and debris flow; flooding – social conflicts) decrease of food production, soil-,air- and water pollution and contamination	decrease of food production, food contamination, soil-,air- and water contamination
Responses	research and legal regulations, incentives	research and incentives

7. Policies and recommendations

Stephen Nortcliff and Li Xiubin

7.1. Soil Sealing – Policies in Europe and China

Land and soil are vital resources in both Europe and China. The future developments in both Europe and China are underpinned by the land and soil. In Europe over the second half of the twentieth century and continuing in to the twenty first century there has been a substantial land take for urbanisation and associated infrastructure. The rate of this loss of land (soil sealing) has occurred at a rate twice as fast as the growth in population. Whilst in China the loss of land through sealing has not occurred over such a long period of time it has in the last twenty years accelerated and is now occurring at a rate in excess of that in Europe. The sealing of soils, when the ground is covered by impermeable material, such as concrete or asphalt, is one of the major contemporary causes of soil and land loss and then reduction in agricultural production capacity in both Europe and China. Land degradation by sealing is irreversible, there are only limited amelioration strategies available. Whilst it is not feasible to prevent future loss of soil and land by sealing it is essential that future loss is limited.

Policies for limiting soil sealing

1. **Targets for Land Take**. Setting targets for the annual amount of land to be sealed by urbanisation and associated developments has been adopted in some European countries such as Austria, Belgium (Flanders), Germany and Luxembourg. These targets are principally used to monitor land take and are not binding limits. Whilst they may create an awareness of the loss of soil by this process as there are no penalties for exceeding these targets they do not directly control the process. China has also such a land control system for urbanisation, but the phenomenon of illegal land take remains widespread. An official investigation shows that each year there is about 37,000 cases of illegal land take, some 30,000 ha of farmland is involved.
2. **Land Planning**. Local land planning regulations where restrictions are placed on the use of new land for development and encouragement to use previously used (brownfield) land can have a significant impact on controlling land take locally. In the United Kingdom the expansion of most towns and cities is constrained by a ‘greenbelt’ around them a policy first established in London in 1933, but extended across the country in 1955. These policies can impact on the rate of land take, particularly when coupled with broad guidance to land planning authorities to minimise land take. ‘Primary farmland’ can be another option to protect land that is most valuable for farming from sealing.
3. **Protection of specific sites**. Within Europe a number of countries have policies to protect land which is of particular scientific or cultural interest. These sites include important ecosystems, archaeological sites, particular soils, etc.
4. **Regeneration of brownfield sites**. Coupled with the planning regulations and guidance an encouragement to focus development on previously used (brownfield) land has had an impact in slowing the rate of land take in a number of European countries by reusing sites rather than

leaving them abandoned. There may be additional costs involved in reusing this land, but in some cases there has been an additional impact in regenerating inner city areas.

5. **Intensive use of urban land**. Besides the spatial expansion of built-up land, intensification of urban land use can also provide space for cities. Of course the living condition will be reduced and public facilities will be subject to greater pressure while land use intensification is raised. So density should be kept in balance with green space and urban public facilities. The density of residential area is quite high in China, but that of industrial area is very low.

Policies for mitigating the effects of soil sealing

Whilst the priority should always be to limit soil sealing, it is not always possible for no sealing to occur. Under these circumstances strategies should be adopted to mitigate the effects of soil sealing. These mitigating strategies include:

1. **Increasing the use of permeable materials and surfaces**. The incorporation of permeable materials and surfaces in infrastructure development may assist in preserving some of the soil functions such as the connectivity between the surface and subsurface soils thereby reducing the amount of runoff and peak flows following rainfall. Reducing the sealed surface may also assist in groundwater recharge and evaporation from the permeable surface which will increase urban cooling.
2. **Green infrastructure** has the potential to reduce the heat island effect of urban areas. Green infrastructure development is effected through the planning process and is now frequently a part of new developments. Within established developments the opportunity for green infrastructure is less, but every opportunity should be taken to increase the amount of green infrastructure. Recent developments in green roofs are a small contribution to this. Measures committed to the improvement of soil quality and microbial activity like metal pollution control and loose of soil should be promoted.
3. **Avoiding the wastage of soil**. Whilst the soil is sealed in many developments, a frequent component in many developments is the initial removal of the topsoil. This is a valuable resource and should be reused wherever possible and appropriate.

