Short Crop Rotation under No-Till Improves Crop Productivity and Soil Quality in Salt Affected Areas

Article *in* Journal of Agronomy · December 2023

DOI: 10.3390/agronomy13122974

8 authors, including:

Aziz Israilovich Nurbekov
Tashkent State Agrarian University

Botir Khaitov
International Centre for Biosaline Agriculture

agronomy

MDPI

Article

Short Crop Rotation under No-Till Improves Crop Productivity and Soil Quality in Salt Affected Areas

Aziz Nurbekov [1,2,*], Muhammadjon Kosimov [1], Makhmud Shaumarov [1], Botir Khaitov [3,*], Dilrabo Qodirova [2], Husniddin Mardonov [2] and Zulfiya Yuldasheva [2]

1 Food and Agriculture Organization (FAO) Regional Office in Uzbekistan, 2, University Str., Kibray District, Tashkent 100140, Uzbekistan; muhammadjon.kosimov@fao.org (M.K.); makhmud.shaumarov@fao.org (M.S.)
2 Faculty of Agrobiology, Tashkent State Agrarian University, Tashkent 100140, Uzbekistan
3 International Center for Biosaline Agriculture (ICBA), Regional Office for Central Asia and the South Caucasus, Tashkent 100084, Uzbekistan
* Correspondence: aziz.nurbekov@fao.org (A.N.); b.khaitov@biosaline.org.ae (B.K.)

Abstract: Soil productivity and crop yield were examined in response to legume-based short crop rotation under conventional (CT) and no-till (NT) tillage practices in saline meadow-alluvial soils of the arid region in Bukhara, Uzbekistan. Compared with the CT treatment, crop yield was consistently higher under NT, i.e., winter wheat 9.63%, millet 9.9%, chickpea 3.8%, and maize 10.7% at the first experiment cycle during 2019–2021. A further crop productivity increase was observed at the second experiment cycle during 2021–2023 under NT when compared to CT, i.e., winter wheat 17.7%, millet 31.2%, chickpea 19.6%, and maize 19.1%. An increase in total phyto residue by 20.9% and root residue by 25% under NT compared to CT contributed to the improvement in soil structure and played a vital role in the sustained improvement of crop yields. In turn, the increased residue retention under NT facilitated soil porosity, structural stability, and water retention, thereby improving soil quality and organic matter content. Soil salinity more significantly decreased under NT than in CT, reducing salinity buildup by 18.9% at the 0–25 cm and 32.9% at the 75–100 cm soil profiles compared to CT. The total forms N and P were significantly increased under NT when compared to CT, while the efficiency of the applied crop rotation was essential. This study showed the essential role of the NT method with legume-based intensive cropping in the maintenance of soil health and crop yield, thereby touching on recent advances in agro-biotechnology and the sustainable land management of drylands.

Keywords: conventional tillage; no-till; crop yield; bulk density; structural stability; saline soil; arid region

Citation: Nurbekov, A.; Kosimov, M.; Shaumarov, M.; Khaitov, B.; Qodirova, D.; Mardonov, H.; Yuldasheva, Z. Short Crop Rotation under No-Till Improves Crop Productivity and Soil Quality in Salt Affected Areas. *Agronomy* **2023**, *13*, 2974. https://doi.org/10.3390/agronomy13122974

Academic Editors: Mariola Staniak, Ewa Szpunar-Krok and Małgorzata Szostek

Received: 27 September 2023
Revised: 12 October 2023
Accepted: 19 October 2023
Published: 1 December 2023

1. Introduction

Cotton was the main agricultural crop for Uzbekistan during the Soviet empire (1924–1991). As a result, this monoculture practice caused extreme soil and environmental degradation and the pollution of water resources and the environment. After the country's independence in 1991, the cotton area gradually decreased while the share of wheat production increased substantially to ensure food security in the region [1]. Population growth puts pressure on agricultural production, leading to intensified land usage along with extensive application of chemicals, i.e., fertilizers and pesticides, which has led to more environmental contamination [2].

Soil salinity and drought are the two most significant constraints that adversely affect the productivity of crops in dry areas like Uzbekistan [3]. The detrimental effects of soil salinity on plant growth and development are followed by reduced crop productivity, dysfunctional cropping systems, an imbalance in mineral nutrition, and specific ionic toxicity [4]. Therefore, it is essential to transition to climate-resilient food and feed crops and adopt innovative cropping systems and sustainable technologies that efficiently use available resources.

