Soil Organic Carbon Dynamics in Response to Tillage Practices in the Steppe Zone of Southern Russia

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Abstract: Soil organic carbon (SOC) content is a vital indicator for soil health. The use of moldboard (traditional) plowing for many years had led to a prominent decline in the SOC and soil organic matter (SOM) in Southern Russia. Application of no-tillage (NT) is a sustainable alternative to conventional tillage (CT) as it offers an advantage for SOC store. The aim of the study was to assess soil organic carbon dynamics in response to tillage practices in the steppe zone of Southern Russia. The conservation of SOC under different tillage systems (CT and NT) was evaluated in comparison with the soils of the virgin soils (VS) in three different regions of the steppe zone of the Lower Don region (Southern of the European part of Russia). The SOC content under the conditions of CT was significantly lower than that in the VS and demonstrated an inclining trend when using NT technology. We estimate that the transition to NT over an area of 5.5 million hectares will lead to a significant reduction of carbon emissions into the atmosphere (by ~39 × 10^9 g/year), thereby SOC deposition will be (~5.1 × 10^12 g C) and high economic advantages will be reaped (with cost savings of up to 27%) in the Rostov region of Russia.

Keywords: soil organic carbon; conventional tillage; no-tillage; virgin soil; yield; carbon conservation

1. Introduction

Soil health and fertility are closely related to the soil organic carbon (SOC) content [1–4]. The content of SOC depends on the quantity and quality of soil organic matter (SOM) (plant litter), which enters the soil at a certain rate of mineralization. Mineralization can be controlled by various processes that protect the SOC content from decomposition [5,6]. In the past decades, SOC content in agricultural soils has decreased significantly. This is primarily due to the irrational use of hazardous pesticides. Soil is one of the main sources of CO₂ emissions into the atmosphere, surpassing other sources [7–10]. Therefore, even the smallest change in the amount of soil CO₂ emissions can cause a significant annual carbon sink into the atmosphere. The Paris Climate Agreement was held within the framework of the 21st UN Conference and the Framework Convention on Climate Change in Paris (COP21) [11]. According to the agreement, in order to achieve a reduction in the ambient temperature by 2 °C, it is necessary to limit annual CO₂ emissions to 9.8 Gt (9.8 × 10^15 g) C. Annual greenhouse gas emissions are estimated at 8.9 Gt (8.9 × 10^15 g) C and the global estimate of soil carbon reserves at a depth of 2 m is estimated at 2400 × 10^15 g C [12]. Carbon emissions and total SOC reserves (8.9/2400) result in a carbon content of 0.4–4% (0.4–4 ppm). Within the framework of COP21, an agreement was drawn up with “4 ppm”. The goal is to increase the global SOM stocks by 0.4% annually to offset global greenhouse gas emissions. It is possible to bring the carbon content to the desired levels through the employment of bio-rational and sustainable soil treatment technologies viz. crop rotations,
biomass, and tillage systems (mini till, no-till, etc.). According to V. Stolbovoy et al. (2018), the accumulation of organic carbon by deposits (0.8–1.2 × 10^{12} g C), may lead to accumulation by arable and pasture soils to 2.4 × 10^{12} g C [13,14].

Dehumification is one of the crucial processes required for SOC accumulation. Generally, it is accompanied by the deterioration of soil properties, as well as the decrease in overall fertility. With intensive use of agricultural lands, there is an alteration in the carbon balance in the soil along with an acceleration of the mineralization of SOM [15–21]. For the improvement of the soil’s health and quality, recycling of the stock of organic matter is required [22–25].

One of the most important tools for carbon deposition in the soil is the use of zero-till technology (no-tillage). Previous reports demonstrated improved binding of SOC in the NT technology rather than the conventional tillage (CT), even though NT is an important strategy for reducing anthropogenic CO₂ emissions [26–28]. In the United States, the use of NT led to the increase in SOC content from 0.27 to 0.57 Mg C/ha/year [29–32]. While in Europe, the SOC increased up to 0.85 Mg C/ha/year, respectively [33]. Finally, the primary objective of the current study is to assess the effect of different tillage systems on SOC conservation in the steppe zone of Southern Russia.

