Humus Indicates Soil Quality

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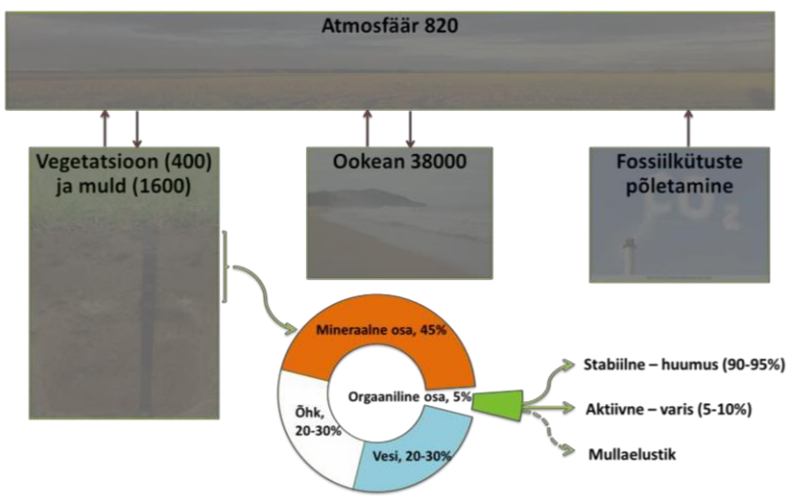
It is widely known that humus is the most important indication of soil quality. But what is in it? In many languages, the word “human” originates from the stem of humus (*hum*). In Latin, “*humus*” bears many meanings (land, soil) and the English word “human” is derived from it.

Humus is one of the forms of the organic matter of soil. As in a typical mesophile field soil, humus forms the larger part of the whole organic matter, these are colloquially used as synonyms. The organic matter of soil improves the structure and water storage capability of the soil, the exchange capacity of plant nutrients, the buffering capability (pH change). It is an energy source for the soil biota. The organic matter of soil is closely connected with the carbon and nitrogen flow of the ecosystem. Soil is one of the greatest carbon reserves of the world (see drawing). Therefore, soil is seen as an influencer of the climate change on a global level. In case of negative humus balance, it is believed a farmer contributes to climate becoming warmer, and in case of positive humus balance a farmer is seen as the saviour of the world. Thus, the organic matter of soil is not just a question of soil fertility and agriculture, but it participates in the worldwide environmental and climate politics and has become a solid currency in the carbon quote business in some countries.



Atmosphere 820

Vegetation (400) and soil (1600) | **Ocean 38000** | **Burning fossil fuels**

Mineral part, 45%
Organic part, 5%
Air 20-30%
Water, 20-30%

Stable—humus (90-95%)
Active—litter (5-10%)
Soil biota

Although organic matter forms a smaller part of the soil than the mineral part (except peat soils), it is extremely important from the perspective of the functioning of the soil and its fertility. Soil fertility means its capability to supply crop with nutritive elements and water and to supply plant roots with oxygen. Neither organic matter nor humus is meant to feed the crop, but it ensures favourable growth conditions in optimal quantity and quality. Nutrients digested by crop are released to the soil during mineralization. Humus matter includes 2–5% of nitrogen and a considerable amount of phosphorus and sulphur. It helps to optimize the use of nitrogen fertilizer successfully according to the humus content of the soil. Not just the composition but also the decomposition of humus is vital for efficient soil. The saying “what moves, wears out” applies to soil as well. To maintain soil fertility, it is important for the humus composition and decomposition to be balanced in field soil in the longer run. To evaluate it correctly, it is necessary to differentiate between different forms of organic matter of the soil, the methods defining these forms, and the calculation possibilities. The humus balance of the soil is derived from how much humus is added and how much humus mineralizes with the applied agricultural techniques. To maintain its functioning capability both from the perspective of productivity and environment, the soil must receive continuous “fresh” organic matter in the amount that would compensate the expenses made in course of the operation. To put it simply, the organic part of the soil is divided into three: 1) living organisms, 2) dead, not decomposed, and half-decomposed plant and animal remains (plant litter), 3) specific organic matter of the soil (humus). Plant litter sedimented in the soil starts to change mainly in the participation of microorganisms, whereas a part of the organics mineralizes and another part turns into humus. The speed of decomposition and humification and its percentage depend on the content of the plant litter, the characteristics of the soil, climate, and soil biota. In general, the best conditions for the formation of humus in the context of Estonia is in a mesophile pH-neutral soil integrated with sandy loam. Good air circulation guarantees quick mineralization in sandy soils with too light integration, but there will not be enough clay particles in the soil by which the humus matter could form stable compounds. Therefore, sandy soils have less humus in essence. In waterlogged soils, the decomposition of organic matter is slow due to lack of air, and the general content of organic matter is higher than in mesophile or extremely drained soils. There are just a few examples on a certain humus storage capability of every soil depending upon its type, integration, and humidity conditions. Hence, the purpose cannot be to equalize all the soils but to know how to preserve the humus condition that corresponds to the specifics of the soil.