Proper land management strategies as a main driver of sustainable agriculture can be implemented to diversify cropping systems, enhance crop production, improve food security, and raise nutritional well-being in the long term [5,6]. In this regard, farmers' knowledge and qualifications are essential in managing efficient cropping systems and improving soil organic matter. Soil health should be perceived as a guarantee of sustainable agriculture and food security in changing climate conditions and natural resource depletion [7]. Expansion of agricultural lands is not an option in this region when water resource scarcity is high [8]. In this situation, crop diversification must be used sparingly, focusing on developing climate resilience in farming without harming the environment.

Tillage might have various impacts on the production system in the short and long terms since soil quality directly impacts plants' capacity to grow and build an appropriate root system to exploit water and nutrients. Therefore, the increase in soil physical structure and subsequent mineralization of N under conventional tillage increase crop production in the short term [9]. However, extended continuous cultivation tends to lower soil porosity through the mechanical breakdown of the structure and compaction of the topsoil [10]. On degraded soils, conventional tillage may lead to slight improvements in crop output in the short term; however, over the long term, it may be neutral or lead to yield reductions due to deterioration of soil structure. As explained in recent studies, continuous tillage lowers the amount of soil organic matter, causes soil erosion and subsoil compaction, and also releases more greenhouse gases [11].

In contrast, the no-till practice as a main component of conservation agriculture (CA) is essential in managing dry arid soils, which facilitates the buildup of SOM and soil nutrients. Long-term application of continuous no-till (NT) increases the stability and microporosity of degraded soils while increasing crop yields [12]. The actions of the soil biota, which flourish under NT, enhance nutrient cycling and soil microbial activity substantially. Significant tillage-induced structural improvements in degraded soils can start 3 to 5 years after NT set-up, and increased crop yields usually accompany it [13]. Despite the benefits of NT, this agrotechnology was not widely adopted by crop producers in arid zones, yet the effect of NT on crop yield and soil characteristics depends on climatic variables, crop rotation, and soil management strategies, and is thereby defined as site-specific [14]. In NT systems, the diversification and intensification of crop rotations is a new climate-smart strategy that attempts to enhance crop yield while lowering environmental impact [15].

Our hypothesis was that intensive legume-based short-term crop rotation under NT will improve soil quality in dryland agriculture, thus increasing crop yield in the short term. A key question is whether the short crop rotation system under the NT practice could offer a potential solution as a climate-resilient agriculture measure to achieve food security in the long term in degraded marginal regions. This study aimed to improve crop productivity and soil health using a short crop rotation system under a climate change impact scenario in harsh and saline environments.

2. Materials and Methods

2.1. Research Initiative

Since 2018, the Food and Agriculture Organization of the United Nations (FAO) has been implementing the regional project "Integrated natural resources management in drought-prone and salt-affected agricultural production landscapes in Central Asia and Turkey" (CACILM-2) funded by the Global Environment Facility and other donors. The project aims to scale up integrated natural resources management (INRM) practices that minimize pressures and negative impacts on natural resources, reduce risks and vulnerability, and enhance capacity of rural communities to cope with and adapt to drought and salinity.

One of the project's target countries is Uzbekistan, where land degradation, soil salinization, water scarcity, and climate change pose serious challenges for agricultural production and food security. The project has been working with the Ministry of Agriculture and other national partners to integrate resilience into policy, legal and institutional frameworks for INRM, as well as to provide incentives for climate-smart agriculture at national and sub-national levels.

The project's main objective is to help rural communities cope with or adapt to the effects of land degradation, soil salinization, water scarcity, and climate change, which threaten their livelihoods and food security. The project does this by promoting sustainable land management practices that minimize pressures and negative impacts on natural resources, reduce risks and vulnerability, and enhance resilience. The project also supports the implementation of the United Nations Convention to Combat Desertification (UNCCD) and its National Action Plans in the country.

This research work, conducted from 2018 to 2023 in the demonstration project territories of Bukhara Region in Uzbekistan, aims to enhance soil productivity in saline arable lands. By applying short-rotation schemes and conservation agriculture practices such as zero tillage, mulching and integrated pest management, this work provides scientific evidence and practical solutions for improving soil quality and crop yield in saline conditions.

