SOIL QUALITY AND LAND USE IN HUNGARY

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Abstract

The analysis approach has been based on government statistical data, land use technology characteristics as well as geographic information databases. Soil quality characteristics, land use systems (conventional, modern intensive, modern low intensity, integrated, ecological) and development, ecological background of crop production and tillage recommendations on Hungarian soils are elaborately discussed. Over the past century (from 1938 to 2010) profound changes have been introduced regarding the cropping structure of the country. The results obtained support a conclusion, that land use changes have induced increment of risk factors in agricultural area.

Keywords: soil quality, land use, tillage systems, crop production

Soil quality

A multifunctional part of the environment, soil is a conditionally renewable natural resource; the most important medium for multipurpose biomass production; the integrator and reactor of other natural resources; a natural repository of water, heat and plant nutrients; a substance with a huge buffering and detoxication capacity for natural and human-induced stresses; a habitat for soil-dependent organisms; a factor of biodiversity. Soil resources may be used and conserved at the same time, but the preconditions of soil resilience must be ensured: constant attention and special care are needed to preserve the unique ability of soil resources. Tillage is an important part of these land use and soil care actions (*Várallyay*, 2008).

As the natural conditions (climate, relief, and hydrological and soil conditions), land use practices and traditions change slowly and the development of technology is so variable, it is only natural that there are so many forms of soil management, including tillage operations. Natural conditions in the region are relatively and generally favourable for rain-fed biomass production. These conditions, however, show very high spatial variability, often are irregular and not very predictable. Under such circumstances it is an important fact that soil is the largest potential natural water reservoir. This water storage potential, however, often is not (or only partly) used because of limited infiltration and water retention. Soil tillage, therefore, can be effective in preventing and moderating these limitations, facilitating infiltration and increasing the available moisture range.

The idea of soil quality improvement and/or maintenance can be considered as a relatively new concept both in soil science and agroecology. In all probability, plant production cannot be sustained when soil quality is declining (*Dexter*, 2004, *Karlen*, 2004). They also agreed that soil quality is focused on dynamic soil processes and properties influencing plant production risks even in the long term. Land use factors, including tillage, affect soil quality both in the short and long term. In Hungary, any method of tillage may be considered as beneficial if the soil is not damaged while fulfilling plant demands or if the soil's physical and biological quality is improved (*Birkás et al.*, 2004). Examination of the soil physical quality factors may give a chance to assess their interactions in different land use systems. The need to reduce the tillage- and technology-induced damage of field operations is one of the main goals of land management. In fact, the primary consequence of the conventional (regular) land use system is the deterioration in soil quality, which limits the moisture management and workability. Moreover, as soil quality condition decreases, soil sensitivity to climatic extremes may increase. As it stressed, to maintain good soil quality by the adopted land use system may reduce the effects of climatic extremes at reasonable cost (***Birkás et al.,*** 2006).

Land use

Land use is the sum of land utilization categories (e.g. field cropping, grassland management, forestry etc.) the crops or other plants sown or planted in the given site(s) and the modes of their production (***Birkás et al.***, 1999). The quality of arable land use is determined by the plants of different biological requirements and effects and the consequences of the use of the production techniques applied in growing them. It is possible to harmonise site and cropping system through land use and tillage. Without such harmony soil, site and environment may be damaged. The use of arable land is favourable if the environment suffers no new damage even over a longer period in the course of the production of crops adapted to the sit and to economic circumstances. Land use is unfavourable if the production technology or some of its elements deteriorate or aggravate the state of the soil and/or environment (***Birkás et al.***, 2008).

Arable land use systems can fall in categories depending on their impacts on soil and environment and the endeavours of farmers: early low intensity (~1000-1860), ***conventional*** (~ 1860, from the first year of deeper tillage till nowadays), early intensive (~1960-1980), ***integrated*** (~1980-), ***modern intensive*** (~1990-), ***modern low intensity*** (~1990-), and ***ecological/organic*** (~1980-). In the early 21st century five (those in italics) of the above are being applied. The factors taken into account in their review and appraisal: yield, productivity, plant, manure application, chemical load, weed control, energy input, level of equipment, required expertise, tillage and environmental damage (***Birkás et al.,*** 2008).

Conventional land use, involving the application of a variety of manures and fertilisers, enables varying yield levels depending on weather, site, soil fertility and the great variety of crops in use. Tillage is usually a matter of routine in terms of depth and mode based on ploughing. Crop protection is somewhat ad hoc, weeds are mechanically controlled, for the most part. The implementation is simple, its use is easy to master and they are, accordingly, not characterised by high rates of efficiency. Tillage interventions (primary and secondary tillage, seedbed preparation), are carried out more than once until the desired parameters are achieved. Soil and environment damage is caused in particularly wet or dry seasons (by unsuitable tillage implements). Conventional land use is not suitable for bringing already ongoing soil degradation to a halt and it is causing new damage as well. We are to suggest, that conventional land use together with conventional multi-traffic tillage is gradually transformed into the modern systems in response to environmental and cropping challenges. In some areas of conventional land use even the land use category may be changed (reforestation, returfing) with the aid of protection.

