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SOIL – A VALUABLE ENVIRONMENTAL RESOURCE – QUALITY, HEALTH, ECOSYSTEM SERVICES

Summary

Soil is an environmental resource adapted to agricultural use. It is often treated as a renewable resource, since cultivated with maintaining proper practices is a living organism and a good substrate for the biomass production. On the other hand, it is the product of a very complex process, therefore especially if it is constantly subjected to the processes of exposing to degradation, can become a non-renewable resource. From the point of view of the preservation of its quality and regenerative capacity, farms should consider not only economic, but also agro-ecological characteristics of the habitat in which they operate. This means that the effects on achieved yields are not the only ones that should be considered in the analysis of the costs and benefits of agricultural activities. Soil is a living product, a useful resource, not only for production, but also for environment and society. Its welfare is important for the quality and quantity of food production as well as to maintain a balance in the environment. The paper is a review article, discussing the importance of soil as an environmental resource, through the prism of its quality, health and capacity to develop ecosystem services. It also treats of the problem of environmental and economic losses resulting from the degradation of the soil environment and the benefits of its maintenance. The examples of actions conducive to raising and maintaining the quality of soil and its health were discussed.
***Key words**: soil health, soil quality, ecosystem services, organic matter*

GLEBA – CENNY ZASÓB ŚRODOWISKOWY – JAKOŚĆ, ZDROWIE, USŁUGI EKOSYSTEMU

Streszczenie

Gleba jest zasobem środowiska przystosowanym do użytkowania rolniczego. Często traktowana jest jako zasób odnawialny, gdyż uprawiana z zachowaniem prawidłowych praktyk rolniczych stanowi żywy organizm i dobre podłoże dla produkcji biomasy. Z drugiej jednak strony jest wytworem bardzo złożonego procesu, przebiegającego powoli i z tego względu, zwłaszcza jeśli stale podlega procesom narażającym ją na degradację, może stać się zasobem nieodnawialnym. Z punktu widzenia zachowania jej jakości i zdolności do odtwarzania, gospodarstwa rolne powinny rozważać nie tylko ekonomiczne, ale i agroekologiczne cechy siedliska, w którym prowadzą działalność. Oznacza to, że efekty w osiąganych plonach nie są jedynymi, jakie należy rozważać w analizie kosztów i korzyści działalności rolniczej. Gleba jest żywym tworem, zasobem użytecznym, pełniącym funkcję nie tylko produkcyjną, ale także środowiskową i społeczną. Jej dobrostan jest istotny dla jakości i ilości produkowanej żywności, jak również dla zachowania równowagi w środowisku. Artykuł ma charakter przeglądowy, omawiający znaczenie gleby jako zasobu środowiskowego, poprzez pryzmat jej jakości, zdrowia i możliwości pełnienia funkcji ekosystemowych. Przybliżono ponadto problem środowiskowych i ekonomicznych strat wynikających z degradacji środowiska glebowego oraz korzyści, jakie niesie jej konserwacja. Podano przykłady działań sprzyjających podniesieniu i zachowaniu jakości gleby oraz jej zdrowia.
***Słowa kluczowe**: zdrowie gleby, jakość gleby, usługi ekosystemu, materia organiczna*

1. Introduction

Soil is one of the most important resources of the natural environment to which a special role is attributed in agriculture since it is the basis for production of consumption and feed plants. This approach is not surprising due to the fact that entire human existence and development are, in fact, inseparably connected to soil [44]. In the course of agricultural activity, people influence the soil both in a positive manner (improving and maintaining its fertility or abundance) as well as negative manner (e.g. by deforestation of erosion threatened areas, depriving the agricultural lands of the flora cover, diversified crop rotation or introducing excess of chemicals in the soil, contaminating it along with the biological life).

The basic function of agriculture through the use of the soil is production of food, and continuous growth of the human population generates the increase of demand for it [13]. This results in the frequent use of soil in a very intensive manner, posing a threat for its quality and health. The modern intensive agriculture has to face challenges and guarantee food security to the world, concurrently, however, as noted by Pretty [31], "*There is something wrong with the contemporary agricultural systems (...). Despite the great progress in increase of productivity (...), hundreds of millions of people are still hungry and malnourished. Other millions eat too much or improper types of food. The environment health is also suffering due to degradation accompanying multiple agricultural systems that have developed in recent years.*" Similar irregularities are noticed also by other authors [32, 42], pointing out that the environmental damage driven by agriculture is very common, and the applied agricultural practices determine the level of food production, but, at the same time, are also decisive in

terms of environmental quality, including soil.

The production resources used in manufacture of food such as, for instance, seeds, soil, fertilisers, water, are often perceived to be renewable sources. In such an approach, agriculture can potentially be deemed a highly balanced environment. On the other hand, possessing multiple features of a typical mining industry, it is characterised by impact on the lack of balance in the environment [4].