2.2. Climate and Soil Characteristics

This research was conducted in saline meadow-alluvial soils of the Bukhara region in the southwest of Uzbekistan in the 2019–2022 growing seasons. This site lies in the central Kyzylkum desert, 206 m above sea level, with 39.46° N and 64.25° E geographical coordinates.

The harsh climate of this arid region is characterized by sharp climate variability with recurring periods of severe drought. This region has a total of 270–280 frost-free days, with an average annual evapotranspiration of up to 2000 mm. Annual rainfall ranges between 90 and 150 mm; however, the main part of this precipitation falls between January and April, before the start of the vegetation period. The year 2021 was drier during the study period with only 93.0 mm precipitation. The warmest period was July with 39 °C and the coldest temperature was 0 °C, recorded in January. Accordingly, the highest relative moisture was about 70% in January, while it reached the lowest point in July, ranging between 25 and 30%.

The texture of soils is heavy-textured sandy loam. The low precipitation and excessive evaporation caused a buildup of soluble salts, contributing to an increased salinity level in the soil. The soil salinity varied between 4.8 and 7.4 dS/m, and the pH index was 7.6, which is slightly alkaline. The humus content was 1.1%, relatively low in the soil surface and further decreased in the deepest horizons. The soil chemical structure consisted of total N 0.07%, P 0.14%, and K 0.8%, and in available forms NO_3 44.3 mg kg^{-1}, P_2O_5 13.5 mg kg^{-1}, and K_2O 120 mg kg^{-1} at the 0–30 cm depth of the soil (Figure 1).

2.3. Experiment Design

A field experiment was set up in Autumn, 2019 by planting winter wheat (*Triticum aestivum* L.)—Alekseevich variety. The next June millet (*Panicum miliaceum* L.) Saratovskaya-853 variety was planted, which was harvested in October 2020 and forage pea (*Pisum sativum* L.)—Vostok-84 variety—was the next crop in this short crop rotation system. The planted forage pea was harvested in May 2021 and maize (*Zea mays* L.)—NS-205 hybrid—occupied the experiment plot. After harvesting maize in September 2021, winter wheat was planted for the second cycle. Therefore, each short crop rotation cycle continued for two years and the experiment was conducted during the 2019–2021 and 2021–2023 growing seasons. A strip-plot design was used in an area of 1200 m^2 with a total of two experimental units (CT and NT) installed in three replications, each with an area of 100 m^2.

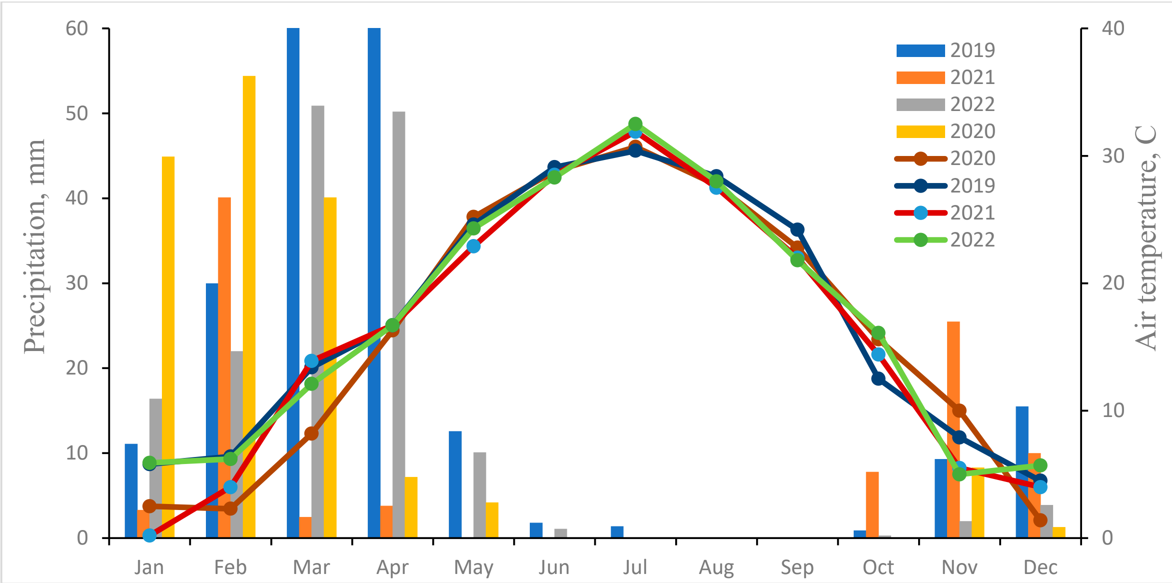

Figure 1. Weather conditions during the experiment years 2019–2023.