7.2. Agricultural Intensification – Policies in Europe and China

Land and soil are vital resources in both Europe and China. The future developments in both Europe and China are underpinned by the land and soil. In Europe over the second half of the twentieth century and continuing in to the twenty first century there has been a sustained process of agricultural intensification with yields rising rapidly in response to both developments in crop breeding and increasing use of fertilizers and pesticides. Within Europe this process was begun when fertilizers, in particular nitrogen fertilizers were relatively inexpensive and there was a tendency to work at the upper end of the fertiliser response curve, where additional fertiliser inputs produced increased yield but the rate of such increases were very small. As a result of this there was inefficient use of the added fertilizers with resultant build up in the soil and, particularly in the case of nitrogen considerable loss to surface and ground waters with serious negative impacts in the form of pollution and in some cases the loss of drinking water supplies. Fortunately this problem was recognised and policies were implemented to manage the use of fertilizers in terms of crop response efficiency, economic efficiency and environmental efficiency. An important element in environmental protection was the development of 'nitrate sensitive zones' and nitrate vulnerable zones' where management of both organic and inorganic fertiliser additions was managed in terms of total nitrogen load of the system with the aim of protecting water resources.

In China the intensification of agricultural production is a more recent phenomenon, occurring principally in the last two decades. The drivers for increasing agricultural production are the demand for food and fibre from a large and growing population, and the changes in diet associated with economic development. This has been supported with substantial national subsidies for farmers' use of fertilizers which has resulted in a dramatic increase in fertiliser use in the last decade. China as a consequence of the increased availability of nitrogen fertilizers and the substantial subsidy in the cost of these fertilizers has seen a significant increase in their use with a corresponding marked increase in yields. Whilst these yield increases have made a significant impact on China's food production and food security, there is increasing evidence of overuse of nitrogen fertilizers, estimated to be in the region of 30-60% in some areas (Ju et al. 2009). Recent survey work amongst farmers in China has suggested application rates could be cut in many situations by at least 30% with no loss of crop production or risk to national food security (Ju et al. 2009). Improved nitrogen management would have economic and environmental benefits across all scales, from local (e.g. higher net farm incomes) to the regional and global (e.g. reduced pollution in the China Sea and lower GHG emissions).

Whilst the environmental consequences of high levels of fertiliser and pesticide use are a major concern in relation to agricultural intensification, other consequences of inappropriate agricultural practices coupled with intensification include soil structural damage and loss of soil through soil erosion.

Policies and practices for limiting land degradation through agricultural intensification

1. Nitrogen Fertilizers – The problems
   The major problem with excessive use of nitrogen fertilizers is the leaching of nitrate to ground and surface waters. The problems caused by leaching may be reduced if
   a. The fertilizer is not applied in the autumn
   b. The recommended amount is used
   c. Fertilizer is applied when it is needed
   d. There is no crop failure.

   Losses of nitrate to ground and surface waters may also occur through mineralisation of crop residues left in the soil (these will increase with increased yield in response to fertilizer application). Mineralization of soil organic matter also occurs when old grassland and woodland are brought in to cultivation and may occur in organic farming systems where leys are part of the rotation.

   In addition to the pollution impacts on surface and ground waters it is now increasingly recognised that there is also a significant contribution to emissions of nitrous oxide – the most powerful agricultural greenhouse gas.

2. Management of Nitrogen Fertilisers
   Key to the successful management of fertilizers and in particular the management of nitrogen fertilizers is sound guidance and advice. There has been considerable progress through scientific experimentation and extensive field trials in both Europe and China in developing guidance to farmers. In Europe (e.g. the United Kingdom) there have been additional environmental drivers through national and European legislation to force farmers to use their nitrogen resources more efficiently. In addition the increasing costs of nitrogen fertilizers has also been an economic driver towards more efficient use.

