Some Approaches to Measuring Soil's Carbon Sequestration Potential in Ukraine

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Abstract: The Strategy on reducing greenhouse gas emissions for the period up to 2030 was adopted in October 2021 at COP26. However, it does not take into account the potential of arable soils for carbon sequestration. Meanwhile, on a global scale, carbon sequestration by soils is regarded as one of the most important tools to combat further increases in atmospheric carbon dioxide. According to preliminary estimates, the amount of carbon that can potentially accumulate in the soils of Ukraine is 757,7 million tons, of which 23,3 million tons - in the arable soils of Polisia, 350,3 million tons in the soils of the Forest-steppe and 384,2 million tons soils of the Steppe of Ukraine. At the same time, modern assessments of the sequestration potential, do not usually involve assessment of erosion processes and the spatial heterogeneity of humus accumulation conditions, which significantly change the carbon cycle in slope soils. This article discusses four possible approaches to assessing the potential of soil sequestration as well as the popular, but difficult to implement, method of carbon accumulation modeling. The authors consider three variants of the balance method for assessing the potential capacity of soil sequestration based on the difference between potential and real content of organic carbon. All three approaches give similar results for assessing the sequestration potential of chernozem soils.

1 INTRODUCTION

The apparent exacerbation of climate change is forcing the world community to step up its efforts to reduce greenhouse gases (GHG) emissions and carbon content in the atmosphere by its sequestration. In 2021, Ukraine took several important steps to achieve climate neutrality. In June, the government approved the second Nationally Determined Contributions (NDCs) for Paris Agreement (Cabinet of Ministers of Ukraine, 2021a). In October, the Cabinet of Ministers adopted the Environmental Security and Climate Change Adaptation Strategy of Ukraine until 2030 (ESCCASU30) (Cabinet of Ministers of Ukraine, 2021b).

Analysis of this Strategy (Ministry of Ecology and Natural Resources of Ukraine, 2021) shows that agriculture and agricultural land are currently considered mainly as a source of additional emissions. The main sources of GHG emissions in agriculture and land use are internal fermentation and organic waste management in livestock, mineral fertilizers and loss of humus (dehumification). Among the ways to reduce GHG emissions in the agricultural sector and land use, Land Use Change and Forestry (LULUCF), ESCCASU30 lists measures aimed at reproducing organic carbon content in soils. However, direct sequestration of carbon by soils is not considered as a mitigation option. Moreover, the Strategy does not take into account the amount of carbon sequestration by soils which is not calculated, yet.

Only forestry considers carbon sequestration in the planning of forest area increase. However, carbon

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sequestration by soils in the world is one of the most powerful real mechanisms for reducing GHG in the atmosphere (The Food and Agriculture Organization, 2020; Abdullah et al., 2018; Lal et al., 2004; Han et al., 2016). Most of the carbon in terrestrial ecosystems accumulates in soils.

According to the estimates of (Scharlemann et al., 2014) for landscapes of cool temperature moist, cool temperature dry and warm temperature dry zones, typical for Ukraine, the share of organic carbon contained in the soil is from 76% (Dry Steppe) to 92% (Forest-Steppe and Steppe) of the total carbon of terrestrial ecosystems.

According to the State Forest Resources Agency of Ukraine (State Forest Resources Agency of Ukraine, 2021), Ukraine's forest cover is now 15.9%, and there are plans to increase it to 18% by 2030 (Cabinet of Ministers of Ukraine, 2021b). Agricultural land already occupies about 43 million hectares, i. e. 71.2% of the territory (Land Directory of Ukraine, 2020).

Geographical location and natural conditions make Ukraine one of the main producers of agricultural products in the world. The aggravation of the global hunger problem requires an increase in world food production, and therefore Ukraine should not expect a significant reduction in arable land and an increase in forest cover. These expectations are not only unrealistic, but also irrational.

It is obvious that although afforestation is a necessary measure, the scale of the impact on the carbon balance in Ukraine's forests is not even close to that of the agricultural soil. Thus, in our opinion, in the current Strategy for Adaptation of Ukraine to Climate Change, the importance of increasing the humus content in soils is clearly underestimated.