Salt leaching was conducted two times during the January–March period before the experiment was set up. During the vegetation period, surface furrow irrigation was applied 4 times with a norm of 1100–1200 m^3 hectare^{-1} based on crop water requirement. The following rates of mineral fertilizers were applied: $N_{220}P_{180}K_{60}$ kg ha^{-1} for winter wheat, $N_{150}P_{70}K_{30}$ kg ha^{-1} for millet, $N_{50}P_{25}K_{20}$ kg ha^{-1} for forage pea, and $N_{300}P_{180}K_{120}$ kg ha^{-1} for maize. Traditional furrow irrigation was conducted at a norm of 900–1000 m^3 for each hectare and 4–5 times during the vegetation period depending on crop water requirements, but the same norm was strictly applied to each plot of the experiment.

A digital recorder (L93-4, Hangzhou Logger Technology Co., Ltd., Hangzhou, China) was used to measure the soil's temperature. This device automatically records soil temperature at one-hour intervals during the whole growth period and was installed in the surface 20 cm soil profile of the planting row in each plot.

A Vence tudo SA 17600 seed planter was employed for seed planting in the NT plots. On the other hand, several agromashinaries were employed for CT, i.e., mouldboard plower, tiller, discing, rotavator, and leveling operations, which consumed a lot more resources and time. All other agronomic operations in vegetation periods such as weeding, cultivation, plant protection, and other measures were conducted similarly for all experiment plots according to local agronomic practices.

2.4. Chemical Content of Soil and Plant Samples

Soil samples were taken in sealable plastic bags at 4 suggested depths of 0–25, 25–50, 50–75, and 75–100 cm based on the envelop method from the experimental plots. The collected soil samples were air-dried for two weeks at room temperature, followed by grounding and sieving through a 2 mm mesh before chemical analysis. The standard methods developed by Ryan, Estefan, and Rashid [16] were used to determine soil physical (soil texture, bulk density, pH, EC parameters) and chemical characteristics (NPK, humus content). An amount of 10 mL of 50% perchloric acid was poured on 0.5 g soil samples placed in a tube, and, after shaking for a minute, 1 mL of concentrated sulfuric acid was added and the process was followed by decomposition by heating on a hot plate. Kjeldahl distillation, the vanadate method, and an inductively coupled plasma spectrophotometer were employed to analyze total N, P_2O_5, and K_2O, respectively. The Tyurin method was used to determine soil organic matter [17]. The standard core method was used to calculate soil bulk density (g cm^{-3}) in each soil layer.

2.5. Statistical Analyses

Using the CropSTAT software (Version 7.2.2007), analysis of variance (ANOVA) was performed on the collected data, which included crop yield, residue retention, soil nutrient content, and soil physical and chemical characteristics. The Tukey test was used to determine whether there was a trait difference at $p < 0.05$.

3. Results and Discussion

3.1. Crop Yield

A consistent increase in crop yield with significant differences ($p \leq 0.05$) under NT is associated with the proper land management of a short crop rotation system. At the first experiment cycle during 2019–2011, crop yield was consistently higher under NT as compared to CT, i.e., winter wheat 9.63%, millet 9.9%, chickpea 3.8%, and maize 10.7% (Table 1). A further crop productivity increase was observed at the second experiment cycle during 2021–2023 under NT when compared to CT, i.e., winter wheat 17.7%, millet 31.2%, chickpea 19.6%, and maize 19.1%.

Table 1. Crop yield (t ha^{-1}).

Experiment Cycles	Tillage	Winter Wheat	Millet	Forage Pea	Maize
2019–2021	CT	6.54 c	2.51 c	1.85 b	12.59 b
	NT	7.17 b	2.76 c	1.92 b	13.94 a
2021–2023	CT	6.76 c	3.11 b	1.68 d	11.87 c
	NT	7.94 a	4.08 a	2.01 a	14.14 a
$LSD_{0.05}$		0.53	0.45	0.09	1.23

Means separated by identical lower-case letters (a, b, c, d) in each column are significantly different at $p \leq 5\%$.