The specifics of humus as compared to other organic matter lie in the fact that humus matter is strongly connected with the fine mineral part of the soil in the soil and is predominantly really stable. A blade of grass rich in nitrogen can decompose in the soil within a couple of months, but certain compounds of humus remain in the soil up to thousands of years. In Estonian field soils, about 1–3% of the humus mineralizes per year. As the humus content of the soil is a relatively stable indicator, the identification of changes needs a lot of time. In a long-term field experiment at Eerika of the University of Life Sciences, where the initial humus content of the soil was ~1.7%, the humus content dropped by 0.14% in a crop rotation without organic fertilizers in 15 years, and in a crop rotation with solid manure it increased by 0.25%. Similar slow changes have found scientific proof in field experiments conducted elsewhere as well. Hence, the information about a miraculous preparation or technology increasing the humus content of the soil within a few years many times should be treated critically. As an example, there was an organic experiment conducted in Jõgeva and covered by Maaleht (an Estonian newspaper), where allegedly the soil organics jumped from 1.4% to 4.1% in five years. For such a change to take place there should have been 17 t/ha organics in dry matter left in the soil every year. If to presume that the increase of humus content is 0.5% per year, it would take about 350 t/ha of green manures per year to achieve it. Let the reader decide, if it is really possible. Such misconceptions arise easily from the circumstance that several methods and units are used to define the forms of organic matter in the soil. The definition of the general content of organic matter as ignition loss is suitable first and foremost to analyze peat and forest floor. Speaking of mineral soil, the most trustworthy ways to identify the stable and high-quality humus of a soil is either acid digestion with chemicals (incl. the Tjurin method well known here) or dry burning on an element analyzer (the Dumas method). The content of organic carbon is calculated with these methods; however, it is important that the carbon in the content of carbonates has been removed from the sample beforehand. During the last decade, the Agricultural Research Centre has used the near-infrared reflection spectrometer (the NIRS method) to define the organic carbon of the soil. Hence, the complex humus matter is not defined directly, but the most widespread way to ascertain the humus content is to calculate it on the basis of organic carbon, taking into account that there is 58% of carbon in the content of humus on the average. In addition to the definition of the content of organic carbon (humus), the humus reserve (t/ha) and its change are even more important. Besides the humus content, the thickness of the humus layer, its bulk density and the volume of stones are taken into consideration. In addition to the aforementioned, the cultivation technology has a significant impact on the formation of the humus supply. Several cultivation studies have shown that the concentration of organics increases in the surface layer of 5-10 cm when cultivation is minimized or not ploughed, but taking into account the whole humus layer, the humus reserve might even become smaller.

Analyzing the structure of the growing area of the arable crops of the recent years and the resource of manure in Estonia, it becomes evident that the humus balance is negative in crop rotation for lots of land users. 5–6 t/ha of organic dry matter must reach the soil for the mineralization and humification to be balanced. Since the middle of the 1990s, we have about three times less manure than needed. Therefore, to maintain the humus reserve, it is necessary to use even more alternative organic fertilizers in addition to regular manure, such as green manures, composts, biochar, etc. We can influence the humus content with agricultural techniques. The most important ones are the correct selection of cultures in crop rotation (their roots, stubble, etc.) and a skillful use of organic fertilizers. Thus, the plus side is significantly dependent on fertilization, culture, and yield. The influence of fertilization to the humus content of the soil is either direct or indirect. Organic fertilizers influence the humus content of the soil directly. The indirect impact of the fertilizers becomes evident via plant nutrition. The yield increases thanks to fertilizations and with that the amount of plant remnants in the soil and on the soil surface.