The authors propose to quantify carbon sequestration, using modeling carbon cycle processes (The Food and Agriculture Organization, 2020; Zomer et al., 2017; Lal et al., 2018). The basic model for the prediction of carbon sequestration is recognized (FAO, 2020). The Rothamsted carbon model (RothC) (Coleman and Jenkinson, 2014) is freely available for the scientific investigation allowing researchers to predict changes in organic C content in soil depending on climatic parameters, soil particle size distribution, application of organic fertilizers and quantity, and quality of organic residues entering the soil monthly. The use of the RothC model is quite promising for Ukraine as well, but it is currently not adapted to local conditions and requires a large amount of very specific input information that limits its application. In addition, in our opinion, the model does not take into account such an important aspect as the local potential for sequestration of organic carbon by soils, which depends on the specific thermodynamic conditions of soil formation.

In our opinion, determining the upper limit of possible accumulation of carbon in the soil is fundamentally important in predicting its sequestration because it allows researchers to develop specific measures for specific areas.

Quite a few researchers emphasize that the rate of carbon sequestration by soils is not constant and it gradually decreases until the soil reaches a certain equilibrium level of humus content (Lal et al., 2018). However, there is no consensus on exactly how this slowdown in sequestration occurs and how to quantify its pace. This happens due to the complex processes of organic matter transformation in soils and a great variety of soils, keeping in mind possible combinations of soil formation factors that affect the course of carbon accumulation.

Thus, when estimating the sequestration potential, most studies assess carbon sequestration rate of soil, as "constant during the first 30-50 years". The source of this approach can be the work of a recognized authority in assessing the carbon sequestration potential of R. Lal and his colleagues. They approximate time to achieve equilibrium of the soil carbon system by stimulating carbon sequestration, which, according to their estimates, is 25-50 years for most soils (Lal et al., 2018).

However, it is obvious that the change in the rate of carbon sequestration over time will depend not only on natural and climatic conditions and the amount and quality of organic matter entering the soil, but also on soil condition, and in particular the degree of degradation (here by degradation we mean the processes that lead to the loss of organic matter). However, it is obvious that the change in the rate of carbon sequestration over time will depend not only on natural and climatic conditions and the amount and quality of organic matter entering the soil, but also on soil condition, the degree of degradation. The relative share of lost organic carbon compared to equilibrium non-degraded soils characterizes the degradation degree. It determines the undersaturation of the soil with carbon, and, consequently, the temporal dynamics of carbon sequestration. Kogut et al. (2021) determine the active period of sequestration by introducing the concept of a certain "steady-state time" of organic carbon content, which, according to the authors, varies from 30 for medium-plowed fertilized arable land to 5,000 years for highly eroded meadows. Although the idea of "characteristic time" is quite valid, the quantitative assessment of "characteristic time" provided by Kogut et al. (2021) has, in our opinion, been based on a poorly substantiated expert judgement, which reduces the importance of the sequestration potential assessment results.

An important practical aspect of the quantitative assessment of carbon sequestration is consideration of sequestration in the system of CO2 emissions trading, which is to develop in Ukraine in the near future (Prohorchuk, 2021). The calculated amount of sequestered carbon with the receipt of "carbon certificates", should allow landowners to monetize the sequestered carbon. To do this, special electronic services are created, such as multi-sided platform AgreenaCarbon from Agreena company that allows the so-called "carbon farmers" to obtain carbon certificates for sequestered carbon. According to Agreena's managers, this company is successfully operating in the EU agricultural sector, and already has successful experience of cooperating with several major Ukrainian agricultural producers. Ukrainian agricultural producers can already sell the obtained certificates on the international voluntary market of carbon certificates (Shneider et al., 2019).

In addition, the EU is expected to introduce a so-called "carbon duty" on agricultural products. Quantitative evidence of carbon sequestration by soil will be another way to reduce the costs of farmers.