The above is reflected in the attempts to verify and estimate the environmental losses resulting from agriculture [15, 29, 39, 41, 43] where attention is given to the fact that intensification of agriculture causes imminent environmental, social or economic effects, referred to also as externalities.

Referring the above to the soil resource, it must be emphasised that it is exposed in a direct manner to damage in the course of agricultural activity. As noted above, its production role is very significant. However, the agricultural producer determines its value - which is reasonable to a certain extent - from the economic point of view of the agricultural farm. Very good and good soils are most frequently used to sow highest income earning plants. This translates into poorly diversified crop rotation, limited to a small number of cultivated plants. These soils, in order to achieve even higher productivity, are additionally fertilised with agricultural chemicals. The richness of weaker soils is usually enriched with chemical fertilisers. This approach is not conducive to preservation of high quality and health of the soil ecosystem or to proper fulfilment of the soil's environmental purposes. A farmer has to remember that effects in the obtained crops cannot be the only parameters worth considering when analysing the costs and benefits of the applied agricultural practices, but also those that are conducive to environmental protection, including soil maintenance [11, 27]. The meaning of this resource must be also considered in terms of the environment. In this approach, it is a live, dynamic ecosystem, the well-being of which is essential both for food production, but also for up-keep of global environmental balance. In such an approach, the soil, as a live resource, manifests a unique balance in terms of the physical, chemical and, most importantly, biological factors forming it [16, 28].

In the subject matter literature, one can encounter a statement that soil is a renewable resource of the environment due to the fact that the process of its renewal is of biological nature. Human activity consists in collecting the generated biomass that has used the valuable nutrients from the soil. If a return of the nutrients occurs in the course of production, the soil reconstruction process will continue since people can reconstruct soil understood as its ability to produce the biomass [49]. On the other hand, however, soil is a product of a very complex process, with a slow course and, due to this fact, it can become a non-renewable resource if it undergoes continuous degradation processes [24]. Therefore, from the point of view of maintenance of its quality and renewal capacity, agricultural farms should consider not only economic, but also agro-ecologic features of the habitat in which they conduct their agricultural activity and implement practices conducive to maintenance of the soil quality and health [27].

2. Objective and scope of paper

The article, having an overview nature, discusses the problems of the soil as an environmental resource in terms of its quality and health as well as providing environmental or social services by it. Attention is brought to the fact that soil undergoes continuous processes causing its degradation and, as a result, influencing also the non-production zone of agriculture. It discusses the problem of environmental and economic losses connected with soil degradation and provides examples of agricultural practices conducive to improvement and maintenance of the soil quality and health.

3. Soil quality and health versus the soil ecosystem services

Soil is a resource adjusted to be used in agriculture. Its relation to productivity is well studied, however the soil condition has an impact also on the purity of water or air [9]. In order for the soil to properly provide the so-called environmental (ecosystem) services, it must be characterised with good quality and health. These notions are broadly discussed in literature [1, 19, 22, 28] and frequently used interchangeably, although, as claimed by various scientists, they possess different meanings. The soil quality is more connected to its functions, and its health depicts it as a limited, non-renewable and dynamic live resource [7, 23]. The notion of soil quality is not new. The attempts to define it root to the 70's of the previous century [22] which resulted from the overall increase of interest in the quality and health of the environment. Although there are multiple disputes remaining to date among the scientists regarding definition of soil quality, this notion can surely be used in order to determine whether the management of agricultural lands is conducted in a sustainable manner [5, 14, 28, 52].

Using the definition developed by Doran et al. [10], the soil quality determines its physical properties and means its capacity to function within the boundaries of the given ecosystem, maintaining, concurrently, its biological efficiency, natural environment quality as well as health of plants and animals. An interesting statement is also provided by Schjønning [34]. He claims that the soil quality means "how well the soil provides what we want to obtain from it". Here "how well" means a reference to classification, whereas "what we want to obtain from it" - refers to its most important functions, based on taking the balance in the use of this resource into consideration.

In a more in-depth consideration of the problem, the soil quality can be determined by means of: verification of its structure (if it is formed by hard solid bodies or if it is brittle), determination of smell that can suggest content of certain compounds, presence of actinobacteria, ongoing fermentation processes. Furthermore, the soil colour is essential since it can provide evidence for abundance of organic matter and biological life [16].

As opposed to soil quality, its health as an ecosystem refers to the capacity of self-regulation, stability, resistance and no stress symptoms. A healthy soil is usually very rich in biological diversity and capable of providing proper nutrient circulation [26, 45]. The soil health is described mostly by means of its biological life, capacity to form and maintain balance between soil organisms, organisms and the soil as well as organisms and the environment [7]. Healthy soils are characterised by:

a) high biological diversity,
b) high stability of the living organisms dwelling in it (resistance and capability of self-recovery after protection chemical or biological interruptions),

c) ability to maintain free flow of energy and matter,
d) ability to suppress various pathogens and pests,
e) ability to improve the plant health,
f) impact on maintenance of high quality of the aqueous environment and air [28].

