The environmental feasibility of transitioning to no-tillage farming in Karakalpakstan

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Abstract. The aim of the research was to study the effect of no-till technology on soil parameters, in particular on humus content, reduction of soil salinity, structure and biological activity of the soil. The studies were conducted on medium loamy light gray soils of the northern districts of Karakalpakstan. The article presents the results of scientific and practical work on the use of no tillage on sowing sesame on salinized irrigated lands in the northern districts of Karakalpakstan. One of the main conditions of Conservation Agriculture is to ensure the most complete soil cover with plant residues. Therefore, it is recommended to cultivate crops that leave more stubble and straw, such as wheat, barley, oats, triticale, and rye, in the first year. Preserving stubble and straw is beneficial for the soil and the life of soil microorganisms. Plant residues, as they decompose, increase the content of soil organic matter, reduce the bulk density of the soil, improve the water-holding capacity of the soil, and, acting as mulch, help to preserve soil moisture and reduce evaporation, and therefore reduce the seasonal accumulation of salts, especially in the upper soil horizons. During two years using the no-tillage technology, soil indicators improved, soil biological activity in the soil increased, and seasonal accumulation of salts in the upper soil horizons decreased due to straw mulch. Qualitative soil assessment using the visual soil assessment method showed that over two years use of no-tillage, soil properties improved, including structure, compaction, from 17 to 22 points.

1 Introduction

In recent years, due to the decrease in the flow of the Amu Darya River, low water levels have been frequenting in Karakalpakstan. Hydrological drought associated with climate change is widespread in the region. Hydrological drought is particularly felt in the lower reaches of the Amu Darya River. In such years, the rural population, especially in the northern regions of Karakalpakstan, experiences great difficulties, since their main sources of

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livelihood are agricultural and livestock products. The local population and farmers understand that in the future, the river flow will steadily decrease, and they are puzzled about how to run their household and agriculture in such conditions.

The agricultural technologies currently used in agriculture in Karakalpakstan largely do not ensure the rational use of natural resources, expanded reproduction of soil productivity, ecological balance in the agrobiocenosis, which ultimately leads to the instability of farming in this extremely arid region. Conservation agriculture has recently attracted great interest from agricultural scientists and farmers as the most sustainable technology that ensures continuous reproduction of soil productivity.

Long-term intensive tillage has led to soil environment degradation, reduced fertility, difficulty in increasing maize yield, and low nitrogen (N) use efficiency in the Mollisol region of northeast China [1]. Organic no-till and strip-till systems have gained attention because of their reported capacity to enhance soil health and suppress annual weeds [2].

Low soil productivity, close occurrence of groundwater and soil salinization of Karakalpakstan require the choice of an alternative farming system that can ensure successful overcoming of salinization, restoration of lost soil productivity, thereby increasing the yield of agricultural crops. Conservation Agriculture, in particular no tillage (direct sowing without any soil cultivation) helps to restore soil fertility due to natural processes occurring in the soil. When using no tillage, the processes of deflation and soil erosion are completely eliminated due to the preservation of crop residues and straw on the soil surface. Straw and crop residues gradually decompose and enrich the soil with organic matter, which improves the vital activity of soil organisms, which are of no small importance in activating natural processes of soil formation. Zero-seeding of agricultural crops on permanent ridges and irrigation along permanent furrows protects the soil from excessive compaction of the soil on the ridges, significantly reduces water consumption for irrigation, reduces material and labor costs for cultivating agricultural crops, thereby making it possible to make a profit by reducing the cost of agricultural products.

Conservative tillage systems tested in the hilly area of the Transylvanian Plain (Romania), confirms the possibility of improving the biological, physical, chemical and technological properties of the soil. Conservative components include minimum tillage systems and surface incorporation of crop residues. The minimum tillage systems rebuild the soil structure (hydrostable macroagregate content increases up to 2.2% to 5.2%), improving the global drainage of soil which allows a rapid infiltration of water in soil. The result is a more productive soil, better protected against wind and water erosion and needing less fuel for preparing the germination bed [3].