Modern intensive land use is aiming at optimising the yield, turning out marketable produce (cash crops). During this phase the use of chemicals is adjusted to the actual requirements (it is less excessive). Soils are exposed to substantially lower chemical loads (partly form ecological considerations) than in the early intensive phase. Tillage involves a variety of methods reaching different depths, including deep tillage from time to time. Crop protection involves both chemical and biological techniques. Productivity is maintained, in the majority of cases, by high energy inputs, applying an array of up-to-date equipment. Alleviating the disadvantages of intensive farming requires substantial knowledge and expertise. Modern intensive land use – its reasonable ratio may be modified again and again –

is justified by the proportion of the area under crops (e.g. sugar beets, sowing wheat, maize and sunflower) that can be economically produced in this way.

Modern low intensity land use has dropped some of the elements and features of its early version. Low or moderate yields are in line with the plans and resource inputs. Developing and improving machines and technology is an ongoing process, in the pursuit of reduced costs. Systems involving two or three crops are applied that are suitable for turning out mass produce. The low intensity form of land use is also suitable for growing energy crops. Small and medium quantities of fertilisers are applied in order to reach the planned yield levels. Pests and pathogens are controlled by chemicals, and weeds are controlled by combined methods. The average energy input is low, but sometimes, to improve the soil condition, highly energy-intensive interventions are applied. Environmental damages that have been caused are usually remedied. Modern low intensity land use may be suitable primarily for producing mass products, or for energy crops. The proportion of the area utilised through modern extensive land use – in sites of medium or lower quality that are still suitable for cropping – will gradually increase to a reasonable percentage.

Integrated – adaptable, value preserving – *land use* is likely to be the future's dominant trend in farming, is one of the pre-requisites of sustainable development. Integrated land use maintains the effectiveness of farming ultimately in harmony with preserving the state of the environment along with the state of other natural resources (*Birkás*, 2000). Both economically and ecologically suitable crops that can be used as foodstuffs and crops improving the state of the soil are being produced, in alternation. Organic manures and fertilisers are applied without creating an environmental load and particularly without causing pollution. Crop protection relies on combinations of chemical, mechanical and biological methods. Tillage involves a variety of adaptable and structure preserving techniques affecting the soil to varying depths, where defects are encountered remedial, improving and maintaining types of interventions are applied. Interventions to improve or restore the state of root zone are applied as required.

Reducing the physical and chemical loads to which soils are exposed is undertaken with the aim of preserving the environment and maintaining the reliability of cropping. We found some of the most important features of tillage underlying integrated cropping:

- improving or maintaining the soil physical condition, thereby maintaining of the soil water transport mechanisms,
- controlling the soil biological activity in a favourable way,
- preserving the soil organic matter content,
- preserving favourable effects of preceding crops, and alleviating unfavourable preceding crop effects,
- reducing the prevalence of pathogens, pests and weeds, impeding the growth of perennial weeds,
- alleviating the soil physical load by preventing tillage induced environmental damage (compaction, erosion) through sparing the soil physical, biological and nutrient condition,
- mitigating the extreme climate stress and thereby fluctuations in quantity and quality of yields.

The integrated cropping features may be completed the following ideas. Harmonising the state of the soil changing in the wake of tillage with its water transport mechanisms is a reasonable expectation. The soil should be in a condition that helps the infiltration of water in a rainy period, along with retaining water in a dry period. The requirement of fine crumbles should be re-considered in relation with some crops. Winter cereals, wide-row crops, rapes, mustard, oil radish etc. crumbled soil should be aimed, i.e. aggregates (between 2.5 and 10 mm) should make a lot larger proportion of the soil than the dust fraction (of particles below 0.25 mm) that easily go silting and block soil pores under the impact of rain drops. Soil aggregates, created by biological processes are more resistant to water and the pulverisation of the tillage implements. The largest proportion of the arable land will be utilised by integrated land use. At present its expansion is hindered by unfavourable soil conditions and weed infestation. Soil physical and biological conditions are expected to improve after the adoption of soil conservation tillage. Harmonising land use with tillage systems in a long run may bring about faster and more effective improvement.

Ecological – or in a narrower sense: biological – land use is characterised by the application of materials of natural origin and of methods preserving the natural environment. It aims to produce high quality output while avoiding materials polluting and/or damaging the environment. The weakness of ecological land use lies in its limited capability to reliably suppress pathogens since the produce is intended to be kept free of chemicals. After the adoption a balance develops over time in which pests' natural predators also find themselves adequate habitats. Weed control relies on combined application of mechanical and biological methods. As to the level of equipment or the energy input, there is a need for adaptation. Environmental protection may be ensured by applying a variety of soil protecting tillage techniques. Ecological land use has been adopted and may be adopted in the future primarily in particularly sensitive areas that need protection and it may expand as required.

Materials and methods

The analysis approach has been based on government statistical data, land use technology characteristics as well as geographic information databases.