As one can notice, the soil health is determined by physical and chemical factors, however the biological factors are specifically decisive in terms of the soil life and proper course of multiple processes taking place in it.
Soil is a very complex structure. Healthy and good quality soil is capable to provide various environmental and production services. In other words, these are benefits that people gain from the soil, i.e.: food, water, wood, fibres as well as its impact on the climate, regulation of floods, diseases, contamination or water quality. It is also of importance that soil supports environmental services connected with circulation of elements in the nature as well as that it provides services of recreational value [52].

The ecosystem services provided by the soil environment are broadly recognised and well documented in the literature. These can be, in most general terms, referred to:
a) fertilising (soil as a place of accumulation and intake of nutrients by the plants),
b) function of a contamination capturing filter, a reservoir (e.g. collection of water for plants),
c) supportive function (soil as a physical support for plants and animals dwelling in it, stepping on it as well as for the technical infrastructure developed by people),
d) participation in climate regulation by means of binding of organic carbon (soil organic matter as a resource of atmospheric CO_2) as well as regulation of greenhouse gas emission,
e) protection of biodiversity (healthy soil is an environment for thousands of species of organisms regulating, for instance, the abundance of pests, or neutralising contamination),
f) resource-related (as a source of valuable materials) [8, 33].

Table 1 contains a specification of the environmental and production services provided by the soil ecosystem used for agricultural purposes. One must, however, remember that soil is an element of the entire agro-ecosystem, therefore its quality, health and manner of use are decisive in terms of environmental, cultural, historical, recreational or aesthetic services provided by the entire agro-ecosystem [8]. As it can be seen in table 1, the abundance of services provided by the soil is vast, from the production, environmental as well as social point of view. All soil functions are interrelated. Especially living organisms, being an integral part of a healthy soil, have impact on the processes taking place in it. The impact of, for example, symbiotic organisms dwelling in the soil on the obtained crop yield is also positive, due to binding of nitrogen by bacteria or phosphorus by the mycorrhizal fungi. Their participation in biogeochemical cycles is also important, and the soil meso- and macrofauna as well as small animals play a significant role in formation of proper soil structure, having influence on other organisms and water. The quantity and diversity of soil organism species is also an ideal depiction of the relations between the decisions made by the farmer in relation to the resource management and the final production results, efficiency and health of plants and animals [12].

4. Degradation of the soil and its connection with the environment

Rational resource economy, including soil, is one of the most important factors conditional for existence of environmentally sustainable agriculture. As shown by practice, intensive agriculture, in particular, consumes great amounts of fuels, water and uses the superficial layer of the soil in a non-sustainable manner. It is exposed to destruction processes the pace of which exceeds the pace of possible renewal, and the process of formation of 1 cm of the resource can take from 20 to even up to 1000 years [21]. Deterioration of quality and health of the soil is also a very current problem for the humanity due to the fact the area of the land necessary for food production is decreasing.

In Europe soil degradation has only recently been recognised as a common problem [20]. This, however, is not a new phenomenon in agriculture since it has been estimated that during World War II the poor extensive agricultural farms led to degradation of ca. 550 million hectares [21].

Currently, soil undergoes degradation increasingly due to intensive agricultural economy. The data for Poland show that ca. 29% of the country, including 21 of agricultural lands (mostly arable lands), is at risk of erosion, and

Table 1. Services and properties of the soil ecosystem [20]

Services and characteristics of the soil ecosystem assigned to / in:									
nutrients by:					**water by:**			**structure/construction of soil by:**	
delivering for plants	**contribution in plant production**	**soil creation**	**regulating elements cycles**	**moving**	**delivering**	**filtration**	**flood control**	**support**	**erosion control**
retention function, delivery of nutrients, fertility, nutrient uptake	contribution to plant production, base for primary production	possibility of soil renewal, soil fertility, soil formation, its structure, the levels	cycles control of the main elements, mineralization of nutrients, nitrogen regulation	moving of nutrients, particles and gases in the soil	water supply for plants and water flow in the soil	filtering, cleaning - participation in the provision of safe drinking water	mitigation of flood and drought, the function of a buffer, and water storage	physical support for the plants, contribution to the quality of the landscape and its stability	regulating of erosion
climate regulation by:		**biodiversity in the area:**			**resources and landscape:**				
carbon sequestration	**the production of greenhouse gases**	**habitat**	**population regulation**	**recycling**					
accumulation of carbon - the importance of organic matter, climate regulation and human-induced changes	control of the gases contained in the atmosphere	soil as a vital component of habitat, biodiversity protection	control (biological) of potential pests and pathogens, regulation of plant and animal populations	biotreatment of pollution. mineralization of organic matter	soil as a source of raw materials for production (eg. clay, sand), the direction of land use shapes cultural, recreational and aesthetic functions of agri-ecosystem				

over 700 thousand ha has been destroyed to such an extent that it is unsuitable for further agricultural use. A solution is sought in exclusion of agricultural use of lands (especially arable lands) and implementation of forestation, tree planting and other forms of use allowing to protect the soil under a year-round flora cover [48].