2. Materials and Methods

2.1. Study Area

The objects of research were the fertile fields of the steppe zone of several regions of Southern Russia, the soils of which were treated with CT and NT, as well as virgin soils (VS). A map of the location of the sampling points of soils and crops grown over the years of the study is shown in Figure 1. The main crops for all the regions studied included winter wheat, barley, sunflower, and corn (Table 1). The fields in region no. 1, after many years of using CT, have been processed over the past 10 years using NT technology. The area of this plot exceeds 5.5 thousand hectares. Here, 30 fields with different processing technologies were compared in pairs: 15 fields with NT and 15 fields with CT. Fields with different processing were located at 50–100 m from each other. The depth of sampling of soil samples was 0–10 sm.

Figure 1. Schematic map of the location of soil sampling sites: (A) Map of Europe with the location of sampling sites from 3 regions; (B) Location of sampling in Rostov region: Region 1-Haplic Chernozem Calcic; Region 2-Haplic Chernozem Pachic; Region 3-Calcic Chernozem.
Table 1. Characteristics of soil sampling sites.

| Point No. | Agricultural Crop       | 1 Year | 2 Year | 3 Year |
|-----------|-------------------------|--------|--------|--------|
|           | Haplic Chernozem Calcic (Region no. 1) |        |        |        |
| 1         | NT 1                    | Linum  | Wheat  | Pea    |
| 2         | CT 1                    | Wheat  | Wheat  | Barley |
| 3         | NT 2                    | Linum  | Wheat  | Sunflower |
| 4         | CT 2                    | Wheat  | Wheat  | Barley |
| 5         | NT 4                    | Coriánđr | Wheat | Sunflower |
| 6         | CT 4                    | barley | Wheat  | Barley |
| 7         | NT 9                    | Sunflower | Wheat | Mustard |
| 8         | CT 9                    | Sunflower | Wheat | Pea    |
|           | Haplic Chernozem Pachic (Region no. 2) |        |        |        |
| 9         | NT                      | Wheat  | Wheat  | Wheat  |
| 10        | CT                      | Wheat  | Wheat  | Wheat  |
|           | Calcic Chernozem (Region no. 3) |        |        |        |
| 11        | NT 1                    | Sunflower | Sunflower | Sunflower |
| 12        | NT 2                    | Corn   | Corn   | Corn   |
| 13        | NT 3                    | Pea    | Pea    | Pea    |
| 14        | NT 4                    | Wheat  | Wheat  | Wheat  |
| 15        | CT                      | Wheat  | Wheat  | Wheat  |

Here, in 7 field crop rotations, grain crops (winter wheat and barley)—49%, corn for grain—10%, sunflower, sweet clover, alfalfa, saalfoin, vetch—10%, grain legumes (chickpeas, lentils, peas)—8%, winter cruciferous crops (camelina, rapeseed, mustard)—6.5%, coriander—6%, flax—4%, safflower—2.5%, buckwheat—2.0%, and perennial herbs—2% were cultivated. Sowing in case of NT is carried out using the following machines: tractor Buhler Versatile 2375 + Great Plains NTA 3510 (10.7 m) and Case Magnum 315 + Great Plains NTA 3510 (10.7 m), all crops were sown with a row spacing of 19.1 cm. When using NT, the fuel consumption was 26 L/ha, while the fuel consumption with the conventional technology using dump plowing was 74.1 L/ha [34–36].