Results

Background of crop production

General data. The total area of Hungary is 9,303,000 ha, of which 79 % or 7,356,000 ha is agricultural land, and 48.2% or 4,502,000 ha is arable land. The topsoil textures of Hungarian soils can be characterised as follows: sand 15%, sandy loam 12%, loam 47% and loamy clay and clay 26%, *Table 1*). On 59% of the soils the demands of crops can easily be met by soil tillage, while on 41% this is more difficult. Approximately 34.8% of the soils are sensitive to degradation and compaction, 13.9% are non-sensitive 23.0% are slightly sensitive and 28.3% have moderate sensitivity. There are different levels of soil degradation on 40% of agricultural land (that is 2,560,000 ha). About 85% of Hungary's territory is suitable for different purposes in agriculture and forestry, depending on the fertility of soils. Accordingly, agriculture is the largest user of land. The quality of cultivated lands, soil types, physical features, slope and climatic conditions are all good for agricultural production although there are substantial regional differences. The climate is continental, although extreme phenomena have occurred more frequently in recent decades. The average annual precipitation decreases from 600-800 mm in the west to 450-500 mm in the east, with the largest amount occurring in autumn and early summer. During the past 15 years, 2000, 2003, 2007, 2009 and 2011 were dry, 1996, 1997, 2002, 2006, 2008 were average, and 1998, 1999, 2001, 2004, 2005 and 2010 were rainy years.

Water surplus and deficit. While Hungary is located in the Carpathian Basin, the country has really exposed to the risk of floods and excess surface waters (52% of country, or 2/3 of cultivated land). The natural conditions (climate, water, soil and biological resources) of the Carpathian Basin are generally favourable for rainfed biomass production. The negative water balance is equilibrated by horizontal inflow (surface runoff/seepage in the unsaturated zone; and groundwater flow). In addition to the hardly predictable atmospheric precipitation pattern, there are two additional reasons of extreme soil moisture regime (the simultaneous hazard of water-logging or over-moistening and drought sensitivity (*Várallyay*, 2007, 2011). Water output of the rivers depend on the water management of countries upstream, while flood plains along the rivers and smaller streams cover total of 35,000 km^2. Moreover, about 25% of the territory consists of low-lying plains that have no natural drainage and 10-15% of regularly cultivated land is affected periodically by water-logging. Annual average area covered by internal waters (for 2-4 months) is about 130,000 ha. However, more then 500,000 ha fields were water-logged in 2010 and the damage has prolonged to the end of the next spring.

Table 1 Agricultural statistical data of Hungary

Area of Hungary (km²)		93.030	
Agricultural area (without forests) (million ha)		5,34	
Number of inhabitants		9 972 000	
Agricultural area per capita (ha)		0.55	
Arable land (million ha)		4,502	
Grassland (million ha)		0,763	
Forests		1,913	
Orchards, vineyards (million ha)		0,176	
Others (reeds, fishponds, million ha)		0,100	
Uncultivated land area (million ha)		1,947	
Proportion of arable land per country's area (%)		48.2	
Proportion of arable land per agricultural area (%)		59.5	
Proportion of less favoured areas (LFA) (%)		38.2	
Vulnerable areas according to Nitrate Directive (% of agric. area)		33.5	
Proportion of land under organic management (% of agric. area)		2.3	
of which:			
- arable land (%)		48.3	
- grassland (%)		51.7	
Water-logging damaged (million ha)		0,3 – 0,5	
Compaction problems (from total area, million ha)		1,9	
- Soils, sensitive to degradation and compaction (%)			34.8
- Soils, non-sensitive to degradation and compaction (%)			13.9
- Soils, slightly and moderately sensitive to degradation and compaction (%)			51.3
Area affected by water erosion (from total area, million ha)		2,31	
Area affected by wind erosion (from total area, million ha)		1,4	
Acidification, severe (from total area, million ha)		0,65	
Acidifacion moderately, weakly (from total area, million ha)		3,9	
Salinization problems (from total area, million ha)		0,946	
Salinization in deeper soil layers (from total area, million ha)		0,245	
Irrigable/irrigated area (2010, million ha)		0,17/0,036	
Topsoil texture (%)	sand	15	
	sandy loam	12	
	loam	47	
	loamy clay and clay	26	

Source FVM 2009, AKI, 2011.III/3; www.mindennapi.hu (22, June, 2011), Stefanovits (1990)

In the other hand, risk of the occurrence of moderate droughts has increased significantly across all seasons and probability of severe drought in the spring and winter periods has also increased. The probability of severe drought is particularly large in the plain areas (mainly in Great Plain), at the same time the Transdanubian region is only subject to more moderate droughts. A review of the precipitation conditions of the growing season indicates that rain alone does not meet the water requirements of vegetation. The annual water balance is negative, that is 450–600 mm precipitation vs. 680–720 mm potential evapotranspiration. Over and above, in Hungary, primarily thanks to the transition and the accompanying crisis of the sector which resulted in a reduction of inputs, there is no significant diffuse or point source water pollution of agricultural origin. The protection areas of the 700 vulnerable water supplies cover some 8% of the country.