As indicated above, good quality and healthy soil has a positive effect both in the environmental and production aspect of agriculture. However, as much as sick soil does not fulfil its production and environmental functions in a proper manner, the agricultural activity can provide multiple dis-services for the entire eco-system, including the soil, resulting in reduction of its productivity and raised costs of production. Examples of agricultural dis-services having a negative impact on the ecosystem, including soil, can be: losses of entire habitats, loss of nutrients or poisoning with pesticides of non-target species [51].

Many soils used agriculturally, despite the efforts in implementation of good practices, is exposed to continuous process of degradation in time that we can refer to as reduction of the actual or potential usability of the given land. One can speak of the following types of degradation:

a) physical, when a specified mass of soil is lost due to the effect of wind or water (erosion) and as a result of deterioration of the air-water properties of the used soil;
b) chemical, when nutrients are lost, harmful compounds are accumulated, there is salinity, acidification and, as a result, drop in the soil fertility;
c) biological, when the content of organic matter in the soil decreases (organic carbon - C_{org}.) and when there are disadvantageous changes in the soil microorganism composition.

These processes are strictly interrelated. For example, physical destruction of the soil (downflow, deflation, compression) can lead to full loss of the agricultural land as well as nutrients, and to decrease of the organic matter content or disappearance of biological life in the soil. On the other hand, soil poor in organic matter and biological activity loses the thickness of the arable-humus layer which can contribute to its compactness (heavy soils) or, conversely - to its excessive looseness. Whereas, excess of nitrogen in the soil contaminates it and the waters, paradoxically leading to the drop of diversity of plant species and decrease of biomass production [21]. Some ecologists claim that this drop in biological diversity caused by excess of nitrogen can influence further aspects of ecosystem functioning, that is greater proneness to drought [36]. Moreover, pesticides introduced to the soil are not neutral for its environment. As put forth by D. Pimentel et al. [30], only 0.1% of the applied pesticides actually eliminate pests. The remaining 99.9% has a negative impact on the environment. All this decreases the environmental role the soil due to impairment of the capacity to store water, mineral elements, loss of organic matter, typological changes, limitation of resistance to chemical or biological stress [48].

The cause of the above processes is rooted in multiple errors made in the course of conducted agricultural activity. For example, cultivation can expose soil to water or air erosion, repeated ploughing can weaken its structure, sowing of mono-culture plants as well as plants deprive the soil of its humus, removing nutrients, and using improper machines can result in soil compacting [27]. Intensive cultivation, thickening the subsoil, results in decreased water ascent and reduces plant yielding as well as water infiltration capacity during abundant precipitation [18]. Moreover, organisational changes in agriculture, especially intensive industrial agriculture [25], employing high amounts of agricultural chemistry and where no organic matter is introduced to the soil, lead to decay of life in it. As a result of mineralisation there is a decrease by 2-4% of organic matter from the soil annually [50] and if it is not supplemented, the biological life in the soil will disappear.

Soil degradation has an impact on its productivity and the drop in crops is one of the negative effects. As stated by Bauer and Black [3], losses in soil productivity result from the drop of organic matter content in the soil and drop of fertility. The conducted studies of, for example, spring wheat, showed that dry mass and seed crops were connected with higher content of organic matter in the soil.

Apart from the issue of productivity loss, soil degradation results in increased costs incurred for its reclamation. Moreover, this gives rise to environmental, social and economic costs, exceeding the scope of the farm and soil environment. These are external costs (externalities). The agricultural farm, intervening in the natural environment, can cause negative effects in other farms and other disciplines of human activity, both production and consumption-related ones. Activity of the given agricultural farm can be detrimental for the perpetrator of the damage himself (decrease of the agricultural soil fertility due to erosion caused by agrotechnical procedures, decrease of fertility due to improper crop rotation) [43]. Literature provides examples of estimations determining the value of external losses connected with agricultural use of soil. For example, Tegtmeier and Duffy [41] state that selected externalities arising from agricultural activity amounts in the USA within a single year (2002) to 5682.9–16,889.2 million dollars. 2242.7-13,394.7 million dollars out of this value accounts for the external costs connected with soil disturbances. The authors indicate that agricultural practices cause soil erosion due to defective cultivation, intensive breeding or leaving it without a flora cover. In consequence, its quality and capacity to provide environmental services diminishes. The authors emphasise, in particular, that soil degradation reflects significantly in the water quality. This gives rise to, for instance, additional potable water treatment since the soil ceases to provide the filter function, losses in self-cleaning capacity of the water reservoirs located near the fields, loss of recreational function of various areas. There is also another study [6] showing research results indicating the danger of the erosion effects, exceeding the agricultural farm itself. They show that the losses resulting from agricultural activity are detrimental not so much to the farmer himself or the future consumers of the food products, but to the users of waters outside the farm. According to the authors of the study referred to, the estimated losses in soil productivity estimated (for 1983) ranged between 550 million dollars to 1.2 billion dollars, whereas the environmental losses arising from soil erosion outside the farm, estimated for ten agricultural regions, can be twice as high (Fig. 1). Slightly newer studies [17] also show that erosion of the soil contributes to substantial economic losses in agriculture (53€/ha) and accompanying costs such as silting of dams, reservoirs, road destruction (32 € /ha).

