PROPER UTILIZATION OF SOIL STRUCTURE FOR CROPS TODAY AND CONSERVATION FOR FUTURE GENERATIONS

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Abstract. The paper presents the analysis of the structure and land utilization in Poland as an example of a global situation and also concentrates on the influence of farm machinery usage on soil composition and soil compaction. Some aspects of soil conservation methods developed in different countries of the European Union are presented. Also some law regulations as Good Farming Practice are described in the meaning of constant monitoring of the situation concerning soil protection in the area of the EU. A presence and influence of moisture on plants grow is described on the example of Alabama ideal soil conditions. Heavy farm equipment utilized for soil tillage proposes can have great influence on soil compaction. The influence of soil density and soil moisture content on soil compaction was described. Also a management system concerning soil conservation development of the farming system in Australia was presented. The importance of cultivated field preservation from soil erosion was described.

Key words: soil structure, land utilization, farm machinery usage, soil composition, soil compaction.

Introduction

The future of agricultural development to obtain a proper level of food production and fulfill the general demand of human population is proper soil conservation on a country and global scale. Soil is generally defined as the top layer of the earth's crust. It is formed by mineral particles, organic matter, water, air and living organisms. Soil is the interface between the earth, air and water. While soil is the physical upper layer of what is usually referred to as "land", the concept of "land" is much wider and includes territorial and spatial dimensions. It is difficult to separate soil from its land context. However, this communication focuses on the need to protect the soil layer as such, due to its unique variety of vital functions [1; 2]. The structure of land utilization in Poland is presented in Table 1. The data presented in the annual statistical yearbook of agriculture 2009 show, that the total area of land in Poland is equal 31 267 900 hectares. About 52 percent of that value is land utilized by agriculture. About 39 percent of the total area of Poland is arable land. About 30 percent forests represent and 15 percent – other activities.

The valuation of soil classes is presented in Table 2. Taking into account only arable land and orchards, they cover 11.5 percent of good and very good quality of soils. Grassland covers 14.4 percent of such soils. Concerning bad and very bad quality of soils for the same specifications, we have the following data: arable land and orchards 31.0 percent and grassland 42.1 percent.

Table 1

Structure of land utilization in Poland in thousands of hectares
(Statistical yearbook of agriculture, 2009)

Years	Agricultural land					Forests
	Total	Arable land	Orchards	Meadows	Pastures	
2000	17 812.3	13 683.5	256.7	2502.8	1369.3	9003.9
2002	16 899.3	13 066.5	271.0	2531.3	1030.5	9089.5
2005	15 906.0	12 222.0	296.5	2529.2	858.3	9172.6
2006	15 957.3	12 449.3	292.4	2390.2	825.5	9200.4
2007	16 177.1	11 869.1	336.8	2497.4	773.8	9229.3
2008	16 154.3	12 093.8	329.4	2450.3	734.1	9254.6

Soil valuation coefficient for arable land and orchards is equal 0.85, but for grassland 0.59.

Table 2

Valuation of soil classes in Poland in thousands of hectares

(Statistical yearbook of agriculture, 2009)

Specification of soil classes	1985	1990	2000
I	70.0	68.7	67.8
II	550.3	544.1	536.4
III	4199.1	4201.7	4201.9
IV	7545.6	7493.4	7402.9
V	4310.3	4267.1	4197.2
VI	2269.7	2229.7	2114.9

To show farm machinery involvement in crop production in Poland, in Table 1 the data of the quantity of tractors working in agriculture are presented.

Table 3

Tractors working for crop production in Poland

(Statistical yearbook of agriculture, 2009)

Specification	2000	2001	2002	2005	2007	2008
Total amount of tractors in thousands of units	1306.7	1308.5	1364.6	1437.2	1553.4	1566.3
Average tractor power in kW	31.8	31.8	38.3	39.3	39.8	39.9
Land area per 1 tractor in hectares	14	14	12	11	10	10

The above data show involvement of farm machinery on the scale of field operations, which have direct influence on the soil structure condition [2; 3].