Salinity and acidity. In areas with saline soils (solontsak, solonetz, saline meadow soils, saline chernozem soils etc.) is also a risk if temporary water-logging occurs bringing up more excess salt from deeper layers. Inappropriate water regulation, land use changes (conversion to arable), using deep ploughing, disturbance of deeper soil layers, irrigation can exacerbate the negative processes. To avoid the worsening the situation strict land use and water management (no irrigation/ strict irrigation water quality, keep down water table) related rules must be followed. In our country 50% of soils belong to the category of acidic soils, and within this 13% of soil covers strong, and 42% has average or weak acidity. The intensification of soil acidification is attributable to the misuse of chemical fertilisers, acidic deposits from the atmosphere, various acidic industrial by-products, waste and the lack of adequate soil improvement (liming). Soil acidification processes may be reversed to a significant extent by the application of environment-friendly nutrient management, increasing the organic content of soil, the use of farmyard manuring and regular liming.

Implementation of the Nitrate Directive. Nitrate pollution of groundwater is primarily associated with large-scale intensive animal husbandry sites, using liquid manure technology. A total annual production of liquid manure is around 11 million m^3, and approximately 80 000 ha of agricultural land required to accommodate this amount. Moreover, about 3.4 million m^3 of livestock manure is produced every year in nitrate sensitive areas. According to VM sources, about 1500 settlements located within the nitrate sensitive areas. The “good agricultural practice of manuring" allows farmers to comply with requirements. Within domestic total emission, agriculture’s share is most significant in ammonia (98.8%), nitrous-oxide (74.9%) and methane (52.6%). For this reason, reduction of nitrate emissions is most important priority.

Crop production

Hungary is well-endowed for agricultural production, including crop production. The country has fertile soils and a high number of sunshine hours. Almost two-thirds of the country’s total area is under agricultural cultivation. Among other EU member states, only Denmark and the United Kingdom have higher proportions. The agricultural area of the old EU member states has tended to decrease in the past few years, while the proportion of cultivated areas in the new EU member states has not changed. Although Hungary accounts for only 3% of the total agricultural area of the 27 EU member states, we play a major role in the production of a number of agricultural products.

In the EU-27, an average of one third of the agricultural area is devoted to cereal production. Cereal-production land accounts for 30% of the available area in the old member states, while the share is much higher (44%) in the new member states. Hungary produces cereals on half of its agricultural area. This proportion is only exceeded in a few member states. Oilseed crop production as well as fodder cropping is of high importance in recent years. The position of crops in the land use system may be established in terms of site or purpose of production. Some crops can be grown only in better sites, and other can be grown in all cropping areas. Different purposes of production – e.g. high quality or large quantity – take different resource inputs and, in some cases, different technological standards. Rational land use and proper soil management – to guarantee normal soil functions – have special importance both in the national economy and in environment protection (*Várallyay*, 2011).

Over the past century (from 1938 to 2010) profound changes have been introduced regarding the cropping structure of the country (*see paper from Jolánkai et al.*).

The results obtained support a conclusion, that land use changes have induced increment of risk factors in agricultural area. Major territories of Hungary are exposed to wind erosion, and some one third of the country is exposed to water erosion as well. Subsurface water bodies (water table, ground water, karst etc) are available in most parts of the country, however the magnitude and utility of them is rather diverse. Some two thirds of the country is exposed to potential nitrate pollution susceptibility. Less favourable agricultural areas are scattered all over the country including large homogeneous areas in the Northern and Eastern parts as well as the Danube-Tisza interfluvial areas. Location of the endangered areas can be correlated with the presence of employment failures like increment of jobless population (*Jolánkai et al.,* 2011). In an environmental viewpoint crop production can be evaluated as follows:

- crop production-induced environmental loading is low,
- mineral fertilization used in arable fields (2010, NPK kg/ha): 70,
- mineral fertilization used in sown area (2010, NPK kg/ha): 81,
- pesticide treated area (2005) 3,449,500 ha,
- main problem is not the fertilization but the poor nutrition management (and soil fertility deterioration)
- 80-100 million m^3 of soil, 1.5 million t of organic matter is lost from eroded and tillage-induced soil surfaces annually,
- lack of environment-conscious farming in the less favoured areas.

Two, relative new land use management systems requires more worthy of notes.

Integrated crop management. The spreading of environment friendly plant production practice with reasonable nutrient management, integrated plant protection, crop rotation, basic soil protection and appropriate tillage to protect the soil and the water above and under the surface. Initiating of this systems subjects to the provisions, e.g. minimal supported area, arable crops or horticultural plants etc. Some specifications are alsoreferred to this system.

- fully soil testing in 1st and last farming (pH, humus%, plasticity limit, totel water soluble salts, $CaCO_3$, NO_2+NO_3, P_2O_5, K_2O, NO_2+NO_3, Na, Mg, SO_4, Mn, Zn, Cu, plus toxic elements: Cd, Cu, Ni, Pb, Zn, Hg, Cr, As),
- nutrient management plan and fulfilment on the basis of soil sampling,
- N-fertilizer limit 170 kg/ha/year,
- high loading pesticides in green pea and sweet corn production is prohibited,
- in some vegetable production can only be used unlimited (green) and moderately limited (yellow) pesticides,
- one of the produced plant kinds is to be resistant to one disease at least,
- crop protection forecast is required.