Region no. 2 (soil type Haplic Chernozem Pachic) is an area where minimum tillage has been used since the year 2000, and direct seeding has been used since 2008. In the production dropping of winter wheat, 14 full-profile sections were laid: 6 in the fields using NT (grain seeder NT Semeato TDNG-420 (Brazil); 5 minimum tillage to a depth of 10–12 cm (heavy disc harrow (BDT-3)); 3 moldboard plowing to a depth of 25–27 cm (four-furrow mounted plow (PLN-4-35)). For comparison, soil samples were taken from four full-profile sections on VS. Several soil samples were taken from soil horizons and then combined into a mixed sample.

The experimental fields with Calcic Chernozem (region no. 3) were occupied by various crops (sunflower, corn, peas, winter wheat), cultivated using NT technology for the past 7 years.

Soil sampling from regions no. 1, 2, and 3 was carried out during the growing season (from March to October) in a 3–6-fold analytical repetition.

The use of different crops (linum, wheat, coriander, barley, sunflower, mustard, pea) on Haplic Chernozem in comparison with Haplic Chernozem Pachic and Calcic Chernozem was due to the difference in crop rotation. The variety of crops determines the effect of root exudates on the microbial community structure and the content of trace elements in the soil [37].

Strategic management of crop residues is highly essential for improving the soil quality for sustainable agriculture [38,39]. The introduction of crop residues led to an increase in SOC, micro-nutrient availability, improved soil physical properties (aggregate weight, soil moisture infiltration, etc.), and most importantly, improved crop yield [40]. Residue
application can improve soil quality and yield in cereal production systems in the semi-arid steppe zone of Southern Russia.

2.2. Climate

The amount of atmospheric precipitation is a determining factor in the development of the processes of mineralization and humification of SOC. The amount of precipitation in regions 1–3 is shown in Table 2. The highest amount of precipitation during the growing season in regions 1 and 2 was between 260–300 mm.

| No | Type of Soil             | TSUM | TWIN | WW  | NF      |
|----|--------------------------|------|------|------|---------|
| 1  | Haplic Chernozem Calcic  | +22–+23 | −6−−9 | 260–300 | 165–175 |
| 2  | Haplic Chernozem Pachic  | +22–+23 | −4−−5 | 270–300 | 180–190 |
| 3  | Calcic Chernozem         | +23–+24 | −5−−7 | 250–280 | 170–180 |

Table 2. Average annual rainfall and soil temperature.

Note: TSUM-Average temperature in July (°C); TWIN-Average temperature in January (°C); WW-Precipitation during the growing season (mm); NF-Duration of the frost-free period (days).

While in region 3, the amount of precipitation was 10% less than in regions 1 and 2. This is due to lower air temperature values in January for Haplic Chernozem Calcic (region no. 1) and in July for Haplic Chernozem Calcic (region no. 2) and Haplic Chernozem Pachic (region no. 3). In region 3, the average air temperature was 1–2 °C higher than in both the other regions. The yield of crops is directly affected by the length of the days of the frost-free period. The shortest frost-free period of 165–175 days was monitored in the region no. 1, while the longest frost-free period was observed in region no. 2 for 180–190 days.

2.3. Soil Sampling and Organic Carbon Analysis

For all 3 regions under study, hundreds of samples from more than 40 fields were analyzed in a profile with a 3 to 5-fold analytical repetition over 5 years. After sampling, soil samples were air-dried in a ventilated room; organic residues were collected and sifted through a 0.25 mm sieve. SOC content was determined following the method of Turin and Nikitin (1972), through wet oxidation of organic matter with 0.4 mol·L⁻¹ K₂Cr₂O₇ in sulfuric medium and external heating [41]. The SOC was calculated using Equation (1):

\[
SOC = \frac{A}{m} \times 100
\]  

(1)

where, SOC: soil organic content (%); A: content of organic carbone (mg); m: mass of the soil sample (mg).

Samples of virgin soils (VS) were taken along the profile (0–90 cm). With conventional tillage (CT) and no till (NT), soil sampling was carried out from a depth of 0–30 cm.