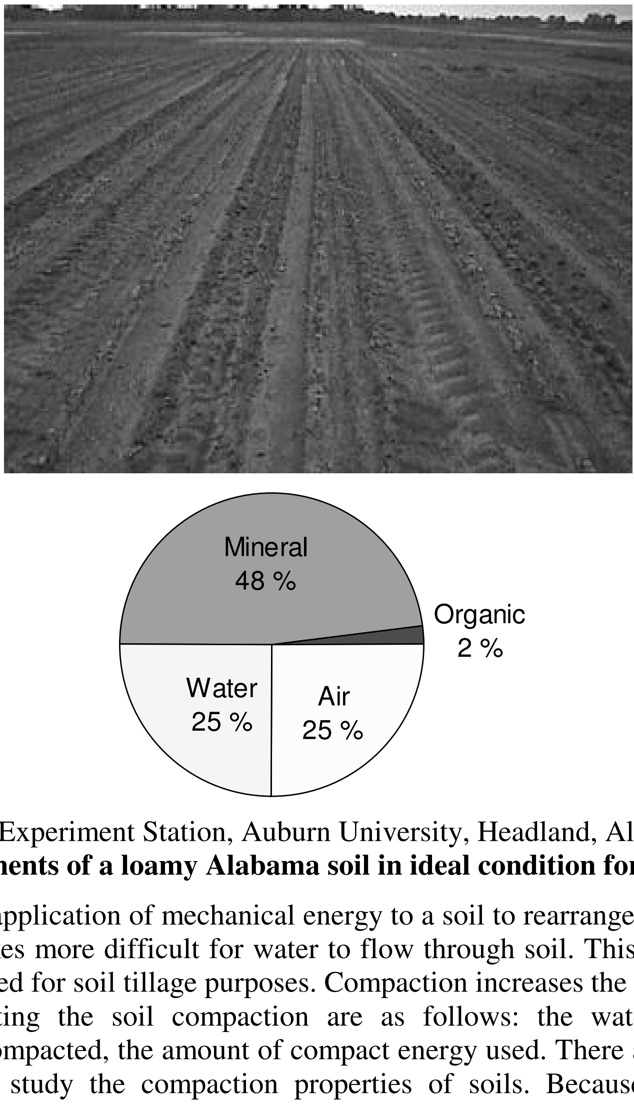
Concerning the situation in other European counties, for example in the UK, England is developing an overall soil strategy. They consider several types of pressure on soil and list sustainable responses. It sets out a new set of key soil indicators and targets, and addresses the relation between soil and land-use planning. In Denmark and Sweden soil protection is considered an integral part of general environmental protection. In Sweden a monitoring program on ecosystems includes several soil parameters. In France a national action plan on soil management and protection has been agreed that emphasis on the prevention of future pollution. It contains a new soil monitoring network based on a 16 km to 16 km grid, the completion of the national soil map and maps on erosion risks and soil organic matter. Austria has developed a soil information system with the Internet access. In Slovenia soil protection is a part of the National Environmental Action Program that deals with cleaning up of degraded soils and the implementation of sustainable use of agricultural land. The program is prepared on the basis of detailed existing soil data, accessible through the Internet. In Hungary soil protection is driven by the general environmental protection legislation, as well as by specific legislation on the protection of arable land, the protection of soil, land and groundwater and the redemption of contaminated sites.

Methods of soil conservation

As agricultural production is so dependent on soil and 77 % of land in the EU is used for agriculture and forestry, agricultural policy has by definition a huge impact on soil. The reform of the Common Agricultural Policy in the context of Agenda 2000, building on measures introduced in the 1992 reform, established the importance of rural development policies as the second pillar of the CAP. In 2000 new rural development plans were approved including a definition of Good Farming Practice (GFP), based on verifiable standards where soil protection received considerable attention. GFP constitutes a core element of the new rural development policy: the granting of compensatory allowances in less favor areas is conditional on the respect of GFP and agro-environmental measures provide compensation for undertakings going beyond this baseline. Good Farming Practice is defined as the standard of farming which a reasonable farmer would follow in the region concerned. It entails in any case compliance with general mandatory requirements including environmental legislation but the Member States may establish additional requirements associated with good practice. Within the rural development plans, some Member States facing erosion risks included practices such as tillage following contour lines, while some with low soil organic matter have banned the burning of cereal stubble. Maximum livestock carrying capacities have been defined by several Member States to avoid soil degradation through overgrazing. Agro-environmental measures aimed at soil protection range from overall farm management systems such as organic farming (including maximum stocking rates) and integrated crop management (ICM) to specific measures such as no-tillage or conservation practices, grassland strips, winter covers, use of compost and the maintenance of terraces. Measures aiming at a reduced use of pesticides, such as integrated pest management (IPM) or promoting balanced rotations can also contribute to improve the condition of agricultural soils.

Results and discussion

Soil nutrients are very important to plant growth; available moisture is more critical to their vitality. Water is essential for the transport of nutrients to and from the plant. This transport occurs laterally within the soil, and vertically within the plant. Water, therefore, is the lifeblood of the system. Without sufficient moisture, photosynthesis is impossible. Perhaps, a proper balance of available water is more important. Root systems of plants also require air in order to survive, with too much water, plants will literally drown. As an example, components of a loamy Alabama soil in the USA ideal condition for plant growth is presented in Figure 1.