Ecological crop management. A production system that sustains the health of soils, ecosystems, and people relying on ecological processes, biodiversity and cycles adapted to local conditions and combining tradition, innovation and science. It rely special techniques in crop rotation, green manure and/or compost and biological pest control to maintain soil productivity. In this system excludes or strictly limits the use of manufactured fertilizers, pesticides, plant regulators, and genetically modified organisms. It may promote production structure diversification, innovation and market-orientation. Some problems, including disease control requires peculiar attention.

Tillage recommendations on Hungarian soils

In our S&T project (HR-43/2008; OMFB-01289/2009) soil and soil state assessment and analyses, data collection in land use, soil tillage, fertilization, and climate threat was planned and accomplished. In this chapter the features of the most important soil types and soil tillage suggestions are presented.

Chernozem soils

These soils are classified as Chernozems in WRB and as Mollisols in ST. The favourable natural attributes of chernozem soils include humus building processes, deep fertile layer, favourable water, heat and air transport and balance, workability, crumb forming and easy availability of their nutrient contents. The most important goals of tillage include preserving these attributes and alleviating circumstances leading to detrimental processes.

Adverse tillage effects weakening the favourable soil attributes are desiccation of the soil, clod and dust forming, traffic-induced damage, puddling the soil structure, pan forming underneath the tilled layer, reducing the water-intake capacity, fostering organic matter loss and weed infestation.

Tillage treatments protecting favourable soil attributes are moisture conservation during and beyond the growing season, maintaining and improving the water-intake and the water storage capacity, soil structure protection (*Figure 1*), disturbing the soil only within the suitable soil moisture range, minimising traffic, encouraging recovery outside the growing season, varying the tillage depth and modes, organic matter protection regardless of the tillage treatment being applied, preventing of weed infestation.

Figure 1 Well-structured chernozem soil (left) and brown forest (right) soil

General tillage recommendations:

- **Stubble tillage**. Chopping and spreading the straw after crops harvested in the summer, followed by applying shallow stubble stripping using cultivator coupled with pressing element or just flat plate disks. Effective mechanical or chemical stubble treatment. Chopping and spreading stalks after harvest in the autumn. Allowing time for soil recovery during the stubble phase or while growing green manure plants. *Checking the soil conditions* after stubble tillage.

- **Primary tillage and surface forming**. Before crops sown towards the end of the summer or in the autumn: loosening and crumbling in a dry season while in a wet season tillage using cultivator to minimise soil damage. *Ploughing* – in the autumn, in the case of suitable soil moisture content – after maize and/or before spring-sown wide-row crops, creating an even soil surface of adequate water intake capacity. *Loosening* to a medium depth to improve the soil condition, if necessary according to the soil condition checks. Tillage should be avoided if it could lead to damage that is difficult to remedy (tillage pan development, dust forming). Damage caused by harvest during a rainy season should be remedied in the next season.
- **Seed bed preparation and sowing**. These should be carried out in a single pass (using a combination machine or using two machines in one go) when sowing takes place in the late summer, in the autumn or in the case of several spring-sown crops. When the two operations are carried out in two separate passes, care must be taken to avoid creating a thick seedbed base, dust forming and moisture loss in a dry soil.

Medium-heavy textured forest soils

Most of these soils are classified as Cambisols or Luvisols in WRB and as Inceptisols or Alfisols in ST. Their favourable attributes include good nutrient, water, air and heat transport and balance, adequate workability and the possibility of alleviating damage by erosion. The goals of tillage include protecting the favourable soil attributes (*Figure 1*), avoiding soil loss and conserving organic matter.

Adverse tillage effects weakening the favourable soil attributes are exposing the soil to erosion, clod forming during a dry period, traffic-induced damage and pan forming by puddling, deterioration of the water-intake capacity, accelerating moisture loss, weed infestation and tillage parallel to slope direction.

Tillage treatments protecting favourable soil attributes are protecting the soil surface as long as possible, conserving moisture, structure and organic matter, keeping up and improving the soil water intake and storage capacity, contour tillage and sowing, avoiding the use when the soil is wet, preventing weed infestation.

General tillage recommendations:

- **Stubble tillage**. Leaving a layer of mulch on the soil surface after harvest in the summer and making the soil suitable for taking in the summer rains. Exploiting the protection afforded by volunteer crops and weeds (before they start flowering), well-timed stubble treatment. Proper chopping and spreading of the residues of row crops grown during the summer, even if it takes two tillage passes. *Checking the soil condition.*
- **Primary tillage and surface forming**. Shallow tillage is a suitable option only where no compaction impedes water infiltration. In soils with a compact layer near the surface tine tillage should be applied, working the soil deeper than the depth of the compact layer. *Loosening to a medium depth* is required where compaction is below 30-32 cm. Loosening must be followed by surface forming in the summer. Harvest residues have to be incorporated in the soil in the autumn. Combining the plough with a loosening tool makes it possible to improve the condition of the root zone and the ploughable layer at the same time, in a single pass.