The reserves of organic matter in each soil layer were calculated considering the SOC_res content using Equation (2):

\[
SOC_{\text{res.}} = SOC_{\text{aver}} \times d \times p
\]

(2)

where, SOC_{res.}: reserves of soil organic content (10³ kg·ha⁻¹); SOC_{aver}: average content of soil organic content (%); d: depth of the soil layer (cm); p: soil density (g/cm³).

SOC_{en.} Is calculated according to Equation (3) [42]:

\[
SOC_{\text{en.}} = SOC_{\text{res.}} \times 517.2
\]

(3)

where, SOC_{en.}: energy content of organic matter (MJ·ha⁻¹); SOC_{res.}: reserves of organic matter (10³ kg·ha⁻¹).
2.4. Statistical Analysis

Variation statistics (mean values, dispersion) were determined, reliability of different samples was established using dispersion analysis (Student’s t-test), and the correlation analysis (Pearson correlation coefficient) was performed. Statistical data processing was carried out using Statistica 12.0 and Python 3.6.5 Matplotlib package.

3. Results

3.1. Content of SOC in Virgin Soils

The SOC content in the VS served as a reference for each soil type. The SOC content of VS for regions 1 and 3 was consistent with previously reported data [43,44]. For region 2, VS near the sampling site for NT and CT was accepted and analyzed as a reference. The SOC content in VS from the 0–30 cm layer of soils in regions 1–3 is shown in Figure 2.

![Figure 2](image_url)

**Figure 2.** Change in SOC (% content) in VS of different soil types (A–C).

The VS of region 1 had a high SOC content in the upper layer of the soil of 4.6%, which showed a gradual decrease in the SOC content 0.9% at a depth of up to 70 cm. In regions 2 and 3, the SOC content in the upper layer was 26% lower than in the upper layer of region no. 1. The high SOC content in the VS of region no. 1 was associated with the humification intensity of plant litter (maybe “waste” is a better term). Dryness in the subzone area (the Western Black Sea steppes) was observed between the periods of late summer and early autumn. However, the moisture was found to be sufficient for the remainder of the growing season. Accordingly, the degree of aridity for the aforementioned areas was marked as the lowest. The SOC humification process under such climatic conditions were decisively more intense and productive.

3.2. Changes in SOC Content in Conventional Tillage versus Virgin Soils

As a result of the long-term use of CT, SOC content in soils is significantly reduced compared to VS. Interestingly, the process of humification and mineralization of SOM in VS are balanced, hence, the soil’s humus state is stabilized. As a consequence of many years of traditional soil treatment, the fine balance between humification and mineralization is greatly disturbed, the air access to the soil has increased, and finally, the oxidation of SOM has increased. Additionally, the microbiological activity in the soil, including the activity of
carbon compounds transformation, was furtherly reduced. When comparing CT with VS for the content, reserves, and energy of SOC accumulation, the following regularities were established (Table 3).

Table 3. Content reserves and energy content of SOC in the topsoil (0–30 cm) of regions no. 1–3 (the numerator represents the indicators for CT, in the denominator-VS).

| No | Type of Soil            | SOC_{aver} | SOC_{res.} | SOC_{en} |
|----|-------------------------|------------|------------|----------|
|    |                         | %          | 10^{3} kg ha⁻¹ | MJ·ha⁻¹  |
| 1  | Haplic Chernozem Calcic | 1.9 ± 0.5  | 83.6 ± 1.4  | 43.2 ± 3.7 |
|    |                         | 2.4 ± 0.6  | 131.2 ± 2.4 | 67.8 ± 1.4 |
| 2  | Haplic Chernozem Pachic | 3.4 ± 0.7  | 75.6 ± 4.1  | 39.1 ± 1.8 |
|    |                         | 4.6 ± 1.1  | 120.5 ± 5.2 | 62.3 ± 3.9 |
| 3  | Calcic Chernozem        | 1.8 ± 0.2  | 23.7 ± 2.8  | 12.2 ± 1.2 |
|    |                         | 2.4 ± 0.1  | 31.4 ± 3.9  | 16.2 ± 1.1 |

Note, SOC_{aver}: average of soil organic content, %; SOC_{res}: reserves of soil organic content, 10^{3} kg per-ha; SOC_{en}: energy content of soil organic content, Mega Joule per-ha.