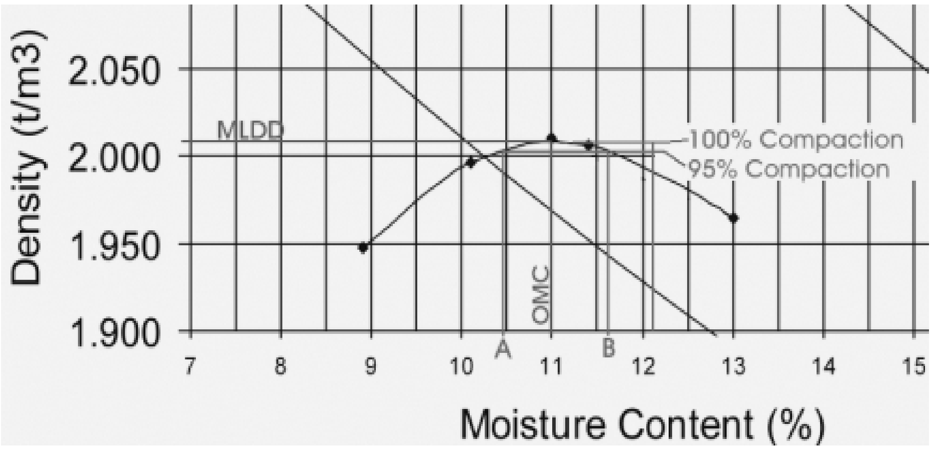


Source: Wiregrass Experiment Station, Auburn University, Headland, Alabama, USA , 2009

Fig.1. **Components of a loamy Alabama soil in ideal condition for plant growth**

Compaction is the application of mechanical energy to a soil to rearrange the particles and reduce the void ratio what makes more difficult for water to flow through soil. This is the case when heavy farm equipment is utilized for soil tillage purposes. Compaction increases the shear strength of the soil [4]. The factors affecting the soil compaction are as follows: the water content of the soil, the type of soil being compacted, the amount of compact energy used. There are several types of tests which can be used to study the compaction properties of soils. Because of the importance of compaction in most earth works standard procedures have been developed. These generally involve compacting soil into a mould at various moisture contents. As an example, it can be the Standard Compaction Test AS 1289-E1.1 published in 1993 by ASTM in Philadelphia USA.

Practically soil compaction occurs when soil is subject to mechanical pressure through the use of heavy machinery or overgrazing, especially in wet soil conditions. Compaction reduces the pore space between the soil particles and the soil partially or fully loses its absorptive capacity. Compaction of deeper soil layers is very difficult to reverse [4]. The overall deterioration in the soil structure caused by compaction restricts root growth, water storage capacity, fertility, biological activity and stability. Moreover, when heavy rainfall occurs, water can no longer easily infiltrate the soil. As a result of large volumes of run-off water erosion risks increase and they are considered by some experts to have contributed to some recent flooding events in Europe [5 – 7]. It has been estimated that nearly 4 % of soil throughout Europe suffers from compaction, but no precise data are available. Estimates of areas at risk of soil compaction vary. While they all demonstrate the importance of soil compaction, enough data were not available on the actual occurrence of compaction, but the data were available on the susceptibility of soils to compaction. Some authors classify around 36 % of European sub soils as having high or very high susceptibility to compaction. Other sources show 32 % of soils being highly vulnerable and 18 % moderately affected and again other sources estimate 33 million hectares being affected in total, meaning 4 % of the European land.



Source: ASTM, USA, 1993

Fig. 2. **Affect of water during soil compaction according to standard AS1289- E 1.1**

Looking at the above example, the curve starts with a compaction point at 8.9 % moisture giving a dry density of 1.948 m^{-3}. The compaction second point at 10.1 % has a dry density of 1.996 m^{-3}. Here we can see that as the moisture of the sample at the time of compaction has under the same compaction effort a greater compaction result is achieved.