All tillage operations should be across the slope. Ploughing in the autumn should be carried out before the arrival of heavier rains and the onset of frost. Levelling the surface after ploughing should be carried out on horizontal surfaces, when the soil is workable enough. Levelling is not necessarily required on slopes, but larger clods should be pressed into the ploughed layer with heavy rolls.

- **Seed bed preparation and sowing**. Combinations of tools should be used on level fields and on easily workable slopes. Surface forming and seedbed preparation and – particularly before cereals, legumes and perennial papilionaceous crops – seedbed preparation and sowing, can be carried out in a single pass. A profiled surface should be formed after sowing, partly in order to protect the soil. A suitable plant density affords effective protection to the soil. On forest soils that are in need of protection sowing in mulch may be a suitable option when row crops are produced.

Heavy textured meadow soils

Most of them these soils classified as Gleyic Chernozems, Phaeozems or hertisols in WRB. In ST they belong to great groups of Mollisols or Vertisols that show aquic moisture conditions. Some of their original attributes are unfavourable, such as their high contents of clay and unavailable water, their high water retaining capacity and poor hydraulic conductivity. They are slow to warm up, which is a disadvantage in the spring but a definite advantage in the summer. In the spring they are characterised by high levels of groundwater table (danger of water-logging), while in the wake of heavier rains they are quickly saturated. As a consequence of high clay contents and extreme soil moisture conditions they are difficult to till. Tillage of such soils should be aimed at alleviating the impacts of the unfavourable soil attributes and at improving their workability (*Figure 2*).

Adverse tillage effects aggravating unfavourable soil attributes are forming a compact tillage pan below the tillage depth, damaging the top layer by desiccation, clod forming, crusting, trampling/driving over, smearing and puddling, organic matter loss and the resulting deterioration in the soil workability, weed infestation.

Tillage treatments alleviating unfavourable soil attributes are maintaining and improving the soil water intake and storage capacity by loosening, covering the soil in the summer to prevent silting and crusting, working the soil only when permitted by the soil moisture content, minimising traffic-induced damage, varying the depth and mode of tillage, preserving and recycling organic matter, preventing weed infestation.


Figure 2 Typical structure of a meadow (left) and an alkaline (right) soil

General tillage recommendations:

- **Stubble tillage**. Chopping and spreading the straw upon harvest in the summer, stubble stripping with flat plate disks, or with conventional disks combined with rolls or with heavy mulch cultivator, leaving a mulch layer on the top of the soil. This surface protection helps triggering the processes of crumbling and the decomposition of organic matter to release plant nutrients. Mechanical or chemical stubble treatment depending on precipitation and weed growth. The best possible stalk chopping after harvest in the autumn. Further chopping of not fully matured and/or wet stalks with disks. *Checking the soil condition*.

- **Primary tillage and surface forming**. Primary tillage preferably including a loosening process before rape. Ploughless primary tillage – with cultivators or disks – before winter cereals, after early-harvested previous crops. *Ploughing* in the summer is not recommended because it might not be possible to supplement it with proper surface forming. The need to maintain the soil water-intake capacity necessitates more frequent *loosening*. Crumbling of the surface of the loosened soil, using tools – flat plate disks, cultivator – preserving the loosened structure resulting from deeper tillage.

Cultivators that are to be used in heavy-textured soils may be used for medium deep (22-25 cm) or deep (32-35) tillage. The benefits of their use include loosening tillage pan layers and preserving the structure of soils that remain wet in their deeper layers (and are therefore easily smeared) even during the summer. *Ploughing* should be carried out only when it is permitted by the soil moisture content. Surface forming in the summer should result in smoothing the excessively rough surface. Large dry clods should be pressed into the worked layer with the aid of heavy clod breaking rollers to help them soak through during the winter. The Campbell roller that can be coupled to the plough is suitable for efficiently crumbling even humid soils, leaving an even soil surface that can take water in efficiently.

- **Seed bed preparation and sowing**. Owing to the possible shortcomings in the seedbed quality soils should not be worked with conventional disks or with heavy rolls when their moisture content is beyond the workable range, and surface forming using leveller implements should not be carried out before the optimum time in the spring either. Less damage is caused by using cross-board levellers and crumbling rollers. There are more opportunities for combining tillage treatments before sowing in the late summer or in the autumn.

In cloddy but levelled soils good conditions can be created for crop emergence by carrying out seedbed preparation and sowing in one pass. Seedbed preparation and sowing of row crops are carried out in two different passes because this type of soil takes longer to warm up. Care should also be taken to ensure that the seeding coulter does not smear the soil at the sowing depth because this will be where cracks appear first during a period of drought. Another possible mistake is puddling a thick seedbed base in the soil that happens to be prone to smearing at the time of seedbed preparation. Soil crusting after sowing may be prevented by creating a profiled soil surface.

Alkaline soils

Most of soils are classified as Solonetz or Solonchaks in WRB. In ST they belong to great groups of Inceptisols, Alfisols, Mollisols or Verisols that show aquic conditions and have a natric or saltic horizon. The attributes of alkaline soils are dominated by shallow fertile layers and the presence of high concentrations of water-soluble – primarily sodium – salts. Such soils show extreme water balance and transport conditions: their topmost layer liquefies and swells upon contact with water, completely blocking infiltration. Their poor workability results from their chemical attributes, poor organic matter quality and high clay content. The goals of tillage include alleviating the effects of the extreme attributes and maintaining, as far as possible, their water transport processes and their workability.