Straw returning has been widely used in semi-arid and arid areas where scarcity of water resources due to its advantages of harvesting and maintaining soil moisture [4]. Excessive soil evaporation induced water loss resulting in drought stress is a significant yield-limiting factor in dry-land regions of China. These results of research of Hongkun Yang and coautors suggest that maize straw mulch combined with no-tillage can not only conserve soil moisture for wheat tillering but also activate the release of plant-available soil N and plant N acquisition for higher grain yield and water and nitrogen use efficiency [5].

In world practice, this technology has now become widely used, as it allows for high yields at lower costs and methods of soil cultivation. At the same time, agricultural crops are cultivated without any processing, by direct sowing, and irrigation is carried out strictly along the furrows. When performing technological operations, agricultural machinery passes only along the same track, that is, along the furrow, which protects the soil on the surface of the ridge from compaction. But, most importantly, the technology will enable the soil to restore lost fertility naturally by creating favourable conditions for the life of soil organisms.

Conservation and conventional tillage directly affect soil environment for crop production. Conservation tillage provides a layer of crop residue which increases soil fertility,

soil erosion, leaching of fertilizer, pesticides and herbicides into the ground water. Studies conducted in different climate zones showed that no-tillage resulted in acidification of surface layer when continued for several years compared to conventional tillage. Some study shows Conservation tillage enhance water infiltration rate and reduce moisture evaporation from soil, while some other study stated slower water infiltration rate in no tillage soil then on tilled. surface tillage and no tillage instead of conventional tillage are to control soil erosion, enhance crop performance, and use energy more efficiently. Decomposition of crop residues kept on the soil surface possibly release allele-chemicals which further strengthen the inhibitory effects on weed seed germination and early growth and development of weed plant. As with impact of tillage on root distribution, no-tillage causes greater and deeper water accumulation in the soil profile and greater root growth. Higher labor, animal or equipment requirement is a major drawback of conventional tillage. Conservational tillage allows elimination of several operations, depending on the conservation tillage systems used [6].

The article presents the results of scientific and practical work on the use of no tillage sowing of sesame on salinized irrigated lands in the northern regions of Karakalpakstan.

2 Methods

The experiment was carried out on irrigated lands in the Chimbay district of the Republic of Karakalpakstan.

In traditional sowing, the soil was processed to a depth of 25 cm, then harrowed and leveled shallowly. After these technological operations, sowing was carried out with the simultaneous introduction of mineral fertilizers using a planter for direct sowing. The seed placement depth was 5 cm, the fertilizer placement depth was 10 cm.

In no tillage, the soil is not processed, sowing is carried out on unprocessed soil using a direct seeding planter SA 11500 with disc coulters. Mineral fertilizers are applied simultaneously with sowing. Watering is carried out using a drip irrigation system.

Soil conditions (humidity, salinity, mechanical composition) were studied by conventional methods by laying soil pits, taking soil samples with subsequent laboratory testing. Protease activity in the soil was studied by the method proposed by E.I. Mishustin et al. A qualitative assessment of soil properties was carried out using the Visual Soil Assessment method developed by G. Shepherd (2000), adapted by J. Benites. The method allows for a visual assessment of the qualitative state of the soil structure, porosity, color, presence of worms, depth of the arable layer, and soil cover with plant residues.

3 Result and discussion

The climate of Karakalpakstan is characterized by sharp continentality and dry air, high temperatures in summer and severe cold winters. The soils of the irrigated zone of Karakalpakstan are meadow-alluvial, meadow-marsh and meadow-sandy light grey soils.