Losses in the soil environment quality and health can be also reflected in the value of the agricultural products purchased by the consumers. Telles et al [42] suggested a model of environmental costs in which they indicated that, for example, soil erosion, increasing the production costs, decreases the.

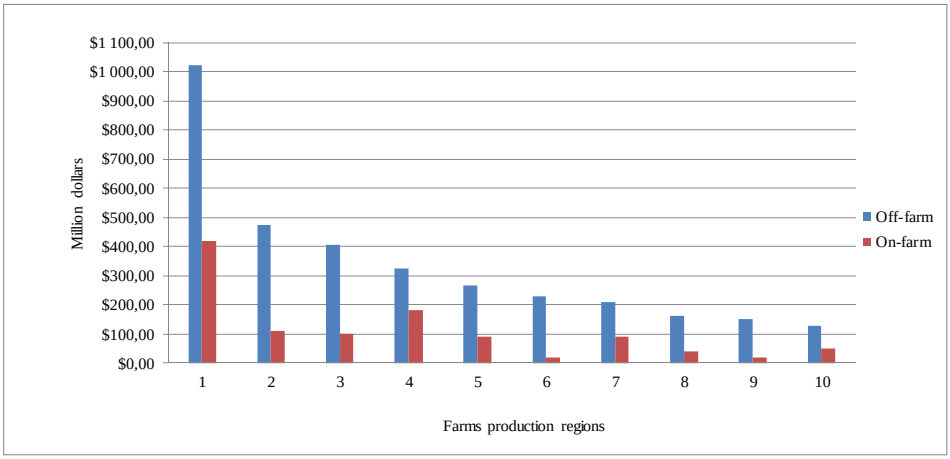

Fig. 1. On-farm and off-farm damage from sheet, rill and wind erosion [6]

demand for agricultural products. This results from the fact that the price of agricultural products increases through additional outlays incurred for the repair of soil degradation damage, being a consequence of agricultural activities. One of the methods, however, that can minimise and repair the degraded soil is use of preservation practices

It seems, however, that one of the most important possible forms of damage caused by the agricultural activity is depriving the soil of organic life (health), i.e. biological degradation, and the research shows that long-term stabilisation of the organic matter content in soil results from the presence of fungi, bacteria, earthworm activity, presence of roots [35]. The content of organic matter and its quality determine the soil fertility and yield, it is conducive to formation and maintenance of proper soil structure as well as its water-air properties. Soil losing its organic matter and biological diversity conditional for the circulation of various important elements is, as a result, exposed to physical and chemical degradation.

The disturbances in the quantity and quality of biological life as well as content of organic matter in the soil can result both from frequent mono-cultures, application of high doses of agricultural chemicals, limitation or lack of organic and natural fertilisers, leaving the soil without flora cover as well as use of intensive plough cultivation methods. It turns out that, for instance, intensive plough cultivation can lead, in one generation, to decrease of organic matter in the soil by up to 50%.

Long-term studies (21 years) confirm that the so-called soil microorganism biomass ($C_{mic.}$) as well as microbiological activity indices are substantially related to the applied production system (ecologic or traditional) and the type of employed fertilising and its intensity. Manure has a positive effect on the soil and the biological parameters of its quality are generally increased in ecologic farms, as compared to conventional ones. For instance, a significant $C_{org.}$ drop (by 24%) was found in the crop rotation that did not involve mineral and natural fertilising. Whereas, in traditional and ecologic farms using manure, it was possible to observe to a long-term substantial drop of the $C_{org.}$ content, and even its increase in case of ecological farms where the animal breeding has clearly diversified plant cultivation. There were also substantial differences noted in the microbiological biomass content in the soil, and $C_{mic.}$ in soils used in an ecological manner was higher by 13% to 35% than in traditionally used soils. Manure has, therefore, a positive long-term effect through increase of the organic matter content for the purpose of humus synthesis and it improves the structure of the soil [14]. Thus, there is a relation between the type of applied agricultural procedures and the quality and health of the soil.

Summarising this chapter, Fig. 2 below presents the manner in which degraded soil can have an impact on the environment by means of multiple processes taking place in it.

5. Agricultural activities increasing the value soil ecosystem services - improvement of soil quality and health

Only appropriate and environmentally-proper management of the soil can guarantee its high quality and health, also in long-term perspective, which is important from the point of view of upkeep of the soil for future generations. Following exclusively the economic benefits resulting from high production efficiency “here and now”, which is usually connected with introduction of high amounts of agricultural chemicals in the soil, is a very short-term oriented activity. Soil deprived of organic matter and where the biological life diminishes is for some time assisted by means of mineral fertilisers and the plants are protected by application of chemical pesticides. However, it gradually loses its ability to reproduce and the plants cultivated in it - resistance to diseases, pests as well as its quality.