   In China the substantial subsidy of nitrogen fertilizers has resulted in them being a relatively lower cost to farmers than their equivalents in Europe and this may have resulted in the considerable overuse to achieve higher yields, a situation similar to the rapidly increased use of nitrogen fertilisers with commensurate yield increases seen in Europe in the 1970s. In a similar situation to that in Europe in the 1970s, China is now seeing substantial losses of excess nitrogen to ground and surface waters. There is also the problem of nitrous oxide emissions, which was not fully considered in Europe during this period of rapidly increasing fertilizer use.

   To ensure that there is appropriate guidance to farmers on the efficient use of nitrogen fertilizers there probably needs to be some restructuring in how fertilizers are supplied and guidance on their use provided. The task of efficient nitrogen fertilizer management is often beyond the competence individual farmer, but is a key component of economic and environmental efficiency. What is required is a system of support providing advice to farmers at a local scale, both in terms of the magnitude of fertilizer applications in relation to crop, soil and environmental conditions, but also in the timing of applications to optimise their use and minimise environmental damage.

3. Soil structural damage

   A further problem often associated with agricultural intensification is the increased occurrence of structural damage through the use of increasingly heavy agricultural machinery. Over the past decade due to the rise in labor costs, the use of agricultural machinery in China is growing very fast. Managing for increasing yields frequently resulted in more frequent passes of machinery and increasingly heavy machinery. A key aspect of soil management to prevent these compaction problems is timeliness of cultivation. It is recognised that soil is increasingly vulnerable to compaction above a given moisture content (which will vary with the nature of the soil). If machinery is used when the soil is above this critical soil moisture level damage to structure is almost inevitable. It is therefore essential that the behaviour of the soil be understood so that soil cultivations and other practices may be timed for periods when the soil is not vulnerable to damage. Timeliness and 'cultivation windows' have become a key part of farming practice in Europe and if adopted in China will make a significant contribution to reducing loss of soil structural properties.

   It is now widely recognised that soil structural strength is strongly correlated with the level of soil organic matter. Below a certain SOM threshold (which will vary for different soils), the soil is less resilient and more likely to be structurally damaged. In some intensified agricultural systems there is also a reduction in SOM with a commensurate loss of soil structural resilience. To avoid this reduction in the resilience to structural damage the SOM must be maintained above the threshold through management of organic matter inputs (crop residues, manure and other organic amendments such as compost and digestates from anaerobic digestion).

4. Soil erosion

   Whilst soil erosion is a natural phenomenon its occurrence often increases following agricultural intensification. There are often a number of potential causes for this increase in soil erosion, some related to the management of the farmers fields, for example the increase in field size and the removal of field boundaries and the tendency to cultivate up and down slopes rather than across the slope. Both these practices often result in increased volumes of water flowing down the slope with an increase in erosion.

   In addition as mentioned above, intensification may result in reductions in SOM levels. When SOM level fall below a critical threshold not only are they potential subject to structural damage they may also be more prone to aggregate breakdown with the consequent increase in the potential to be removed by wind or flowing water. A key component in the prevention of soil erosion is maintaining the aggregate strength which is partially accomplished by maintained SOM levels as indicated above.

Reference

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7.3. Soil erosion, salinisation, landslides, flooding and soil contamination

Chapter 6 outlines the main threats to soil which occur when soil is used inappropriately and soil is degraded. Chapter 6.2 and Chapter 6.3 respectively present the main threats from soil degradation in China and Europe and Chapter 6.4 outlines the similarities in the threats which occur in China and Europe. Many of the soils found in both China and Europe have been impacted by the activities of man from early times as a result of land clearance and consequent biomass production for food, fibre and fuel. When there was a small population and a ready availability of land the land use was generally of low intensity. Normally cultivated land was allowed to recover after a period of use, initially by abandoning one place of production and moving to a new site – shifting cultivation. When sedentary agriculture became established this 'abandonment' occurred in the form of fallow periods, where land was left unused and allowed to recover after a period of cultivation. This practice of fallowing was widespread in China and Europe. As the demands on land and the demand for food, fibre and fuel have increased through population growth the fallow period has been progressively removed as part of the trend to agricultural intensification. Some of the threats to soil arising from this intensification, particularly the overuse of fertilizers and pesticides, the decline in soil organic matter, soil erosion and soil compaction are dealt with elsewhere in this Chapter. Similarly the loss of soil through sealing, an increasingly important threat to soil in both Europe and China is dealt with separately. The other major degradation threats to soil are soil erosion (not related to agricultural intensification), salinisation, landslides, flooding and non-agricultural contamination.