The objective of the article is to analyze possible approaches to assessing the potential carbon sequestration by soils in Ukraine and contribution of carbon sequestration by soils to the balance of greenhouse gas emissions for the period up to 2050.

2 RESULTS AND DISCUSSION

The paper considers the carbon sequestration potential of soils (SOCseq) as a characteristic of the maximum potential amount of carbon that can be absorbed and sustained by the soil, using the equation:

$$PSOC_{seq} = SOC_0 - SOC_1 \qquad (1)$$

Here: SOC0 – potentially possible stable content of organic carbon in the soil;
SOC1 – soil organic carbon (SOC) content at the time of sequestration potential assessment.

Whilst there are no difficulties in determining the current SOC1 content, estimating the potential SOC content in the soil is not an easy task.

The content of humus in soils is a natural result of the interactions among a range of factors, forming one or another type of soil. Thus, these factors limit possible accumulation of organic carbon in mineral soils. This is noticeable in studies of humus accumulation on rock dumps where the process of soil formation began under the influence of self-developed vegetation. Such dumps are, in fact, a natural model of carbon sequestration. In fact, they allow us to trace the real process of carbon accumulation over time.

The authors built a model of humus accumulation according to Makhonina (2004) for the conditions of forest-steppe and forest landscapes of the Urals, Russia, shown in Fig.1. These simulations demonstratea general trend of humus accumulation processes. The most intensive processes of organic carbon accumulation occurred in the soils studied by Makhonina (2004) in the first 30-40 years.

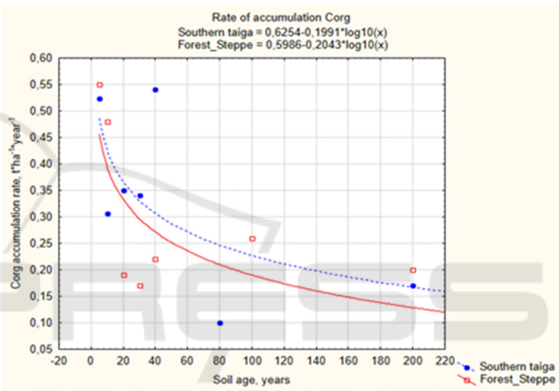

Figure 1: Changes in the average annual amount of accumulated carbon depending on the age of the soil.

However, this process has not stopped even in soils aged 200 years, i.e. the accumulation has not reached the balance yet. According to calculations by Makhonina, it takes 400 to 1500 years for soils to reach an equilibrium level of humus content. Similar data were obtained for the conditions of the Crimea (Ergina, 2013), where studies of different ages of soils show that it takes about 2000 years for soils to achieve a balanced humus state. Lysetsky, Stolba and Goleusov (2016), give a similar order of values in estimating the characteristic time of equilibrium by soil, indicating that the time of equilibrium and slowing of soil processes reaches 1400-1600 years.

Probably, it is the content of organic matter established in soils after they reach "carbon balance" (i.e. equilibrium state) that we can consider the maximum potential level of organic carbon in soils. It is the upper maximum limit of carbon accumulation SOC_0 in determining the sequestration potential.

However, in real conditions of high soil plowing, it is almost impossible to find natural soil standards to determine the sequestration potential. A number of Ukrainian researchers have repeatedly discussed the problem of lack of standards for monitoring the soils of Ukraine (Medvedev, 2012).

It should also be noted that SOC0 content of virgin soils is the maximum possible level of carbon accumulation that cannot actually be achieved in intensive agricultural production. That should be taken into consideration in calculations of the sequestration potential. According to Körschens (2021), this is only possible if 7 billion people refuse to eat. Any agricultural use of soils causes a decrease in their organic carbon content and makes it impossible to maintain its amount at the "virgin" level.