The humus content in the soil of the studied areas in the upper 10 cm soil horizon was only 0.58%, which corresponds to a low supply of humus in the soil, and in the 10-40 cm horizon this indicator fluctuates within 0.22-0.34%, which corresponds to a very low supply of humus in the soil. In areas with conventional soil cultivation, a noticeable decrease in the humus content is observed in the upper 10 cm horizon after two years (from the initial 0.58% to 0.47%), while in the lower 10-40 cm layer an increase in the humus content is observed (Fig. 1). Apparently, this was facilitated by ploughing with layer turnover.

Soil micro-organisms constitute a significant part of soil fertility and play a critical role in maintaining soil ecological functions. Micro-organisms also are key indicators for soil quality and productivity. No-tillage and mulching cultivation indirectly affect the

composition of soil microbial community by changing plant physiological characteristics and root exudates. The two agronomic practices can also improve soil environment by increasing the total amount of micro-organisms in the soil [7].

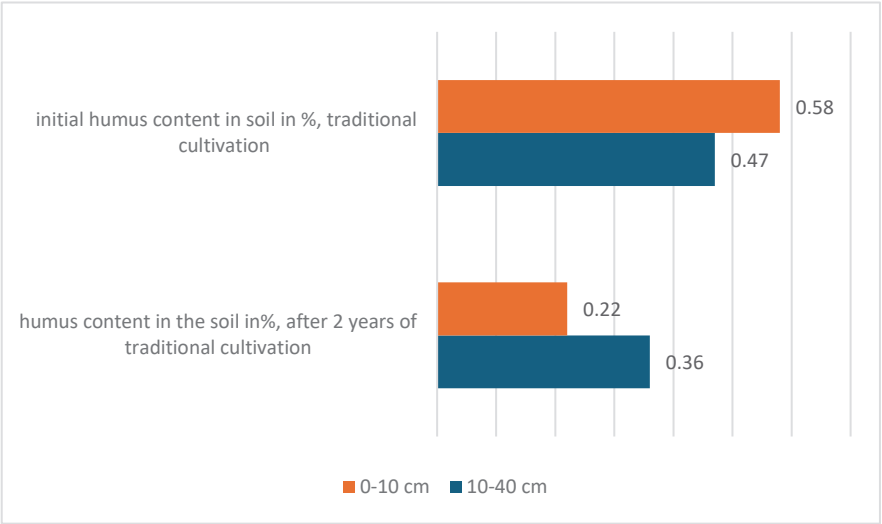

Fig. 1. Change in humus content during annual ploughing

In areas where conservation agriculture was used, an increase in humus content is observed, especially in the upper horizon, while a slight decrease in humus is observed in the lower 10-40 cm horizon (Fig. 2). The increase in organic residues in the field contributed to an increase in the biological (protease) activity of the soil in the field where no- tillage was used. Thus, our observations showed that the protease activity of the soil in the field where no- tillage was used for two years increased almost twofold.

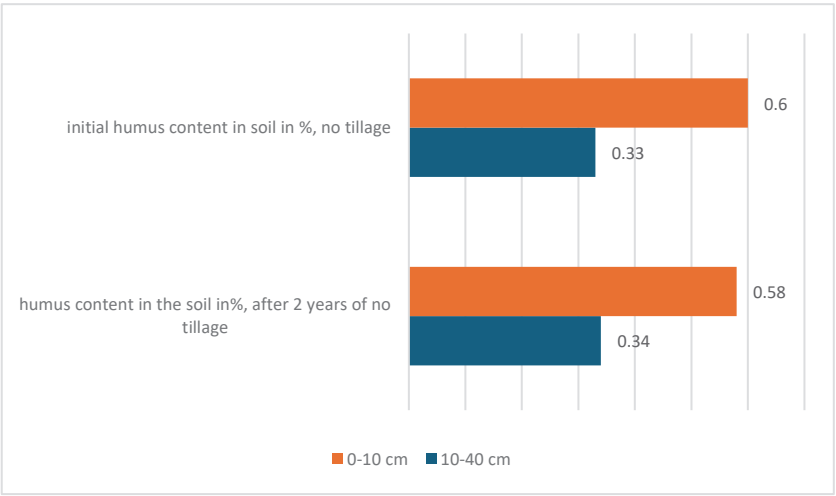

Fig. 2. Change in humus content in the soil as a result of two years of use of tillage

Thus, in the area where no tillage was used, the dry residue content averaged 0.2% (degree - non-saline), while in the area without mulch this figure was 0.8% (degree - slightly saline) (Fig. 3).