During soil treatment, the SOC content in region no. 2 decreased by 26% and in region no. 3 by 25%, relative to VS. Differences in the influence of processing technologies in different types of soils were revealed. For the SOC reserves in the 0–30 cm layer, there were also significant differences between CT and VS for the region no. 3, of 24%. The SOC content in the region no. 3 was 47% lower than for other sites. Since this type of soil is formed under conditions of moisture deficiency (Table 2), the moisture content in Calcic Chernozem was found be below to reduced precipitation in the growing season-250–280 mm. Sufficient soil moisture content intensifies the mineralization and humification process of SOM. Soil samples varied significantly in the energy of SOC when compared with VS. The energy in the SOC in the case of CT Haplic Chernozem Calcic and Haplic Chernozem Pachic is 56 and 59%, which is relatively lower than that of VS. Calcic Chernozem had the lowest energy loss in terms of SOC content, i.e., 32% lower than VS. Therefore, in the traditional treatment of Calcic Chernozem, few losses of reserves and energy of the SOC content were observed versus other soils with higher SOC content.

3.3. Comparison of the SOC Content and Reserves in NT versus CT

With CT, the agronomic transformation of the soil leads to SOC content reduction. While the NT technology prevents the deep plowing of the soil, it reduces the oxidation rate of the SOM. Consequently, it consumes less fuel, implying lesser CO₂ emissions into the atmosphere. The change in the SOC content in regions 1–3, in the case of CT and NT, is shown in Figure 3. The SOC content in region 1 in the case of using NT and CT varies in the range of 2.4 and 2.2%, which is less than VS by 32 and 37%, respectively. In region no. 2, the difference between NT, CT and VS was 15 and 26%, respectively. While for region no. 3, a lower SOC content was observed compared to VS, i.e., 13 and 29% in the case of NT and CT, respectively. The stability of the SOC content was evaluated concerning SOC content in VS (Figure 4). For Haplic Chernozem Calcic (region no. 1), any type of regular mechanical action on the soil (versus VS) reduced the humus content by 32–37%.

The CT in region no. 3 had a significant negative impact on the SOC content (29% lower) in comparison to the VS. However, the SOC content in the Calcic Chernozem soil was the most stable in case NT. Interestingly, the losses were only 13%, which was less than 2 and 19% in the soils of regions no. 2 and 1, respectively.
Figure 3. Comparative analysis of the SOC content in the upper soil layer during NT and CT versus VS (%).

The CT in region no. 3 had a significant negative impact on the SOC content (29% lower) in comparison to the VS. However, the SOC content in the Calcic Chernozem soil was the most stable in case NT. Interestingly, the losses were only 13%, which was less than 2 and 19% in the soils of regions no. 2 and 1, respectively.

Figure 4. Comparative analysis of the stability of SOC content in NT and CT values expressed as % of VS.

Under the anthropogenic load caused by prolonged plowing, the environmental condition was altered (i.e., change in vegetation cover, increase in solar insolation, change in water reserves in the soil, decrease in fertilizer consumption, etc.) along with an increase in the hydrophilic components of SOC [28,45,46]. Empirically, when the amphiphilic neutral part of SOC decreases, the hydrophilic component of SOC increases, which is primarily responsible for the growth of “young” (mobile) forms of humus [47,48]. Cover crops and complex crop rotations combined with NT can capture more carbon, increasing the resilience and the ecosystem functions of soils, especially in soils below saturation carbon levels [49].
3.4. Impact of NT Technology on CO2 Sequestration