Dehumification, as opposed to humus accumulation, can also last indefinitely. Experience shows that the processes of dehumification of soils, provoked by their plowing, occur most intensively in the first decades after plowing, then the process slows down (Degtyarev, 2011; Chendev et al., 2011; Ivanov, A. L. (Ed.), 2013). However, the loss of organic carbon due to its mineralization continues in arable soils not tens but hundreds of years after the plowing of virgin land. Thus, (Chendev et al., 2011) has found that although the loss of organic carbon due to mineralization of soil organic matter occurs most intensely in the first 50-70 years after plowing, it further continues, although less intensively. SOC losses were recorded (Chendev et al., 2011) in chernozems plowed for 140-240 years.

Fig.2 shows traditional ideas about the course of dehumification of soils during plowing.

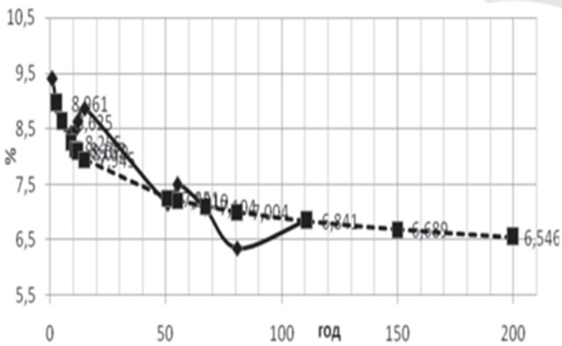

Figure 2: Time course of soil dehumification after plowing (Ivanov, A. L. (Ed.), 2013).

According to the results of monitoring surveys, Ukraine's soils continue to lose organic matter because of their long-term agricultural use. Official data on the change in humus content in soils today use the analysis of literature sources, starting with the first surveys by V.V. Dokuchaev (1882) and continuous soil and agrochemical surveys conducted in Ukraine by the State Institution "Soils Protection Institute of Ukraine".

Fortunately, dehumification, in contrast to, for example, salinization of soils, is a reversible process. The humus lost by the soil is able to recover, and this is what determines the potential ability of soils to sequester carbon.

As discussed above, it is difficult to establish the time of equilibrium during soil recarbonization, and the conditional 20-30 years used in the calculations now do not reflect real ability of the soil to accumulate carbon. Therefore, in our opinion, it is more rational and realistic to proceed not from time but from the quantitative potential of organic carbon accumulation, calculating it by equation 1. The rate of sequestration and approach time of the maximum SOC0 content will depend on the measures taken to reproduce the SOC content.

Figure 3 shows the change in organic carbon content in the soils of Ukraine, calculated from officially published data on the dynamics of humus content in soils (Baliuk et al., 2016).

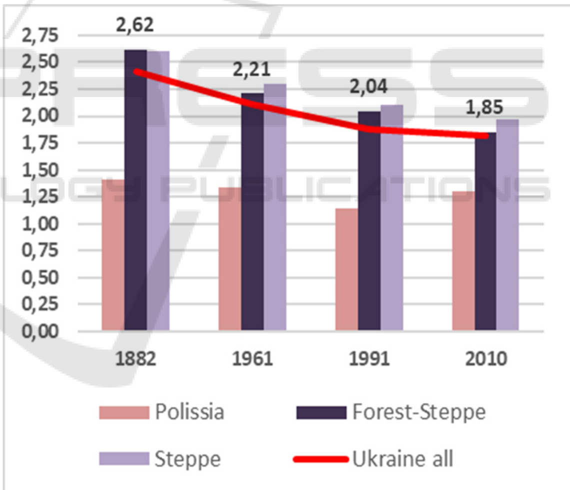

Figure 3: Decrease of SOC (%) content in Ukrainian farm soils (built on the data of Baliuk et al., 2016).

As it is clear from Figure 3, the SOC content in soils is steadily declining, and the rate of organic carbon loss calculated on these data, does not decrease over time (Fig. 4).

Some increase in the average SOC content in Polissya is not due to improved soil conditions, but to the removal of the least fertile low-humus soils from agricultural use. Therefore, we formed the sample for subsequent surveys from samples of more humus-rich soils compared to the previous ones. In contrast, in the Forest-Steppe and Steppe of Ukraine, the rate of SOC losses only increased.