More water is added to the third compaction point prior to being compacted. Its moisture result was 11.4 % with a dry density of 2.006 m^{-3}. Looking at the graph we can see that the sub-sample, although still more dense than the second point, has just gone beyond the peak. The moisture content is now just above the optimum moisture content and may appear to move around under compaction effort [8 – 10]. Finally the fourth point is compacted at even higher moisture content (13.0 %) culminating in a lower dry density result (1.964 $t \cdot m^{-3}$). At this stage, the sample is wet and moving about considerably under compaction effort. The most common need is to determine whether or not the Field Density Test has passed or failed its required specification. In this example, we will say that the field compaction is required to pass 95 % of the 100 % as determined by the laboratory compaction test using AS1289-E 1.1 (Compaction Standard). The graph above shows the MLDD (Maximum Laboratory Dry Density) as being 100 % which it will always be on all compactions. If you draw a line to represent where 95 % (the required compaction specification) would measure up to, where the line intersects the curve we can learn what would the maximum and minimum moisture range be that we need to achieve for the desired compaction (See “A” and “B” above) [11].

The shear strength of unsaturated soils can be assessed within conventional slope analyses by using the total cohesion method.

The total cohesion C_T includes three components and can be expressed by the following equation

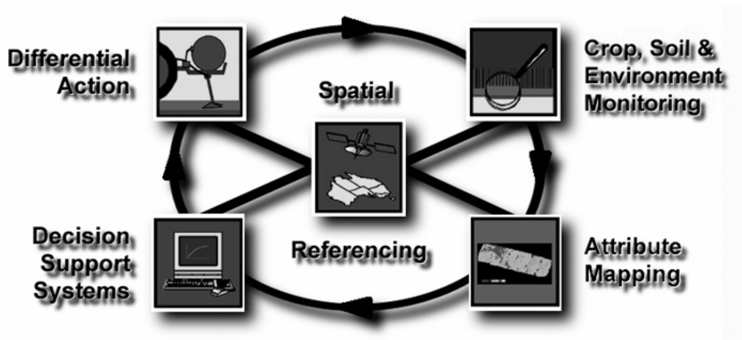
$$C_T = C' + C\varphi + C_R \ (1)$$

However the shear strength Ψ [11] of the unsaturated soil may be written as

$$\Psi = C' + C\varphi + C_R + (б - U_a)\ \text{tg}\phi \qquad (2)$$

where $(б - U_a)$ – net normal stress;
ϕ – angle shearing resistance;
C' – effective cohesion;
$C\varphi$ – suction cohesion;
C_R – root cohesion;
Ψ – shear strength;
C_T – total cohesion.

This equation suggests that the soil shear strength is enhanced by vapor transportation and the root biomass. The suction cohesion varies with changes in the soil moisture, making it difficult to predict. However, soils become stronger and the effective cohesion tends to increase due to the hysteresis phenomenon caused by the wetting and drying cycles. Specific plant communities can sometimes be designed and managed for a net export of water from a site. Vegetation on slopes generally helps to promote infiltration of water into soils. Site-specific crop management (SSCM) is a form of precision agriculture whereby decisions on resource application and agronomic practices are improved to better match the soil structure and crop requirements as they vary in a field. The Australian Centre for Precision Agriculture is located at the University of Sydney, Australia. The five main components for development of a site-specific management system concerning Australian precision farming with a special attention to the soil structure and soil preservation is presented in Figure 3.



Source: University of Sydney, Canberra, Australia, 2010

Fig. 3. **Management system concerning soil conservation development in Australia**

Collectively these actions are referred to as the "differential" treatment of field variation as opposed to the "uniform" treatment that underlies traditional management systems.

Conclusions

The overall deterioration in soil structure caused by compaction restricts root growth, water storage capacity, fertility, biological activity and stability. Moreover, when heavy rainfall occurs, the water can no longer easily infiltrate the soil. As a result of large volumes of run-off water erosion risks increase and they are considered by some experts to have contributed to some recent flooding events in the EU.

After providing general and detail analysis of the global situation concerning soil tillage conservation from the point of view of agricultural crop production and environment protection, we can draw the following conclusions:

1. Soil tillage performs a very important role in crop production, so it needs special attention on national and global scale,
2. The reform of the Common Agricultural Policy CAP) in the context of Agenda 2000 established the importance of rural development policies,
3. Development of Good Farming Practice (GFP) based on verifiable standards, where soil protection received considerable attention, was a proper decision on the way to promising soil tillage conservation,

4. Study of interactions between soil and water is very important in the context of integrated water management system,
5. Because of common utilization during soil tillage quite heavy equipment, it is very important to provide analysis and field study of soil compaction phenomena,
6. The presented standard and theoretical analysis concerning soil compaction can be very helpful in different practical field situations, when planning tillage operations,
7. The major bottleneck for the assessment of soil condition in the EU based on the already existing data still is the lack of harmonized methodologies for monitoring and data transfer, leading to a lack of comparability of data from different sources.

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