From the point of view of the humus balance and on the basis of studies, it should be said that about 10-20% of low-humus soils (~2%) and even more than 30% of humus rich soils from the dry matter of organic matter in the soil is turned into humus. At that, we must consider that the composition of humus is simultaneous with its decomposition. According to the data of literature, the soil humus reserve is mineralized in approximately 2.7% of winter cereals, 1.9% of summer cereals and 0.8% of timothy fields in a potato field per year. As to the agronomical perspective, it is vital that the dynamics of the decomposition of organics matches the dynamics of absorbing the growth and nutrition elements of arable crops. The main technological take is to create a favourable environment to the decomposers and the equation of the balance of nutritive elements. For instance, to add mineral nitrogen or manure in liquid form to straw to accelerate decomposition. Nitrogen-rich clover could be sown as companion crop and to be added to the soil with the straw, so that nitrogen is not leached at the decomposition of the clover.

How to Calculate All This?

The scientists of the Estonian University of Life Sciences have a project at hand to calculate a location-based humus balance calculator of field soils, which takes into account the conditions in Estonia and can be applied practically.

The models of humus balance take the following into account: the characteristics of the soil, land usage, agricultural techniques of the cultivated crops, and the use of nitrogen fertilizers. Different applicable humus balance calculators have been designed in Germany. The numerical data of a model elaborated in other conditions cannot be transferred to the conditions in Estonia directly, and therefore in the course of the project the indicators suitable for the local conditions shall be calculated (humification factors, and carbon balance). On the basis of an analysis of previous studies, factors that take into account the impact that different agricultural technologies (cultivation methods, use of solid and liquid manure, green manures, composts, follow-on crops, removal of straw or adding it into the soil, etc.) will be elaborated. As the humus balance depends on the production level, soil fertility, other characteristics, the crops cultivated, and fertilization, the humus balance calculator designed by us is based upon the characteristics of the soil of a specific field and its surveillance data such as integration, humus or organic matter content, thickness of humus layer, and its bulk density. Since the humus condition of the soil defines the nutrient (nitrogen) supply of the plants, the calculator would also help to optimize (nitrogen) fertilization.

A Few Ways to Regulate Humus Reserve

Organization of straw economy.

Approximately 200 kg of humus comes from one ton of straw. Right after harvesting the crops, the straw should be mixed with the soil in the course of peeling a field (e.g. with the help of a disc harrow), which guarantees a more purposeful use of nitrogen in the decomposition of the straw and a better water and air regime. It should be considered that in straw the C/N relation is very wide (barley 70:1 up to wheat 100:1; optimal for decomposition 1:25(30)), and it may cause the immobilization of nitrogen compounds (transition to build the body cells of microorganisms) in the soil to such an extent that the crop even decreases. If such straw decomposition happens in a period free of crops, it poses no problems. However, if during the intensive straw decomposition period the crop grown on a field, there is competition between the plants and microorganisms in nitrogen consumption. Without additional nitrogen, the straw added deep into the soil decomposes slowly. When ploughing an unpeeled field, a layer of straw might form under the sowing layer, which disturbs capillar flood and fertilizers in the dry soil are left untouched this year.

Considering that that about 20% of carbon taken to soil goes into humus content and ~2% of the humus or carbon reserve of the soil mineralizes per year, it is obvious, that the humus balance remain negative in case of low yield level, if only straw is taken into the soil. In a cereal farm, where only the plant roots and the stubble are taken into the soil after harvesting, the decrease of humus reserve is 2-3 times bigger than it forms from the fresh organic matter. Larger straw quantities (~5 t/ha) do compensate for the lack of organics, but in the decomposition of nitrogen-poor organic matter (straw and cereal roots), there might be periods of lack of mineral nitrogen. From the perspective of the quantity of accruing organic matter and nitrogen economy, the situation improves significantly when legumes are the companion crop to cereals.