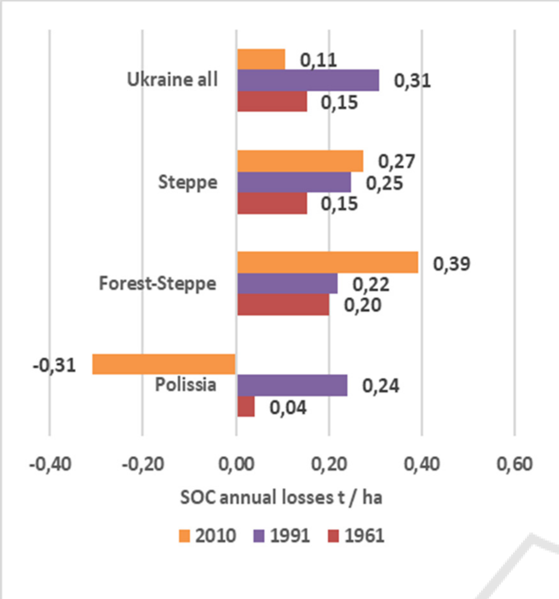

Figure 4: Average annual losses SOC in Ukraine t/ha.

This is easy to explain, as the intensity of soil use was constantly increasing, but organic fertilizers were almost not applied (Baliulk et al., 2016) and increased yields were due to depletion of soil resources. In addition, an important factor in the constant loss of organic matter is soil erosion, which, according to expert estimates, currently covers 13,3 million hectares of arable land in Ukraine (Baliuk et al., 2017)

Table 1 shows the results of the SOCseq assessment for the 0-30 cm soil layer in Ukraine on data from fig. 3. The authors used equation 1 for calculation, for SOC0 - data for 1882, for SOC1 - for 2010.

Table 1: Potential of carbon sequestratition of arable soil in Ukraine (for 0-30 cm).

Zone	arable soils area, ha*10^6	The potential of carbon sequestration in soils (0-30 cm layer)			
		t/ha	Total, t*10^6	%*	CO_2eq-t*10^6
Polissia	5,14	4,2	23,3	3,1	85,3
Forest-Steppe	11,73	27,6	350,3	46,2	1284,3
Steppe	15,58	22,8	384,2	50,7	1408,9
Total	32,45	21,5	757,7	100	2778,4

*share from total potential sequestration

As it is clear from Fig. 3 and 4, major carbon losses occurred in the soils of the Forest-Steppe and Steppe of Ukraine with higher natural fertility and those used more intensively in agricultural production.

Therefore, the soils of the Forest-Steppe and Steppe account for almost 97% of the mass of carbon, which today is potentially capable of sequestering the soils of Ukraine. The total sequestration potential estimated in this way for Ukraine is 757,7 million tons, or 2,78 billion tons of CO2eq. Assuming that we can achieve this level of sequestration in 50 years, an annual reduction in CO2 emissions will come to 55.6 million tons. For comparison, this is 1.46 times higher than the total average annual CO2eq emissions in agriculture, planned in the framework of NDCs for 2030 (Ministry of Ecology and Natural Resources of Ukraine, 2021). The opening of the domestic market for carbon certificates will make investment in the reproduction of humus content in the soil mutually beneficial for farmers, who will increase the fertility of their lands, and for industrial enterprises that can receive additional quotas by investing in carbon sequestration.

The obtained values of carbon sequestration (Table 1) give a generalized idea of the possible amounts of emission reductions through carbon sequestration in the soils of Ukraine. However, they do not assess in detail the sequestration capacity of specific soils in the real economy. In addition, it is difficult to say how correct such calculations are, and whether the 1882 data can be used as SOC0.

To answer these questions, it is advisable to compare the calculation data using SOC0 data from 1882 with similar calculations for a particular soil, where we compare a virgin analogue with arable soil. We have collected data from modern studies of the humus condition of soils that meet these requirements. Table 2 shows the calculated sequestration potential for the top layer of different subtypes of chernozems, where SOC0 is the organic carbon content in virgin soil and SOC1 is in the same soil plowed for a long time. Classification of chernozems is presented in the international format according to the recommendations (International Soil Reference and Information Centre, 2015).

