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Soil Biodiversity – Effects on Carbon Storage and Water Retention from Climate Change Mitigation and Adaption Functions

Literature Review for *CEEweb for Biodiversity*

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We have seen, through many observations and experiments that there are positive correlations between biodiversity and organic matter in soil and the retention of both water and carbon.It is understood that many of the activities humans partake in have a wide variety of effects on biodiversity. This is particularly true with the ecosystem of the soil, which many people may be unfamiliar with and unaware of. The decrease in soil biodiversity and its effects on the world as a whole goes unnoticed to the masses as it is not seen to be as directly influenced as many other factors such as emissions and other more well known "green-unfriendly" activities. When it comes to soil ecosystems, it is possible for human activity to promote increase biodiversity within soil; but unfortunately, the ecosystems have been so negatively affected and have even reached the point of collapse [1]. Of course, this decrease in biodiversity is not just an observation of loss of species within the soil, but also the quality of the soil and its ability to function as soil should function have been affected. Often, it comes as a surprise to many who misunderstand the workings of soil as an entire ecosystem in and of itself which is the habitat to many fauna, fungi, grazers, microbial and bacterial species in addition to earth worms, which allow soil to efficiently produce the crops that we rely on for produce and other agricultural needs [3].Fitter et al., estimates that there exists up to 100,000 different bacterial species for every gram of soil that exists. This is an incredible amount and their populations have been on the decline over the decades. The decrease not only makes species more susceptible to being eliminated more than ever, but it damages the ability of soil to adapt to environmental changes which is worsened due to the existence of a rapidly changing environment that has many negative impacts on life itself. This affects not only the biodiversity, but alsothe cycling of important elements such as Carbon and Nitrogen through the soil. The decrease in biodiversity makes retention of these elements in the soil more difficult and as such, decreases in the retention of water by soil are also found to have a strong correlation [4]. This review hopes to gather and summarise information to support the positive correlations between soil biodiversity, soil organic matter content and the amount of carbon stored and water retained in the soil. As a result, these affect climate change mitigation and adaptation functions of the soil. Focus will be towards the effects of decreasing traditional farming practices, grazing impacts and greenhouse gases.

The discussion of the decrease in biodiversity in soil stems from studies based on scientific observation of the shrinking ability of soil to function throughout the years as we turn towards the use of unsustainable farming methods, such as increasing use of land for biofuel rather than food production [1]. From the European Commission, the Joint Research Centre published an atlas of Europe and where soil biodiversity is most threatened. Based on history and economic development of documented areas in Europe, it can be deduced that there is a correlation between the divergences from traditional farming towards more unsustainable methods of farming have a great affect on soil biodiversity. The atlas (figure 5.2: Map of Soil Biodiversity Potential Threats) clearly shows a gap between the more developed markets of Western Europe and the emergent markets of Eastern Europe and the obvious trend towards heightened threat of biodiversity in the soil[5]. Much of the research has found that loss of biodiversity specifically reduces an important function of soil to resist environmental changes and thus preventing it to respond and adapt to changes [4]. Not only is this a factor to consider especially in areas where temperature differences in seasons are very drastic, but this also plays a huge role in the very real and imminent fact of global warming and thus, global climate change. Even more specifically, the capacity of the ecosystem to capture and retain water, to cycle and store carbon and nitrogen reduces the fertility of the soil, its ability to keep from eroding, compacting, and, in more extreme cases, aid in cases of water flooding [4]. As a result, the cost of subsidising these “services” that soil provides is added in the form of requiring more water, thus more fuel, more fertilizers and also pesticides. The introduction and use of chemicals from regulation additives such as fertilizers and pesticides then have subsequent effects on water, soil, and air quality as well as other natural occurrences such as insect pollination and seed dispersal as well [6]. It is a sad reality of the agriculture industry that the move away from traditional farming practices is occurring. Specifically in Europe, it has been observed that much of the changes seen are a result of policy through laws and regulation of the rural society [7]. Marini et al. also notes the change as a result of societal and cultural changes and demands and of course, technological advancements, which often rule in favour of mass production, mass farming and mass use of unsustainable techniques which in turn harm the biodiversity our earth so dearly needs.

In order to understand how studies on soil biodiversity came about, we must first understand the domino effect of how it has been impacted. Of course the innate nature of human activity has grave effects on the soil depended on so much for the fruits it produces and with the emphasis on the decreases seen in the diversity of life within the soil, it leaves much to desire as to how just the use of offensive machines and introductions of manmade chemicals could directly kill the soil. Although these play a key role in the decline of biodiversity, a huge defining factor is the amount of Carbon stored within the soil. It has been observed that the Carbon content of soil has decreased incredibly and one of the main offenders is not a direct result of human activity, but rather, one could say, of poor management. Livestock grazing has a huge impact on the Carbon found in soil. Carbon is an important component whose presence in soil is extremely desired. In order to sustain the microbiotic life which allows soil to thrive and properly function, carbon is needed as a component of organic matter which helps support the soil communities [8]. It has been observed by Wall et al. that if there are low amounts of organic matter, the distribution of plants is sparser and thus, the function of the soil is affected. However, we must not be quick to judge the livestock. Grazing is an extremely important asset to the soil ecosystem. It is a natural method of “churning” and stimulating the soil and as Schuman et al, points out, it is vital to “influence plant community structure, soil chemical and physical properties, and the distribution and cycling of nutrients within the plant-soil system”. Thus, grazing is actually pivotal in the contribution to the role it plays in the Carbon cycle. More specifically, with quality grazing, organic matter and carbon distribution in the soil can be controlled. Grazing allows carbon (and nitrogen) to be redistributed within the soil and thus, the rates at which they are cycled through the entire system increase, further eliminating, or at least reducing, simple perpetuating losses of the two from the ecosystem [9].