In farms implementing good agricultural practices, especially in ecologic ones, special attention is given to improve the quality and health of the soil. These can be obtained and maintained by the so-called preserving cultivation method as well as use of rich crop rotation, including intercrops and, if only possible, use of natural or organic fertilisers. This soil management approach guarantees improvement and maintenance of high level of soil organic matter, being the basic component of healthy soil. Its presence allows to increase the number of soil organisms, improve the soil fertility, strengthen its structure, improve its physical environment, facilitate soil root penetration. Organic matter absorbs water, becoming its source for the plants. It is also a rich carbon source and stability of soil aggregates reduces emission of CO_2 as well as protects the organic carbon at the same time [33, 36, 37].

Each year, the organic matter penetrates into the soil from the residues of plants, green and animal fertilisers, compost. It also undergoes mineralisation and is used by the plants. It is important to prevent the imbalance between the outflow and inflow of organic matter..

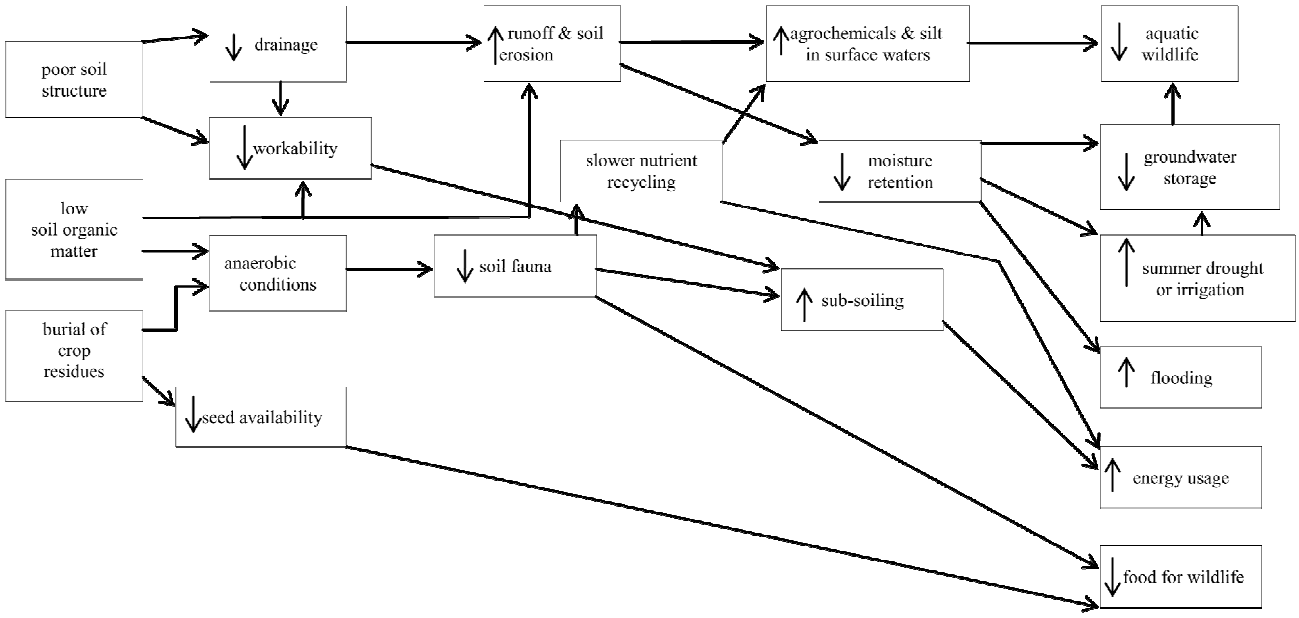

Fig. 2. Processes through which degraded soils affect the environment [20]

The obligation to carry out studies regarding humus content by the farms receiving agricultural environmental-climatic subsidies proves the importance of the positive balance of soil organic matter.

What can, therefore, be the agricultural activities improving the soil quality and health, concurrently contributing to its environmental services? There are multiple practices that can determine the environmental agricultural activity balance. Some of the most important are presented below:

a) **Proper crop rotation.** Due to introduction of high diversity of crops, organic matter penetrates into the soil. It becomes possible to reduce the number of crop pests since their reproduction cycle is interrupted. Thus, the soil is less contaminated with chemical pesticides. This results also in a decreased need for fertilisers since on cultivated plant can provide nutrients for the succeeding plant [21]. In particular, leguminous plants are of great importance, providing ideal environment for the succeeding plants in the first and second year upon cultivation. Diversity of crops and parallel plant and animal production as well as aiming at their balancing provide great protection within the scope of economic and environmental-ecological problems of the farm. Monocultures are more prone to pests, diseases, weeds as well as fluctuations of the market prices. Balancing of the plant and animal production guarantees, on the one hand, obtaining feeds for the kept animals, but, first and foremost, provides own natural fertilisers, being a substrate for development of soil organisms.