Soil erosion

In both China and Europe the main focus of soil erosion by wind and water is that which occurs as a consequence of poor management during the intensification and expansion of agriculture. This soil degradation process however occurs in other forms of inappropriate land management when the soil is left vulnerable to erosion by wind and water. A common example is the erosion during construction projects when large areas of the landscape are stripped of vegetation and, frequently, the topsoil. Wind erosion may occur on these sites if there are prolonged dry periods as the soil surface is not protected by the vegetation and where subsoils are exposed they may be less resistant to detachment and hence vulnerable to loss. In a more humid environment, on sloping lands, the unprotected soil may be subject to soil erosion by water because of the lack of surface protection and the exposure of subsoil materials with low detachment resistance and often lower infiltration rates, particularly where compacted by construction machinery. In addition to the loss of soil there are additional environmental consequences with soil deposition on adjacent land and in water courses. This form of soil erosion is preventable. Codes of practice for construction should be introduced which highlight the vulnerability of the soil to erosion and ensure that working practices are introduced at all stages of the construction process to prevent this soil degradation and soil loss.

Salinisation

Saline soils are found naturally in both China and Europe. In Europe agriculturally induced salinisation arising from irrigation is found in Italy, Spain, Hungary, Greece, Portugal, France and Slovakia. In China agricultural soils affected by salinisation are found in the Huang-Huai-Hui Plain, the western part of

Northeast China, the irrigated areas of the Yellow River, irrigated areas of Northwest China and in coastal regions. In both China and Europe the continuing increases in demand for agricultural produce has resulted in the increase in salinisation as a soil threat. Induced Salinisation is the accumulation of salts in soil and occurs through the input of saline water (in particular the use of waste waters with a high slat content), the application of amendments rich in salts, contamination with substances rich in salts or the solubilisation of salts deeper in the profile and their movement to the upper parts of the profile as a result for crop water uptake or evaporation. The main cause of salinisation is the use for irrigation of waters rich in salts (principally sodium Chloride). Often the process of salinisation is accompanied by sodicisation and alkalinity. Whilst some crops are salt tolerant, many wither and exhibit rapid declines in yield as soil salinity increases as a result of the increase in osmotic pressure and salt toxic effects. When alkalinity is also present the high pH levels significantly reduce plant growth, and because of the high levels of sodium on the exchange complex there is often a direct impact on the structure of soil which further impairs plant growth and may make the soil vulnerable to soil erosion. Avoiding the input of saline irrigation water should be a relatively simple task, but frequently the availability of low salinity water (sweet water) is restricted, particularly where the demand for water has increased substantially and low salinity waters are no longer available.

The priorities for action include

- The identification of waters suitable for irrigation, avoiding waters with high salinity levels.
- Improve the drainage system and maintain lower ground water level.
- Develop low cost methods to reduce the salt content of salt rich irrigation waters.
- If the use of saline water is inevitable select salt tolerant species.
- Develop new cultivation systems that could better tackle the problem.
- Ensure that there is a reliable monitoring system to enable remedial action to take place before the critical levels are reached.
- Develop low cost methods to reclaim soils rich in salts (and sodium).

Landslides

The loss of soil through landslides often involves broad environmental degradation. Soils naturally occur on slopes. These soils are vegetated and stable. Landslides occur when the soils on the slope become unstable and under the force of gravity move rapidly downslope. This change in stability can be caused by a range of factors, often acting together and include natural causes and man induced causes, although many of the natural causes may be accelerated by the activities of man. The natural causes include:-

- Increases in porewater pressure with the soil during rainstorm to destabilise the slope.
- Overall soil degradation following removal of vegetation (e.g. as a result of wildfire burning).
- Removal of the lower slope through erosion.
- Catastrophic effects such as earthquakes (liquefaction may occur).