Russia accounts for about 23–28% of the total annual global CO2 emissions [50, 51], since Russia ranks third in the world in terms of arable land area. Additionally, almost a fifth of the world’s soil carbon reserves are concentrated in the soil cover of Russia [52]. Currently, the carbon balance of the Russian soil is positive and amounts to about 76 ± 32 million tons C, which is 11% of the carbon volume according to the national goal of the initiative “4 ppm” [14, 53]. NT technology has had a positive impact on the ecosystem functions of the soil, including reduction of soil dehumidification in the order VS > CT > NT; carbon conservation by depositing it in the soil; increasing the profitability of agricultural production. The number of technological operations during NT cultivation of crops is significantly reduced. When cultivating crops using NT technology, fuel consumption and the use of machinery are also minimized. The reduction in carbon emissions during transportation with NT is 36% lower than with CT (27 L/ha for NT and 70 L/ha for CT). At the same time, saving 46 L of fuel per hectare. When calculated for the entire region, results show a reduction in CO2 sequestration by $39 \times 10^9$ g C/year (Figure 5).

![Figure 5. Environmental Consequences of NT technologies in comparison to CT.](image)

The transition to the widespread use of NT technology in the Rostov region of Russia (area of 5.7 million/ha) alone can contribute to an increase in the SOC content by 0.3% in a layer of 0–30 cm. This, considering that there is 5.7 million/ha of arable land in this region, can lead to the deposition of $5.14 \times 10^{12}$ g of carbon. Along with fuel-use reduction, this will contribute to significant sequestration of atmospheric carbon. The soil protection and ecological effects of NT use in the south of Russia are being simultaneously accompanied by an increase in the economic efficiency by at least 21–27% in the winter wheat and sunflower cultivation.

4. Discussion

The use of NT in Southern Russia will restore soil health by reducing erosion and increasing the biodiversity of the soil [19, 36, 54–56]. The long-term use of NT will lead to preservation and restoration of soil fertility and soil health through the deposition and sequestration of carbon in humus along with the reduction in fuel use. The application of NT is more sustainable as it helps in sequestering CO2 emissions into the atmosphere [13, 51, 57].

The process of preserving carbon in the soil is influenced by the maintenance of moisture and enzymatic activity of the soil, which indirectly reflect the state of soil fertility [34, 35, 58, 59]. The biogeochemical models are also promising when considering spatiotemporal variability of the fertility of the soil in relation to soil humidity [60]. The introduction of NT in soil treatment affects the growth of weed communities (density, species richness, and composition) in winter wheat [61]. Weed density and species richness
before weeding were greatest in CT and lowest in NT. The potential benefits of periodic plowing depend on the density and composition of seeds sown from weeds, which must be assessed before tillage is performed. The long-term advantages of NT can significantly exceed the short-term yield increase associated with CT.

NT shows the role of the precursor crop in changing the permanganate oxidizable organic content during the season. Soil carbon conservation using NT is affected by soil moisture retention and crop residues [35]. Earlier reports demonstrate that the presence of a mulching layer not only leads to the accumulation and preservation of moisture, but also reduces the insolation of the soil surface and its temperature, improves structure, increases the biological activity of the soil, and provides resistance to erosive processes [19]. The mulching layer includes depending on crop rotation: winter wheat straw, stems and flax leaves, sunflower, etc. Each species of plant differs in its chemical composition, content of organic substances (cellulose, pentosans, hemicellulose, lignin), and ash elements (C, H, O, N, Ca, K, Si, P, Mg), which serve as sources of the formation of various complex humus substances [62]. Approximately, 1 ton of straw contains up to 470–480 kg of organic carbon, which is 3.5–4.0 times more than in manure. The remaining mulching layer on the field contributes to the preservation of moisture in the soil and the mineralization of organic residues. According to [63], with the constant entry of plant residues into the soil, there was also a tendency to increase the content of mobile carbon according to the conceptual model of the hierarchy of Eliott’s aggregates [64].