Adverse tillage effects aggravating unfavourable soil attributes are developing a compact pan layer impeding water intake below the tillage depth, bringing infertile salty layer (B horizon) to the surface by inverting, clod forming (*Figure 2*) and crusting of the topmost soil layer, smearing and puddling on the surface and in the tillage depth, trampling/driving over the surface, organic matter loss reducing workability, and weed infestation.

Tillage treatments alleviating unfavourable soil attributes are maintaining and improving the soil water-intake capacity by medium deep and deep loosening, preventing silting and crusting in the summer by leaving a covering layer on top of the soil, varying the depth of soil disturbance within the tilled layer, minimised and gentle soil disturbance, minimised traffic, preventing pan and clod forming, incorporation of and preservation organic matter and weed control.

General tillage recommendations:

- **Stubble tillage**. Harvest in the summer should be followed by shallow stubble stripping, pressed on the surface with profile rollers. Particular care should be taken to avoid clod forming when working the soil during a dry period, since it impedes weed emergence. When weeds and volunteer crops have emerged and started to grow, mechanical stubble treatment may be carried out to a slightly greater depth than the depth of stubble stripping. After harvest in the autumn stalks should be chopped thoroughly and spread evenly to make for easier tillage. *A soil condition test* will show a true picture of the soil state if carried out after stubble stripping, on humid soil.
- **Primary tillage and surface consolidation**. Shallow crumbling and shallow surface treatment combined with mid-deep loosening is more effective *in a dry season* than ploughing after which secondary tillage is more difficult to carry out properly. Driving over and disturbing soils that are *beyond the workable soil moisture range* should be avoided. Using a bladed cultivator – of a structure adapted to the heavy texture of the soil – makes it possible to preserve the structure of the soil when it is moist or slightly wet. The effects of *loosening* do not last long, in many cases they vanish by the end of the growing season. Attention should therefore be paid to regularly improving the state of deeper layers of the soil. The depth of *ploughing* is limited to the depth to which the soil may be inverted. A field that has deeply soaked through should not be ploughed, or tilled with any other implement in fact. Surface forming in the autumn is not recommended because these soils are prone to settling heavily. Indeed even primary tillage in the autumn is not recommended in fields of alkaline soils that are prone to liquefy under rainwater.
- **Seed bed preparation and sowing**. The narrow range of parameters within which the soil is workable can be best utilised by combining tillage treatments. The timing of surface forming should be adapted to that of sowing and to the soil moisture content. Depending on the quality of primary tillage and surface forming, seedbed preparation and sowing can be carried out in one pass or in separate passes before crops sown in the late summer or in the autumn. In the case of crops sown in the middle of or towards the end of the spring sowing should be preceded by loosening, crumbling and levelling in a combined tillage pass. A profiled surface should be formed after sowing.

Humic and quicksand soils

Soils are classified as Arenosols or Cambisols in WRB and as Entisols or Inceptisols in ST. The favourable attributes of humic sand soils include relatively good nutrient, water, air and heat transport and balance as well as high workability. The goals of tillage include preserving the favourable soil attributes and avoiding organic matter loss. The main principles guiding their tillage are most similar to those applying to medium-heavy textured forest soils.

Quicksand soils are easy to till, they have low organic matter contents and are relatively easily carried by the wind (*Figure 3*). The composition and the depth of their fertile layer are rather heterogeneous and their water retaining capacity is low. The goals of tillage include alleviating their unfavourable attributes and preventing damage by wind erosion in order to improve the reliability of cropping.

Adverse tillage effects aggravating unfavourable soil attributes are exposing the soil to wind erosion, loss of fertile layer, desiccation, clod and dust forming when the soil is dry, aggravating the loss of organic matter and weed infestation.

Tillage treatments alleviating unfavourable soil attributes are surface protection as long as possible, moisture, structure and organic matter conservation, recompaction of disturbed soil as quickly as possible, tillage and sowing direction across dominant wind direction and/or slope, varying the tillage depth within the available limits, refraining from using dust forming tools and preventing weed infestation.


Figure 3 Quick-sand soil (left) and water erosion on a shallow-layered sloping soil

General tillage recommendations:

- **Stubble tillage**. Loose soils are to be protected outside the growing season by leaving field residues as they are or by stubble stripping and leaving a layer of mulch for protection. Mechanical stubble treatment is not carried out on stubble fields with a growth of weeds or volunteer crops: the ripening of weed seeds can be prevented by spraying chemicals or by mowing. If there is only a short span of time between harvest and sowing the seeds of the next crop, the soil should be ploughed to a medium depth and the surface should be immediately pressed down with a combined roll. After early-harvested crops the soil should be covered with a layer of mulch made up of chopped field residues for the winter. Protection for the winter and early spring can also be provided by the frozen residues of some catch crop sown into the stubble. On *humic sand* soils stubble stripping and treatment should be carried out with cultivators or disks coupled with some pressing tool. *Soil condition should be tested* under stubble covered with a mulch layer.
- **Primary tillage and sowing**. The tillage treatments of *loose soils* should be carried out in as short a period as possible. Seedbed should be prepared for crops sown towards the end of the summer or in the autumn by the least possible soil disturbance. Primary tillage should be carried out after stubble stripping – together with surface forming – or right before sowing. Seedbed preparation and sowing in a single tillage pass is a reasonable option. The heavy settlement of quicksand soils may necessitate deeper loosening than the usual depth of primary tillage. Little risk is entailed by primary tillage in the spring before spring-sown crops: this may take the form of ploughing or some type of ploughless tillage (using cultivator or, in some cases, disks), simultaneously with surface forming.

The tillage implements to be used on *humic sand soils* before autumn-sown crops should be adapted to the soil's current moisture content, while the depth of tillage should be determined in view of the findings of soil condition tests. Ploughing in the autumn – when this is permitted by soil moisture, for instance after maize – is recommended for spring-sown crops, leaving an evened soil surface which is suitable for taking water in. *Loosening* for improved soil condition should be carried out if it seems to be necessary according to the soil condition test. Circumstances leading to tillage pan formation should be avoided and car should be taken to prevent dust forming. Any damage caused during a rainy harvest season should be remedied during the next season.

- **Seedbed preparation and sowing** should be adapted to the needs of the crop to be sown. A well-pressed, profiled soil surface that is resistant to wind erosion should be formed.

Eroded soils of shallow fertile layers, on plain or sloping fields

Most of these soils are classified as Leptosols or Regosols in WRB and as Entisols and Inceptisols in ST. Soils of shallow fertile layers will be found on heavily eroded sloping fields (these are usually forest soils) and they may contain layers mixed with stones or pebbles. The shallow fertile layer is of a heterogeneous composition, it may contain little water, and its texture, as well as nutrient content, tends to be poor. On slopes the goals of tillage include protection against erosion by water (*Figure 3*) while on flat or nearly flat fields it is to protect the soil structure. Organic matter conservation and supply are crucial on slopes and on level fields alike.

Adverse tillage effects aggravating unfavourable soil attributes are making the soil exposed to damage by water and wind, desiccation, inverting to a depth exceeding the fertile layer, clod forming when the soil is dry or traffic-induced damage when it is wet, triggering organic matter loss, weed infestation.

Tillage treatments alleviating unfavourable soil attributes are surface protection as long as possible, moisture, structure and organic matter conservation, tillage and seeding direction across dominant wind direction and/or slope, varying the tillage depth within the available limits, refraining from using dust forming tools and preventing weed infestation.

Only shallow-rooting crops of little water requirement, short growing seasons, plants that are not very exacting in terms of habitat, may be grown reliably in such fields, owing to the heterogeneity of the fertile layer. The unfavourable effects of low organic matter contents and of the usually poor workability may be improved to some extent by applying lime and by growing green manure plants.

General tillage recommendations:

- **Stubble tillage**. Soil protection after harvest can be provided for by keeping the soil undisturbed or by covering the soil with a layer of mulch after shallow loosening. Good protection is provided also by a dense growth of catch crop or green manure crop sown into stubble but their water consumption must not be ignored.
- **Primary tillage and surface forming**. The possibility of inverting (that is, the depth of ploughing), is limited by the shallow fertile layer and damage by water erosion, while the depth of loosening is restricted by the stony or pebbly subsoil layer. The need to reduce water run-off and harmful compaction calls for the use of cultivators, loosening implements or ploughs of structures adapted to the given site. The tools and the tillage depth – within the available range – should be varied. Expensive tillage treatments that do not really affect the yield and those necessitating additional tillage treatments should be avoided.
- **Seed bed preparation and sowing**. Owing to the need for soil protection crops that emerge and develop a dense growth should be produced in such fields. Seedbed preparation and sowing or tillage and seeding in a single pass are suitable solutions for densely sown crops of short growing seasons, such as combinations of plant species for forage.

Conclusions

The monitoring survey of Hungarian land use patterns proves that different forms of land use can be found at present agriculture. The modern intensive and conventional forms are more than reasonable and integrated and modern low intensity ones are less than predicted. For soil quality improvement some important step can be adopted, that is: (1) environment-conscious landscape management. (2) land uses systems adoption to the agro-ecological conditions alternative utilization (afforestation, turfing, arboreal energy plantation, wetland creation, erosion control) in poor quality cultivated areas. (3) organic matter management tillage, adaptable crop rotation on erodible areas. (4) land use system adoption to manage water-logging and drought threats. (5) create harmony between land use and soil tillage (using adaptable tillage). (6) avoiding and alleviating soil compaction damages. (7) harmonisation in fertilization and pesticide apply. (8) limiting and reversing of soil acidification by environment-friendly farming, improving OM of soil. (9) prevention of the deterioration in saline soils (no deep ploughing, control of irrigation water, managing of subsoil water table). (10) adaption the possible climate stress mitigating crop production and soil tillage methods.

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