The sequestration potential, calculated for such soils, (Table 2) was slightly higher than the values, obtained on average for Ukraine (tab.1). We can explain this by the fact that the SOC content in the studied chernozems was significantly higher than the average values in the relevant areas of Ukraine. However, the losses of SOC in plowed soils relative to the virgin state were very close to the estimated losses of SOC for 2010 compared to 1882 (Fig. 5).

Relative Losses (RL) are calculated by the equation:

$$RL = (SOC_0 - SOC_1)*100/ SOC_0 \quad (2)$$

RL for data on the zones of Ukraine for 2010 ranged (Table 2) from 8,2 to 29,3%. The maximum losses naturally fall on the more fertile soils of the Forest-Steppe and Steppe. The average relative losses in plowed chernozems in comparison with virgin land (Table 2) was 28,8-30,5%.

In our opinion, this similarity of estimates is in favor of the reliability of sequestration potential estimates, based on generalized data (Table 1). It also confirms possible use of data on humus content in soils of Ukraine in 1882 to assess zonal sequestration potential at the zonal level and the adequate method of quantitative estimates.

Table 2: SOC losses and potential of carbon sequestration for some Ukrainian chernosems (for 0-30 cm layer).

Soil	Source	SOC_0	SOC_1	SOC_{seq}%	t/ha	Relative Losses, %
Luvic Chernozem	*Plisko, 2020*	3,65	2,64	1,02	36,54	27,95
Calcic Chernozem	*Plisko, 2020*	2,05	1,72	0,34	12,11	16,59
Halpic Chernozem	*Kramarenko, 2000*	3,40	2,30	1,10	39,68	32,35
Luvic Chernozem	*Panasenko, Degtiarev, 2015*	4,70	3,32	1,39	49,91	29,57
Luvic Chernozem	*Tonkha, Yevpak, 2016*	4,66	3,32	1,35	48,34	28,89
Halpic Chernozem	*Tonkha, Yevpak, 2016*	3,95	2,27	1,68	60,35	42,46
Average		3,73	2,59	1,15	41,15	29,64
Average for Steppe		3,13	2,10	1,04	37,38	30,47
Average for Forest Steppe		4,34	3,09	1,25	44,93	28,80

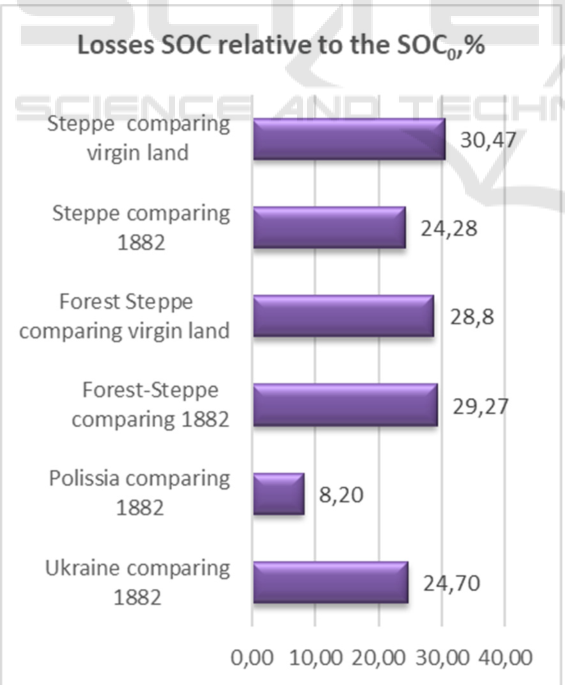

Figure 5: Relative losses of SOC in 2010 in soils of Ukraine for various methods of assessing the initial carbon level.

Thus, the calculated values of the potential of carbon sequestration by the soils of Ukraine can supplement the ESCCASU30 at the regional level. However, the implementation of any action strategy becomes real only if there is a reliable method of transferring this strategy to the local level.