Whilst these conditions occur naturally the activities of humans may increase the susceptibility of slopes to landslides, through actions such as:

- Removal of natural vegetation through cultivation.
- Changing the shape and steepness of the slope through earthworks like terracing.
- Disrupting the drainage of the slope leading to higher porewater pressure.

Avoidance of landslides involves:-

- Identifying slope potentially susceptible to sliding and avoiding substantial changes such as deforestation.
- Avoiding actions to remove the lower parts of the slope.
- Removing potential for increases in porewater pressure through drainage.

Flooding

Flooding directly impacts on the productive potential of soils additionally soil conditions may have an impact on the occurrence of flooding. Whilst some soils, such as paddy, are deliberately flooded as part of the overall strategy for crop growth, in most cases flooding has a catastrophic effect on agricultural activity, impeding crop growth, either directly through the submergence of crops or by the inundation with sediments carried by the flood waters. Saturated soils which remain after the flooding may be difficult to manage through the reduction in structural stability with serious impacts on timing of agricultural activities. In addition to the impacts on agricultural production there are also many occurrences of urban areas being flooded with catastrophic effects including the loss of life and considerable financial losses. There is some indication that across both Europe and China the frequency of floods is increasing, possibly as a result of global climate change.

Soils form a key component of the hydrological cycle, providing a buffer system whereby water arriving at the surface through precipitation infiltrates in to the soil. Within the soil water is stored to provide water to provide water for plant growth; excess water flows vertically in to the groundwater store and laterally as throughflow to rivers. Because of the buffering role of the soil precipitation arriving at the surface does not immediately contribute to flow in streams and rivers, but is released over time and contributes to the base flow of rivers. When the soil is no longer able to accept further precipitation it runs off the surface and provides rapid inputs in to streams and rivers, providing peak flow events. When these peak flow events are of large magnitude floods occur. The acceptance of precipitation by the soil depends on the overall porosity of the soil and the infiltration at the surface. Once the soil is saturated no further inputs will be possible, runoff will occur. In an annual cycle many soils in the humid parts of China and Europe will have periods of time when the soil is saturated, and there have been some recent indications that in these areas the periods of saturation may be occurring more frequently because of climate change (in some examples these longer periods of saturation have been matched by longer periods of drought in other parts of the year). Under these conditions flood prevention involves removing water as rapidly as possible from the soils in to effective drainage systems which are able to cope with the large volumes of water.

A second contributing factor to flooding is where the rate of infiltration of water in to the soil is less than the rate of precipitation. There is some evidence that one of the consequences of global climate change in parts of northwestern Europe has been an increase in the intensity of precipitation inputs and hence the increase in runoff has occurred without changes in the soil infiltration rates. A more common problem in both China and Europe is that the infiltration rate of soils has been reduced. This reduction may have occurred through to broad causes. Firstly changes in the structure and stability of surface soils which are a consequence of the reduction in the levels of soil organic matter in the soil. The second cause of these reductions is the use of machinery which imparts high loads on to the soil, causing compaction and resultant reductions in infiltration. The structural decline through declines in soil organic matter will increase the vulnerability to machine based structural damage.

To prevent the reduction in infiltration rates it is necessary to:-

- Ensure that soil structural degradation is reduced by maintaining or improving soil organic matter levels in the soil.
- Reduce the frequency and size of machinery passes over the soil.
- Ensure that machinery passes over the soil occur at times when the soil is not vulnerable to structural damage. This will require developing an index of ‘soil workability’ or something similar.

Whilst this focuses upon agricultural use of soils there are a number of recent occurrences of substantial runoff events from construction sites. The development of similar codes of practice and the identification of ‘windows’ for on-site activity are necessary.

Soil contamination

Soil contamination arising during agricultural intensification has been considered above. More widespread soil contamination is found associated with other human activities, in particular industrial activities. In considering this non-agricultural contamination it is recognised that it is important to distinguish between local (point) soil contamination which arises, for example from industrial activity or an accidental spillage, and diffuse soil contamination which occurs over large areas from regional to national scale and potentially broader, which may arise for example from atmospheric deposition such as traffic. Because contamination persists many sites have been contaminated for many years, in parts of Europe where there is a long industrial heritage, sites may have been contaminated for over 200 years. Whilst the occurrence of diffuse contamination is known in broad terms detailed information is sparse. It has similarly proved difficult to quantify local contamination. Recent estimates for Europe have suggested that sites where potentially polluting activity are occurring, or may have taken place currently stands at about 3 million (EEA, 2007).