b) **Proper crop rotation** is an important part of soil management. Here, proper means not only aiming at high crop yield, but also maximisation of profits from area unit. This is how industrial agriculture usually functions, emphasising the significance of the chemical soil properties, whereas one cannot forget about the physical and, especially, biological properties. Thus, it is important to provide the soil organisms with nourishment, in the form of natural and organic fertilisers, ploughed green mass. Organic matter provides nourishment for bacteria, fungi, nematodes, earthworms which are decisive in terms of health of the soil and cultivated plants [21].

c) **Year-round coverage of arable lands**. The problem of arable lands left without flora cover can be observed in particular in the winter season. The main contribution of ground cover plants is long-term protection and improvement of soil fertility, especially the soil exposed to erosion, and prevention of erosion as well as stabilisation of the ground are priorities for the purpose of sustainable agriculture [40]. They can also limit the number of weeds and generate income [12, 24, 39]. Arable land covering plants, the so-called catch crops, are quickly growing crops that can grow concurrently with the main crops (siftings) or between two main crops (winter, spring intercrops). They capture nutrients, reduce erosion as well as drain of water and nutrients. In addition to catch crops, stubbles or fixed green crops (grasses), buffer zones can be maintained [38].

d) **Simplified or plough-free**, i.e. the so-called soil preserving. Its function is long-term, significantly reduced intensity of cultivation, rich rotation and coverage of arable lands with flora for the entire year. This system reduces soil degradation and water loss to a significant extent, increases the content of organic matter, stabilises the soil structure and is conducive to presence of a greater biological diversity, as compared to plough cultivation [28, 36]. Simplified cultivation and direct sowing allow to observe a greater number of earthworms than in case of traditional cultivation. Preserving cultivation entails general increase of the number of beneficial soil organisms in the upper layers of the soil profile, resulting from the increased amount of organic matter introduced in the soil. Some studies show also that lack of mechanical procedures and application of intercrops, coverage of the soil with mulch, reduces the growth of weeds [36]. Fig. 3 depicts the abundance of interrelated processes that contribute to the benefits for the environment through application of preservative cultivation.

Use of preservation cultivation can be controversial in relation to the volume of obtained crops, however long-term preservation cultivation provides comparable results in comparison to traditional plough cultivation [36].

e) **Nutrient management.** The basis, however, should be performance of soil examination in terms of the nourishment needs of the cultivated plants.