Here, only limited number of farms can apply this approach because, as mentioned above, there are hardly any virgin analogues of arable land left in Ukraine.

To solve the problem, we can calculate the potential level of carbon accumulation in soils, using calculated coefficients as described below.

Studies of Ukrainian soil scientists have established a quantitative dependence of humus accumulation in soils depending on their genesis, hydrothermal conditions of soil formation and particle size distribution of soil-forming rocks. To characterize the ability of different types of soils to accumulate humus (Polupan et al., 2008), they propose a number of calculation coefficients. The authors propose to use the Coefficient of relative accumulation of humus (CRAH) to estimate the potential carbon content in the topsoil. CRAH is the ratio of humus content in the soil layer 0-30 cm to 10% of the content of physical clay (PhC). PhC is the sum of soil particles less than 0.01 mm. PhC is the main characteristic of the particle size distribution in the scientific schools of the countries of the former USSR.

We calculate CRAH for a soil layer of 0-30 cm by the equation:

$$CRAH = H*10/PhC \quad (3)$$

H – humus content is soil, %

PhC – physical clay content in soil, %

Physical clay is the sum of soil particles with a size of <0,01 mm. Polupan et al. proposed regression equations of CRAH dependence on HTC (Selyaninov hydrothermal coefficient) for the period April-September for the main soil types and subtypes.

Traditionally in Soviet times, when determining the humus content in soils, they analytically determined the content of organic carbon (Corg), calculated the humus content by multiplying the Corg content by a factor of 1,724. Accordingly, it is possible to transform CRAH into Coefficient relative accumulation of organic carbon (RAC coefficient) by the equation:

$$RAC=CRAH/1,724 \quad (4)$$

The sequestration potential was calculated using the RAC coefficient for Luvic chernozem (PhC = 48%, RAC = 0,64) and Phaeozem (PhC = 49%, RAC = 0,42) SOC0 by the equation:

$$SOC_0 = (PhC * RAC) / 10 \quad (5)$$

We obtained SOC1 and PhC values during field surveys of Rohan's polygon and Lubotin's polygon and Phaeozem. RAC values were calculated according to formula 3, and CRAH - according to the regression equations proposed in (Polupan et al., 2016). The evaluation results are given in Table 3.

Table 3: Estimation of sequestration potential using RAC coefficient.

Soil	SOC_0	SOC_1	SOC_{seq}	
			%	t/ha
Luvic Chernozem	2,02	1,27	0,75	29,41
Phaeozem	3,09	2,15	0,94	36,83

Both research sites are located on slopes of about 3° in Kharkiv district, Kharkiv region, Ukraine. Samples were taken on a regular grid at a depth of 10 cm. To calculate the sequestration potential, we selected data from points diagnosed as non-eroded or weakly eroded, and calculated the average value of organic carbon SOC1 for a depth of 0-30 cm for each soil type. Because the erosion of the soils is poor, we obtained slightly higher values than in other methods of calculating relative carbon losses (RL). They are 30,1% for Chernozem and 37,3% for Phaeozem. However, the order of magnitude of the sequestration potential in all these methods of evaluation is close.

There is another important underestimated aspect in the assessment of the soil potential for carbon sequestration, when using equilibrium level of carbon content in the soils of placors as an SOC0. Sloping soils, of which more than 40% are in Ukraine, differ from plakor soils in the course of soil-forming processes and, accordingly, in the ability to accumulate organic carbon. In addition, most of the sloping soils are eroded to some degree, which also affects the intensity of carbon sequestration.

In Ukraine, soil-forming conditions on slopes, as a rule, are more arid (xeromorphism) than on placors. Thus, many sloping soils are xeromorphic, i.e. formed in relatively arid conditions. According to the laws of humus profile of soil formation in Ukraine conditions (Polupan et al., 2008), xeromorphic soils have a reduced profile and lower potential of humus content. Therefore, they have lower carbon sequestration potential compared to modal soils with the same degree of dehumification .