The issue with grazing lies mainly with poor human management of their livestock when there is *overgrazing* done. If there is frequent grazing done in repetition, grasses can also respond negatively due to shorter root lengths and lower biomass quantities in the soil. These will thus contribute to lower amounts of Carbon brought from the grasses into the soil as well [9]. Northern China has a continental, semiarid climate similar to that of Central and Eastern Europe[10]. Based on a study done by He et al. and focusing on Carbon and Nitrogen storage in soil of Mongolian grasslands, experimenting with grazing intensity by sheep, the storage of C and N increased when sites were lightly grazed, just as Schuman et al. had found. On the other hand, if grazing intensity was very heavy, the Carbon and Nitrogen storage actually decreased, more-so under heavy long-term grazing [10]. In terms of specific percentages, long term heavy grazing results in up to 30% decrease in the storage of Carbon in the top 60 cm of soil[10]. He et al. gathered a few explanations as to how the decrease in Carbon and Nitrogen are correlated with grazing such as the basic removal of biomass, decreasing aboveground input of organic matter, decreasing soil infiltrability and nutrient availability, thus decreasing productivity of soil. As well, they are connected with the invasion and subsequent destroying of soil aggregate structures through the aboveground ‘over-trampling’ of livestock. The latter explanation also correlates with the increased susceptibility of the soil to water erosion as well, due to the decomposition of organic matter within soil from over-grazing.Like Schuman et al. there is agreement that lightly grazed grasslands have a certain capacity in which Carbon and Nitrogen are stored in soil and the threshold between how much is too much was reported as 4.5 sheep per hectare [10]. If farms in similar climates zones can account for this quantity of “natural grass-mowers”, not only can they maximize the efficiency of their farm, but they can enhance the organic nature of their farming system with a steady amount of organic soil fertilizer (livestock manure), which also enhance elemental cycling[11]. Organic fertilizer helps to increase the soil fertility which will increase cycling, and the decrease in need of artificial fertilizers will help benefit the environment and enhance food production and decrease the risks that come with production, as well as ultimate long-term degradation of soils and the quality of surrounding water [11].

Through several case studies by Marini et al.,large amounts of support for sustainable farming techniques were compiled. Another cost in addition to harmful chemicals and fertilizers include the need for antibiotics and other medicinal support needed for livestock which are “high-production”. With “high-production” cows, they must be supplied with large amounts of feed that must not only be imported from outside, but generate highly Nitrogen-concentrated “organic fertilizers[1]”, which have a negative impact on soil biodiversity by increasing the fertility of soil [7]. Conversely, it was also gathered that smaller farms were observed to produce smaller amounts of organic fertilizer and ultimately had higher soil biodiversity.Another associated cost with advancing technology is the harm done by heavy machinery which churns the soil, causing harm and death to invertebrates in the ecosystem, which do not have the agility to remove themselves quickly enough [7]. Marini et al. has also suggested, as a way to reduce the effect of the change from traditional farming to less sustainable methods, is to compensate farmers to reduce the amount of organic fertiliser produced by livestock. This means that, since the organic fertilizer with high nitrogen content is a direct result of a feed which has various amounts of concentrates in it (bulking up feed to reduce cost in combination with hay to promote digestion and production of a “liquid” organic fertilizer) and thus a direct contributor to loss of biodiversity. The proposal of the *Meadow Agri-Environment Scheme (AES)* was a way to compensate livestock feed to be more environmentally sustainable and thus would correlate with a decrease in loss of biodiversity.With deterioration of the function[2] of soil to provide for us food and the dependence of the inherent quality of that food as well as diversity of crop, it is important that we focus on sustainable farming techniques to ensure the future of our food products [12].

Although the focus of this paper has been primarily on that of soil, soil functions and soil biodiversity in a farm setting, we cannot ignore the functions of soil in natural areas still uninhabited and untouched by humans. This includes forests and other natural grasslands which cover a much greater area of the earth than farm lands and though their carbon retaining capacity (carbon sequestration) is much greater than “domesticated” lands, they have drawn much attention from the scientific and environmental community because this sequestration ability is decreasing. While this may not have direct correlation with activities previously discussed, the valour of human invasion of these natural habitats, including deforestation, burning of fossil fuels and general industrialization beyond city limits are directly affecting the *earth*’s ability to retain carbon. These activities mentioned contribute to the increase of greenhouse gases into the atmosphere, namely carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O)[13]. One of the more famed greenhouse gases, CO_2 output into the atmosphere from soil has a grave effect on soil function. Primarily, with loss of CO_2 in soil,

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[1] Organic fertilizer also referred to as livestock waste and manure for fertilizing soil.

[2] Specifically, the function of the soil ecosystem is defined as the ability to continue the cycling of nutrients.

there is a subsequent loss in carbon storage and thus soil's fertility and ability to be productive. Rastogi et al. compiled research showing various factors which affect and influence the generation and release of CO_2 from soil, among many include temperature, moisture and tillage practices of soil. Effects of temperature observed on CO_2 evolution increased with temperature as gathered by Rastogi et al. With regards to global warming and increased temperatures setting all-time high records in recent years, this is of particular concern as emissions would result in much depleted carbon reserves in soil, thus further affecting soil's functionality [13]. This is more so an issue with sites which have longer summers and warmer weather as the soil in those regions would be more affected than say, mountainous sites.

Sources

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