Green Manures

The impact of green legume manures to the important chemical and physical characteristics of the soil is not limited to one year but may last longer. Thus, it is necessary to grow lots of legumes in soils that have poor humus content and lack microbiological activities first and foremost. Red clover and white honey lotus are grown as the most widespread green manures. Additional suitable crops are Lucerne, and not so widespread birdsfoot trefoil and lupin. White honey lotus and Lucerne grow well in the calcareous soils of North and West Estonia. In South Estonia, their spread has been stopped by acidic soils. Soil liming creates favourable conditions for growth in those areas as well. The cultivation of red clover depends less on the acidity of the soil.

In favourable conditions, the green legume manures may produce ca 6–10 t/ha of dry matter. Up to 300 kg/ha of nitrogen is taken into the soil in good cultivation conditions with such yields. Not only do the green manures increase the quantity of N on the soil, but they influence the depth of its spread in the soil. Therefore, the impact of the green manures on the following crop on how deep is roots reach into the soil. Tests with barley and green manures at Eerika proved that during the harvesting of the plants there was up to 5 t/ha of carbon in the biomass, and approximately 20% is in the roots in single crop seeding, about 30% in case of companion crop, and up to 50% in the single crop seeding of legumes.

Successive Secondary Crops

Late in the summer, after harvesting the main crops, it is practical to cultivate other crops (follow-on crops, the so-called collecting crops), which help to avoid the leaching of nutrients and improve the characteristics of the soil on the account of accrued organics. Furthermore, successive secondary crops prevent erosion, reduce the loss of organic matter, obstruct diseases and pests and reduce weed invasion. Legumes are also cultivated as successive secondary crops, which provides an added benefit in fixing nitrogen from the air. Crops suitable as successive secondary crops are white mustard, oil radish, rye, buckwheat, bluebell, pea, and winter colza. Different mixes of these crops are cultivated more and more. In the selection of successive secondary crop mixes, the important factors are quick growth, soil coverage, low norm of seed intended for sowing, cheap seed price, later development of generative organs, good capability of fixing nitrogen, effective water usage, and easy disposal. Naturally, when cultivating the follow-on crops later on, their suitability with the order of the crops cultivated in crop rotation should be taken into account (the same species is generally not the best intermediate crop).

Composts

Composting is one of the oldest methods of handling and stabilizing organics, which in its essence is the conversion of aerobic organic matter to stable humus matters. In composting, the “humus factory” works notably much faster than in the soil. Composting reduces the environmental hazards that might arise with the use of fresh organics (pathogen spread, nutrient leaching, gas volatilization, weed seed spread, etc.). The level of conversion to humus depends on the composition, humidity content, and aeration of the composted source material and the activity of microbes. Therefore, composts possess very different qualities and subsequently they influence the characteristics of the soil. Ready compost has a high level of humus matters, but fresh compost, on the other hand, includes lots of easily decomposing organic matters. For a short-term period, composts might be a quick source of nutrients for plants and soil biota, but the long-term effect on the characteristics of the soil comes from the preservation or the increase of stable organic matter content. Humus matters taken to the soil via composts from a stable structure with the fine mineral part of the soil.

Biochar

Unlike green manures, manure, and composts, the organic matter of which is decomposed relatively well, the C found in the content of biochar is stable and can allegedly stay in the soil for hundreds or thousands of years. Biochar is a solid carbon-rich material received by heating the biomass in an environment with no oxygen. In the longer run, adding biochar to the soil is seen as beneficial both in the improvement of the characteristics of the soil in agriculture and the alleviation of climate changes. In both cases, the impact of biochar is based on preserving organic matter in the soil for a long time. The porous structure of biochar and its large specific surface create a favourable living environment for microbes; also these qualities are regarded as the bases for the improvement of water storage capacity and fixing nutrients. Better water storage capacity in the soil helps to prevent nutrients dissolving in water from leaching. Last but not the least, biochar is alkaline, increases the pH of the soil, and thus influences the circulation of nutrients.