Soil erosion affects SOCseq in the opposite way. The greater the degree of soil erosion, the more carbon it is able to potentially accumulate. It is clear that for this reason we must stop erosion processes.

Considering the opposite effects of erosion and xeromorphism when estimating the potential for soil sequestration, we propose to use empirical models of the dependence of SOC content in the arable layer on the parameters characterizing the heterogeneity of sloping soils.

Using the geoinformation relief analysis, the authors developed a method of modeling the potential humus content in chernozem soils of slopes the authors have analyzed a large sample of undegraded chernozem soils of forest-steppe and steppe of Ukraine, and successfully used it to assess slope erosion (Achasov et al., 2019a, 2019b). The same approach, i.e. modeling of the potential carbon content in the soil depending on the spatial heterogeneity of hydrothermal conditions and particle size distribution, is the most promising for the spatial assessment of carbon sequestration potential at the level of individual farms. Our assessment of the chernozem sequestration potential, typical of the Lyubotyn research testing ground, also gave average values of PSOCseq values of about 36 t/ha. However, the advantage of the method of geoinformation modeling is in the possibility of obtaining not point, but continuous estimates of SOCseq, taking into account the spatial heterogeneity of humus accumulation conditions.

Therefore, the authors propose four possible ways to assess the potential of soil for SECseq carbon sequestration:

1. By estimating the difference between historically known data and the results of modern soil and agrochemical surveys. As our research has shown, such estimates give results close to those of real surveys of virgin soils. Therefore, they are quite acceptable for estimating the contribution of carbon sequestration to total emission reductions at the state level.

2. By assessing the difference between arable soils and virgin soil analogues. The method has significant limitations, as there are almost no fertile virgin soils left on the plateaus in Ukraine. Fallow lands cannot be a full-fledged analogue of virgin soil because they are usually partially restored soil that has not reached equilibrium.

3. By determining the theoretically possible level of carbon accumulation in soils at the level of the subtype of the calculated coefficients of dependence of humus accumulation on the content of physical clay (CRAH).

4. By estimating a theoretically possible level of carbon accumulation based on empirical models. In contrast to the first two methods, this method will give slightly reduced values of the sequestration potential, as empirical models use the parameters of arable soils, already dehumified relative to virgin analogues. This approach will lead to more realistic values of sequestration, if used in intensive agricultural production in compliance with technological requirements for the preservation of organic matter.

Simulation of carbon sequestration process is also possible by using mathematical models of humus accumulation, for example RothC (Coleman and Jenkinson, 2014; Shirato, 2020). However, this model needs verification and adaptation to the conditions of Ukraine. We do not know what the upper limit of carbon accumulation is. Moreover, the course of simulated sequestration rigidly relates to climatic parameters and quantity of coming organic residues in conditions of real farms are not always possible to predict.

4 CONCLUSIONS

In order to achieve carbon neutrality of the economy, it is necessary to focus efforts on the reproduction of humus content in the soils of agricultural lands. Dehumified over the long history of agricultural use, Ukraine's soil can now be a huge reservoir for sequestration of organic carbon. According to rough estimates, Ukraine's arable land alone is potentially capable of absorbing 757,7 million tons or 2,78 billion tons of CO2eq of carbon, which is 7,8 times higher than projected annual emissions for Ukraine's entire economy according to NDCs until 2050 (Ministry of Ecology and Natural Resources of Ukraine, 2021).

The authors propose four ways to establish the potential for sequestration of organic carbon in the soils of Ukraine. We can use each of them at a certain level of formation and implementation of the ESCCASU30. In particular, using the first method (according to agrochemical surveys and archival data from 1882), we recommended to assess the general and regional potential of carbon sequestration.

The second method (virgin standards) has limited application due to the lack of standards for all soils of Ukraine, but can be used locally if there is a standard available. It is advisable to use the third method (using RAC cofficient) to design specific measures at the level of administrative districts and communities. To implement the developed measures in specific fields and to audit sequestration for the introduction of carbon certificates, the authors recommend to use the fourth method (geoinformation analysis of the terrain).

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