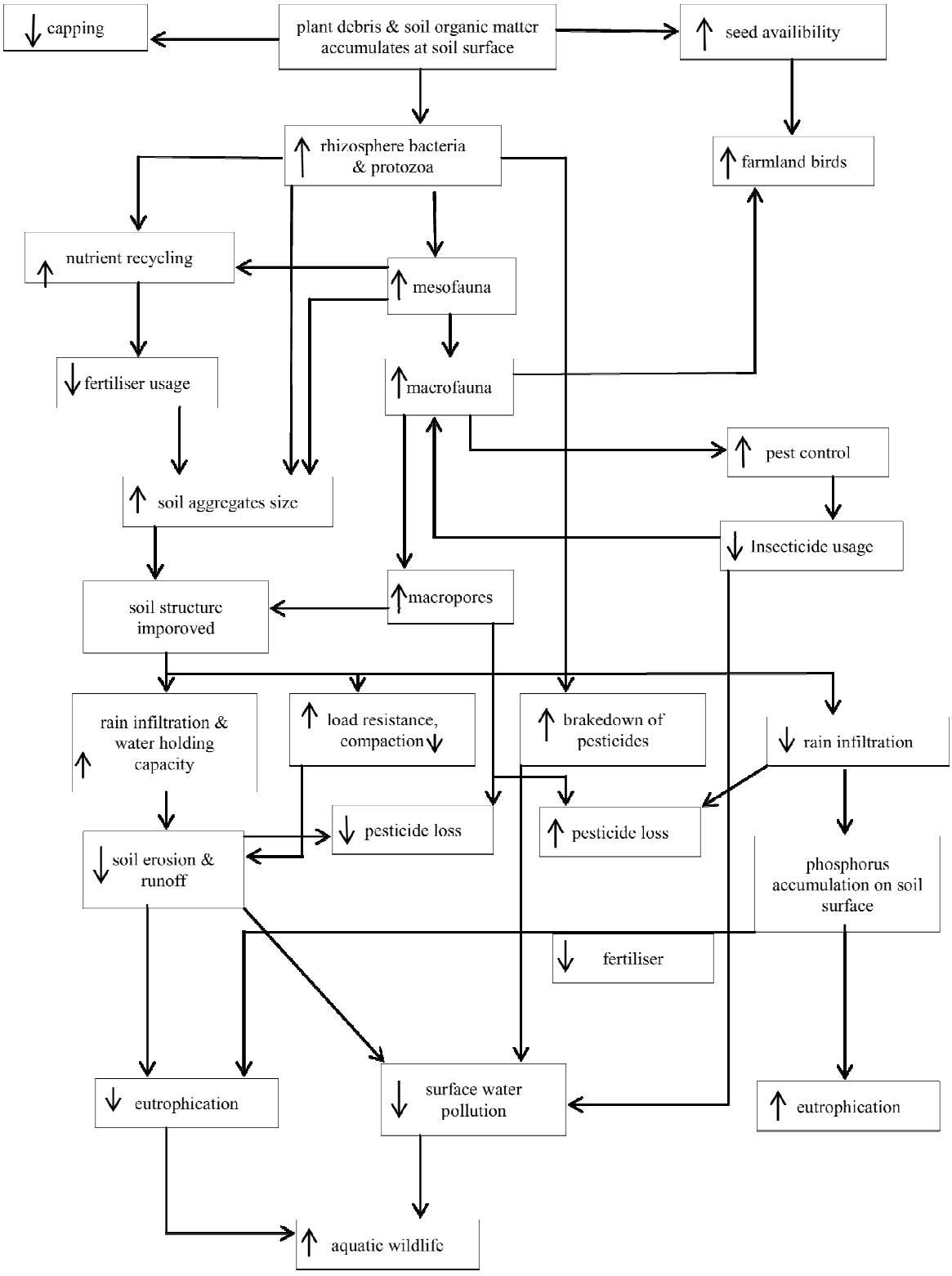

Fig. 3. Interactive processes through which conservation tillage can generate environmental benefits [20]

For an environmentally sustainable farm, it is essential to reduce the chemical mineral fertilisers in order to improve the soil fertility by means of provided organic matter from natural fertilisers, compost, ploughed straw, residues of plants. It is essential to determine the soil organic matter balance. This knowledge allows to implement proper soil management, potential changes in rotation, amount of introduced organic fertilisers, so that a positive balance of organic matter can be provided in the soil. Furthermore, verification of the nitrogen content and other nutrients allows to reduce their loss for the aqueous environment and atmosphere as well as to avoid financial losses.

f) **Implementation of ecological production system.** Ecological agriculture is a system assuming environmental protection, including soil, at the highest level. Multiple research results confirm that ecological farms note diversified crop rotation more frequently, including non-commodity plants, but having a positive effect on the soil quality and health. Ecological farms take greater care of the organic matter content, arable land coverage on large areas for the

entire year. Prohibition to use agricultural chemicals translates also positively into the quality of waters, soil as well as biological diversity [28, 38]. Where it is impossible to implement the ecological system, it seems justifiable to implement extensive production systems, especially in the sensitive areas, exposed to nitrite contamination. Also the attenuated version of traditional agriculture - integrated production, has been gaining increasing importance in the recent years.

g) **Agro-forestry** is a combination of agricultural cultivation, forest and animal breeding. It forms a system of stronger and more stable balance than in case of each of these components functioning separately. Due to the interrelation of the field and forest ecosystem, the diversity of species, deep root systems as well as rich microbiological mass of the soil form a more friendly environment for the soil fauna. Agro-forestry has also impact on the increase of arbuscular mycorrhizal fungi, forming a relation with most vascular plants and facilitating the accessibility of phosphorus to the plants [7, 49].

Obviously, the decision of the farmers to invest in soil preservation and protection of its environment are based on cost and benefit considerations. Farmers usually undertake soil protection when they see it as a business. Techniques conducive to soil protection are particularly liked when they are cheap and, at the same time, bring production effects. However, this correlation does not always occur, especially in a short period [6].

6. Summary

Soil is a crucial element of the natural environment. It also provides multiple economic and social functions, essential for human existence. Maintenance and upkeep of high quality and health is an important factor of long-term maintenance of this resource. Soils with highest quality and health are not only better from the point of view of production and food consumers, but they also play a significant role in stabilisation of the global ecosystem and improvement of air and water quality.

Unfortunately, in the course of use, especially agricultural, they undergo multiple processes leading to the destruction of their physical, chemical and biological properties. The decrease of biological life is specifically dangerous for the soil, resulting in interruption of multiple processes. This, in consequence, has an impact on the productivity of the soil itself as well as the condition of the environment in the surrounding of the given agricultural farm.

Implementation of good agricultural practices, serving the purpose of soil protection, should be an important element of the environmental policy of any country. Regardless, however, of the assumed principles and necessity of their application, the agricultural producers should show, first and foremost, their high pro-environmental awareness. The interest in the soil health only in view of the obtained bonuses may prove to be a short-term activity, until the bonuses are available. It is not a good example of soil environment protection.

Soil protection must involve a long-term approach and each protective action undertaken in relation to the soil resource will surely bring positive results for the quality of the environment and, finally, for the scope of obtained production volume.

7. References

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