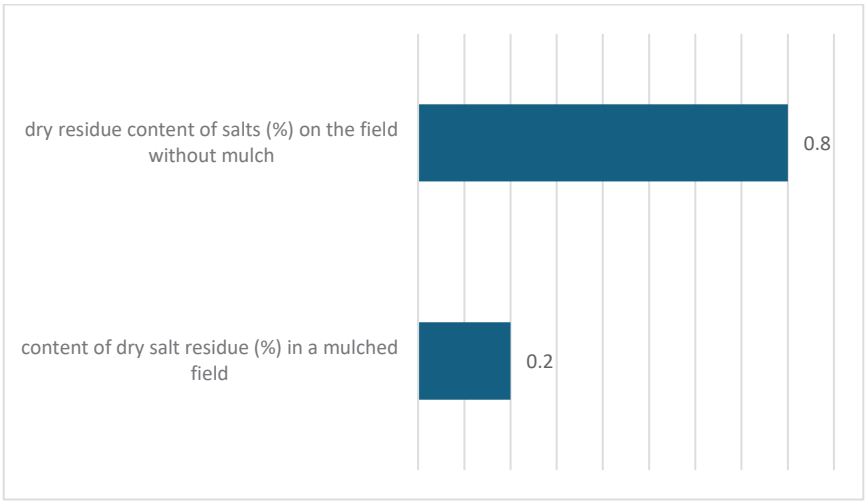

Fig. 3. Reduction of seasonal accumulation of salts under the influence of mulching

A qualitative assessment of the soils showed that two years of use of tillage led to an improvement in the soil properties, including structure, porosity, color, presence of worms, depth of the arable layer, from 17 points to 22 points. (Fig. 4).

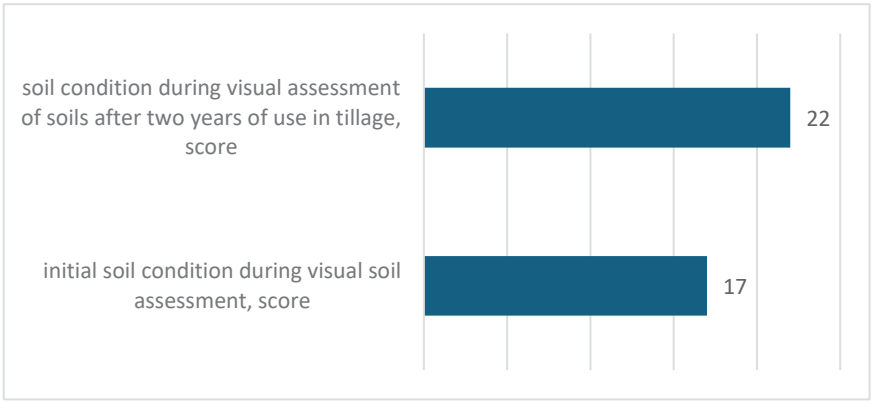

Fig. 4. Improvement of soil parameters using visual soil assessment method (VSA)

We have begun studying the potential of sesame cultivation using no tillage in the northern regions of Karakalpakstan. In the first year of research, encouraging results were obtained both in terms of yield and economic efficiency, such as, thanks to a significant reduction in mechanized work when growing forage crops using no tillage, diesel fuel costs were reduced by 72%, labour costs by 35% compared to traditional processing.