According to the estimates, the total organic carbon stock in a 1 m soil layer in Russia reaches 317.1 Pg (picogram), while the average organic carbon density in this layer for the whole of Russia is 19.2 kg C/m² [65]. Of this amount, 14.4 Pg. (or 0.90 kg C/m²) is stored in the upper soil horizon (0–10 cm). These figures were obtained by the authors based on the information on soil types, growing vegetation, and the degree of soil disturbance. As for the global distribution of carbon in the world, the carbon accumulation index has shifted towards the northern latitudes and temperate zones, with the total contribution equal to 96.4 ± 21.4 Pg C × year⁻¹ [66]. Soil properties are a strong factor for influencing the climate impact on respiration of soils. The vegetation class determines the contribution of autotrophic respiration to the total respiration of soils flux. The heterotrophic outflow of soil respiration in Russia is estimated at 3.2 Pg C year⁻¹ or 190 g C m⁻² year⁻¹, which is 9–20% higher than most previously published estimates [67]. Heterotrophic soil respiration will increase by an average of 12% by 2050 under the representative concentration pathway (RCP) 2.6 climate scenario and by 10% under the RCP6 scenario. Soil respiration in Russia may reach 3.5 Pg C year⁻¹ by 2050. By the end of this century, heterotrophic respiration may reach 3.6 Pg C year⁻¹ (+13%) and 4.3 Pg C year⁻¹ (+34%).

The assessment of soil cultivation influence on the amount and distribution of free organic matter, micro aggregates (unstable and stable under low-intensity ultrasonic treatment), and their components in the upper horizons of zonal soils of the center of the Russian Plain was carried out in one of the studies [68]. The authors reported that during plowing, the carbon content decreases in both unstable and stable micro aggregates. The loss of carbon in unstable microaggregates was ~24% and in stable microaggregates ~37% in relation to indigenous soils. The content of organic carbon (CLF_{oc} and organo-clay (Clay_{rd}) fractions in unstable microaggregates (CLF_{oc}/C_{Clay_{rd}}) differed little in the upper horizons of the main soil types: Albeluvisol (1.1), Phaeozem (0.8), and Chernozem (1.0). Surprisingly, when plowing, they decreased in the order Albeluvisol and Chernozem (0.6), closely followed by Phaeozem (0.5).

With the long-term take advantage of NT, the SOC content was found to be restored at a level close to the VS. Deep moldboard plowing reduces SOC and reduces overall soil quality and health. Based on these results, we conclude that the long-term use of NT (more than 10 years) on the territory of Southern Russia in the steppe zone for soils differing in their properties (pH, granulometric composition), types of crops, and the amount of precipitation preserves and restores the contents of SOM.
It is promising to study the accumulation of carbon in the soil because of the application of NT in comparison with CT over a long period (more than 10 years) to trace the rate and intensity of carbon accumulation, and to study a wider range of biological parameters, including enzymatic activity, the soil microbiome, and other biological indicators.

5. Conclusions

As a result of the assessment of SOC content in the soils in Southern Russia under different tillages, a relationship was established with the type of treatment (CT and NT) and agro-climatic conditions. In the upper soil layer, CT reduces the SOC content by 25–36% compared to VS. At the same time, the SOC reserves for different types of soils in case of CT verses to VS more than 8–25%. The take advantage of NT also leads to an increase in the content of SOC by 5–17% as compared to CT. The lowest dehumidification in different types of treatment was found for Chernozem Calcic of region no. 3. The take advantage of NT technology leads to the sequestration of CO$_2$ emissions into the atmosphere (by $39 \times 10^9$ g C/year), carbon deposition in soil humus (by $5.1 \times 10^{12}$ g C), and an increase in the profitability of cultivating major crops by 27%. The put-in places of NT in Southern Russia allow for sustainably increasing the content of SOC and maintaining the health and fertility of the soil.

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