The extent of the identification of historically contaminated sites in Europe varies between member states. Similarly the policies for remediating these sites vary considerably between member states as do the extent to which policies are implemented. An effective record of contaminated sites is an essential prerequisite to any contaminated soil remediation policy. When contaminated sites are identified it is essential that the sources and pathways and behaviour of pollutants are understood if remediation policies are to be effective. A major concern of owners of contaminated sites and some governments is that the remediation processes are often expensive; often well in excess of the potential value of the remediated land. A key requirement in dealing with contaminated land is therefore the development of lower cost but environmentally efficient remediation practices.

Many industrial processes are potentially polluting and there are many policies which control these activities and their potential to introduce pollutants into the environment. Policies to prevent further contamination include legislation to control emissions, to air and water, from industrial production and controls on waste disposal. Occasionally environmental catastrophes result in uncontrolled pollution, such as the flooding of industrial sites in Germany during extreme weather events, leading to the dispersal of organic pollutants, and the collapse of a dam at the Ajka alumina plant in Hungary in October 2010. In recent years, soil pollution events caused by flooding are frequent in Southwest China, where heavy metal mining activities are very active. To prevent future soil contamination it is essential that industrial processes are fully understood and risk assessments are undertaken into the potential for products and byproducts of these processes to contaminate the soil and the broader environment. This risk assessment must also include models of the potential receptors of pollutants and the pathways to these receptors. The potential for multiple pathways of pollutants to a range of receptors means that policies and legislation which address the nature of materials and the prevention of soil, air and water pollution need to be integrated. The range of potential contaminants is increasing rapidly, particularly in respect of organic contaminants. It is imperative that there is a programme of research to support the identification of new contaminants and develop strategies to prevent them entering the environment or if this is not possible understanding how they may be remediated.

Reference

EEA 2007 Progress in management of contaminated sites (CSI 015) European Environment Agency

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Abstract

To secure adequate food supply is the major challenge for humanity in the 21st century. Growing world population and its urbanization put pressure on this basic need, which is further threatened by the constant loss of fertile land. The assessment of sustainability of food supply under increasing pressure on land resources has been selected as one of the most important priority topics of the activities of Sino-EU Panel on Land and Soil (SEPLS).
The Panel has performed a number of related researches and discussed the results on a scientific seminar in January 2012 in Nanjing, China. This report is an output of this seminar with a summary of the structured discussions on the below issues.
1. Urban and peri-urban development (soil sealing and loss of land functions)
Urbanization and the linked spread of infrastructural development mean sealing of soil surfaces. Soil sealing is the most rapidly growing limitation for soil functions (including biomass production function) both in China and Europe. Soil sealing in China has been taking dramatic degree in the last two decades and the process is estimated to continue in the coming period as well. While urban and peri-urban development is looked as a necessity for social development, its negative effect on natural resources are inevitable.
2. Land degradation
Despite the widely recognized importance of land degradation in the unsustainability of economic development and implementation of various policies to halt degradation (e.g. green for grain programme in China; cross-compliance measures in the EU), loss of land productivity by degradation is an ongoing process both in China and the EU. Major forms of soil degradation (erosion, desertification, landslides etc.) are similar in both regions. Assessment of the causes and consequences of soil degradation processes in relation to policy actions is highlighted among the priorities of the SEPLS.
3. Intensive agriculture and multi-function management of land resources
Intensification and extensification in agriculture can be considered as the main changes in land use in rural areas in both EU and China. While agricultural intensification is one of the greatest threats to the soil and environment and then hampers the sustainable development of agriculture and food security. To meet this challenge, sustainable management of multi-functionality of land resources is undoubtedly an effective strategy, in which the EU has a good expertise. Bilateral exchange of the experience and knowledge benefits the sustainable management of land resources.

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