As is known, no tillage in the first years usually does not give high yields, since the yield increases as the fertile properties of the soil increase as a result of 4-5 years of continuous use of no tillage. Thus, the experience and practice of many countries of the world, where the use of no tillage is gaining momentum, show that the effectiveness of no tillage begins only when the soil restores its fertility due to the increase in soil organisms, which play an important role in the reproduction of soil fertility. Despite this, a significant reduction in the costs of cultivating crops with no tillage allows even in the first years to achieve a high level of profitability compared to conventional cultivation.

One of the main conditions of no tillage is to ensure the most complete soil cover with plant residues. Therefore, it is recommended to cultivate crops that leave more stubble and

straw, such as wheat, barley, oats, triticale, and rye, in the first year. Preserving stubble and straw is beneficial for the soil and the life of soil microorganisms. Plant residues, as they decompose, increase the content of soil organic matter, reduce the bulk density of the soil, improve the water-holding capacity of the soil, and, acting as mulch, help to preserve soil moisture and reduce evaporation, and therefore reduce the seasonal accumulation of salts, especially in the upper soil horizons. Our studies have found that when using no tillage, the biological activity of the soil increases, apparently due to an increase in plant residues left in the field, which, decomposing, will subsequently replenish the reserves of organic matter in the soil.

V.A. Kovda noted that monoculture, lack of crop rotation, refusal to use organic fertilizers lead to biological sterilization and dehumification of soils, which results in decreased productivity and reduced stability of yields. According to P. Patron and A. Skurtul, annual losses of humus from the arable soil layer as a result of its mineralization under irrigation conditions are about 760 kg per 1 ha. To compensate for the loss of soil humus, about 50 centners of dry organic material from post-harvest residues are required annually. As is known, the activity of soil organisms primarily depends on the supply or presence of organic matter in the soil. Therefore, the transition to no tillage is necessary primarily to ensure the preservation and sustainable increase of soil fertility.

The diversity and composition of the soil bacterial community in residue mulching soil were significantly different from those in residue removal soil after 10 years of no tillage in a black soil region of Northeastern China. Soil bacterial richness and diversity were improved after no tillage with 60% residue mulching, demonstrating potential to improve soil health, and this was the most suitable residue mulching quantity in the black soil area of Sanjiang Plain.

Four different tillage practices, namely, zero tillage (ZT), minimum tillage (MT), conventional tillage (CT), and deep tillage (DT), were studied in a randomized complete block (RCB) design with four replications. Tillage practices showed positive effects on soil properties and crop yields. After four cropping cycles, the highest OM accumulation, the maximum root mass density (0–15 cm soil depth), and the improved physical and chemical properties were recorded in the conservational tillage practices. The highest total N, P, K, and S in their available forms were recorded in zero tillage. All tillage practices showed similar yield after four years of cropping cycles. Therefore, we conclude that zero tillage with 20% residue retention was found to be suitable for soil health and achieving optimum yield under the cropping system in Grey Terrace soil (Aeric Albaquept) [9].

CO2 emissions are one of the greenhouse gases that significantly contribute to climate change. The use of reduced soil tillage practices could contribute to the mitigation of CO2 emissions from soils under ongoing climate change conditions. The use of reduced and no-tillage practices in the summer period, the most critical period for CO2 and for water loss from soils, would contribute to the mitigation of CO2 emissions that is required by the European Union. [10]. The results of investigations Aušra Sinkevičienė, Alfredas Sinkevičius,Vaclovas Bogužas,Vaida Steponavičienė showed that reduced tillage systems, compared to conventional deep plowing, resulted in higher soil moisture retention and lower CO2 emissions, showing potential for sustainable agroecosystem management.

Based on the above, it can be concluded that using no tillage, in the conditions of Karakalpakstan, it is possible to cultivate agricultural crops with lower costs and, as a result, reduce the cost of manufactured products. In addition, the environmental feasibility of switching to no tillage lies in the restoration of soil fertility due to naturally occurring soil formation processes and in the binding of CO_2 in the soil due to the rejection of ploughing.

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