The interactive effect of the experiment cycles/years and the tillage practices was not significant; it was likely that longer than this two-year crop rotation cycle is needed to produce significant changes in crop yield. Although a slight yield increase was observed in winter wheat (3.4%), it did not reach a significant level under CT when the first experiment cycle was compared against the second one. Under similar conditions, the grain yield of millet significantly increased by 23.9%. On the contrary, forage pea and maize yields decreased significantly under CT when the first experiment cycle was compared against the second one.

NT with an intensive cropping system composed of totally different families and grown in sequence showed the greatest benefit on crop productivity. Integrating legume such as forage pea into the cropping system might have an essential role in increasing crop yield. It is worth mentioning that legumes enrich soil with nitrogen fixed from air up to 300 kg per ha depending on environmental factors [18]. The combined positive effects of NT and legume-based short crop rotation systems increase water use efficiency, reduce soil erosion, improve soil properties, and enhance crop productivity [19,20].

A slow and steady impact of the used practices on crop yield is also expected in the long term [21]. As the positive effect of NT is well documented, a consistent increase in crop yield was achieved due to a positive synergism between NT and the legume-based short crop rotation system.

3.2. Residue Retention

Total crop residue retention was enhanced significantly ($p < 0.005$) by the NT practice as compared to the CT (Table 2), with a substantial increase exhibited at the second experiment cycle. The main part of root residues was found at the 0–30 cm soil layer in both tillage treatments, i.e., 86.2% under NT and 87.5% under CT. However, root residue retentions were 16.7% and 33.9% higher under NT as compared to CT in the first and second experiment cycles, respectively. Similarly, phyto residues were 17.4% and 24.4% higher under NT than in CT, respectively, for the above-mentioned experiment periods.

Table 2. Phyto and root residues (t ha^{-1}).

Cycle	Soil Treatments	Phyto Residues	Root Residues		Total Residues
			0–30 cm	30–50 cm	
2019–2021	CT	19.5 b	15.9 b	2.1 b	37.5 b
	NT	22.9 ab	18.2 ab	2.8 a	43.9 a
2021–2023	CT	18.8 b	14.7 c	2.1 b	35.6 b
	NT	23.4 a	19.4 a	3.1 a	45.9 a
$LSD_{0.05}$		2.15	1.23	1.04	3.65

Means separated by identical lower-case letters (a, b, c) in each column are significantly different at $p \leq 5\%$.

The integration of organic matter enhances or rebalances the soil's structure, enriches soil organic matter (SOM) and nutrients, and enhances cation exchange and water retention capacities. Soil health also depends on the quality and quantity of SOM, which regulates many soil functions, i.e., soil organic carbon (SOC), soil biodiversity, availability and cycling of plant nutrients, soil porosity, aeration, water-holding capacity and hydraulic conductivity, thermal properties, and mechanical strength [22]. As mentioned in the previous studies, the amount, quality, and decomposition rate of crop residues returned to the soil are directly impacted by agricultural management strategies including reduced tillage and crop rotations [23]. Furthermore, covering soil surface with residues protects from water and wind erosion and salt accumulation, and reduces soil temperatures in arid regions. The beneficial effect of the legume-based short crop rotation used in this study is associated with nutritious and high-quality stubble generated by legumes.

3.3. Soil Chemical Characteristics

The tested soil quality indicators were significantly ($p < 0.005$) affected by the practiced tillage treatments (Table 3). Soil salinity was positively affected by the short crop rotation system under the NT treatment, reducing salinity buildup by 18.9% at the 0–25 cm and 32.9% at the 75–100 cm soil depths compared to CT.

Table 3. Soil chemical analysis.

Soil Depth (cm)	Salinity (ds m^{-1})	Soil pH	Humus (%)	Total Forms (%)			Available Forms (mg per kg)		
				N	P	K	NO_3	P_2O_5	K_2O
CT									
0–25	8.8 b	7.72 a	1.055 bc	0.072 b	0.136 d	0.84 a	44.3 c	13.5 b	120.4 b
25–50	8.4 c	7.70 a	1.033 c	0.070 b	0.150 b	0.79 a	47.2 b	9.0 c	106.0 c
50–75	9.1 b	7.70 a	0.801 d	0.058 c	0.145 c	0.76 a	50.3 a	5.0 d	65.1 e
75–100	10.5 a	7.63 a	0.611 e	0.046 d	0.141 c	0.66 b	49.2 a	2.0 e	55.4 e
NT									
0–25	7.4 d	7.69 a	1.160 a	0.081 a	0.155 b	0.87 a	48.3 b	14.0 b	207.1 a
25–50	7.5 d	7.67 a	1.097 b	0.072 b	0.165 a	0.87 a	54.2 a	24.0 a	130.0 b
50–75	7.6 d	7.63 a	0.886 d	0.063 c	0.155 b	0.81 a	52.1 a	8.0 c	106.0 c
75–100	7.9 c	7.58 a	0.759 de	0.050 d	0.136 d	0.69 b	49.9 b	3.0 e	96.3 d
$LSD_{0.05}$	0.6	0.45	0.57	0.008	0.009	0.014	4.12	8.65	50.68

Means separated by identical lower-case letters (a, b, c, d, e) in each column are significantly different at $p \leq 5\%$.

The results showed that pH level was lower under NT despite no significant difference being observed. It turned out that short crop rotation under the NT and CT treatments may not affect soil pH level in the short term.

Soil humus content at the 0–25 soil depth was 1.16% under NT as compared to 1.055% under CT, exhibiting a 9.95% increase in soil organic matter. Similar results were found in all the studied soil profiles. As expected, humus content decreased with an increase in soil depth.

The total amounts of N and P significantly increased due to the application of NT compared to CT. Total N and P at the 0–25 cm soil profile were 12.5% and 13.9% higher under NT compared to CT treatment. However, the highest p values were found at the 25–50 cm soil profile, showing a 10% increase under the NT practice compared to CT. The tested tillage systems influenced total K content, but a significant difference was not observed in this index.

The practiced NT treatment coupled with a short crop rotation system significantly ($p < 0.05$) influenced available forms of nutrients, i.e., NO_3, P_2O_5, and K_2O. Positive effects in these nutrients were detected in all the studied soil profiles. For example, averaged across the soil profiles, NO_3 was increased by 7.1% under NT compared to CT during the two experiment cycles. Similarly, P_2O_5 and K_2O were increased significantly, suggesting a difference in the effectiveness of the studied NT and CT treatments on soil nutrient balance.

As stated by Boselli et al. [24], organic matter accumulation under NT was considerably higher due to crop residue retention, increasing microbial biomass, diversity, and forming a more suitable environment for the coexistence of soil microorganisms. It is well known that soil salinity also has a negative impact on several morphological, physiological, and biochemical properties in crops [25]. Following four years of NT experiments, Nurbekov et al. [26] reported that NT had the lowest soil salinity level of all evaluated practices due to the reduced evaporation and upward salt movement in the soil profiles. The used short crop rotation under NT positively influenced nutrient recycling and balancing in the soil, which might be related to high crop residue levels, improved soil microbial activity, and rejuvenated natural processes. The application of NT combined with legume-based short crop rotation resulted in increased soil nutrients such as C, N, and P compared to CT-based rotation. More notably, the applied land management practice facilitated the retention of maximum crop residues and decreased soil salinity in this arid region.

3.4. Soil Physical Characteristics

Table 4 indicates that NT application coupled with short crop rotation showed some improving trends in the studied soil physical characteristics at the end of the four-year experiment. Soil bulk density was significantly reduced under NT than in CT in saline meadow-alluvial soils. The significant effect of this land management practice on the improvement in soil bulk density reached 8–13.4%, affecting in-depth soil horizons to a greater extent.

Table 4. Soil physical properties.

Soil Depth (cm)	Bulk Density, (g/cm^3)	Total Porosity (%)	Soil Moisture Content (%)	Water Infiltration Rate (cm s^{-1})
		CT		
0–25	1.42 c	46.21 b	14.16 c	24.5 a
25–50	1.52 b	43.07 b	15.18 c	23.4 a
50–75	1.59 a	40.67 c	19.54 b	22.8 a
75–100	1.60 a	40.30 c	21.67 a	21.9 a
		NT		
0–25	1.31 d	49.42 a	17.39 b	22.9 a
25–50	1.34 d	48.46 a	18.47 b	21.8 a
50–75	1.38 c	46.77 b	20.11 b	21.0 a
75–100	1.41 c	45.65 b	23.48 a	21.4 a
$LSD_{0.05}$	0.57	3.23	3.04	3.65

Means separated by identical lower-case letters (a, b, c, d) in each column are significantly different at $p \leq 5\%$.

Similarly, soil porosity was significantly influenced by the implemented tillage management ($p < 0.05$). Continuous tillage may instantly improve soils' overall porosity by producing a few uneven macropores. In this study, after four years NT resulted in

6.94–13.3% higher soil porosity compared to the CT treatment. Higher soil porosity significantly impacted both the root system development and the nutrient and water availability for crops.

Soil moisture values also showed a positive effect of the NT practice, increasing by 22.8% at the 0–25 cm and 8.4% at the 75–100 cm soil horizons. Likewise, the water infiltration rate slightly improved under NT, but did not reach a significant level in this short-term study.

NT had significantly lowered soil temperature compared to the CT treatment. The soil temperature was lower by up to 9.2% in June, 10.7% in July, 13.7% in August, and 17.5% in September under NT than that in the CT treatment (Figure 2). The reduced soil temperatures during summer likely had some positive effects on crop performance at this experiment, which is in line with previous reports [27]. This intensive short crop rotation system under NT turned out to be effective to moderate soil temperature by intercepting incoming solar radiation with vegetative biomass and phyto residues cover on the soil surface [28]. Phyto residues play a crucial role for reducing the maximum soil temperature by as much as 5 °C in summer and increasing the minimum soil temperature by about 1–2 °C in winter [29]. This lowered soil temperature in summer can contribute to increase soil water storage by reducing inefficient evaporation, especially during drought period. The application of this practice also affects soil microbial activity, SOM composition, soil biochemical processes and structural properties, thereby systematically restores soil health [30]. In this case, the effectiveness primarily depends on the amount of residues left on the soil surface and their quality.

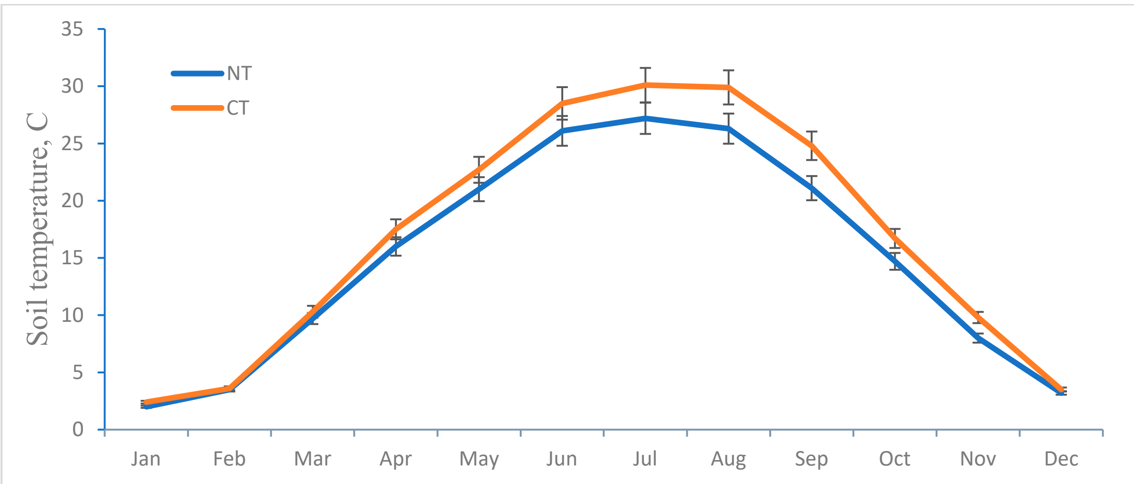

Figure 2. Effect of tillage treatment (NT and CT) on soil temperature (averaged across the experiment years).

Several recent reports highlighted the multifunctional effects of NT management scenarios on soil physical characteristics, i.e., increasing soil moisture retention, while decreasing soil bulk density and temperature [31,32]. Regardless of their composition, gained crop residues under NT improved the physical and chemical characteristics of the soil, which in turn significantly increased soil fertility [33]. The abundant literature indicates that NT lowers wind and water erosion, enhances water penetration and storage, reduces loss of nutrients, improves soil biological activity, and boosts soil organic matter which are indicators of soil health settings [34,35]. Steady improvement of soil quality under NT contributes to the productivity of subsequent row crops, suggesting a potential solution for food security and overall agricultural sustainability in water-limited regions [36]. More recently, the beneficial effects of no-tillage and crop residue management on the characteristics of irrigated silty loam soil in Uzbekistan were documented for a rotation of winter wheat and maize for two years, followed by cotton for another two years [37].

This permanent soil covering maintained via residue retention can result in equal or even better agricultural outcome while drastically decreasing the requirement for and expense of production resources, including fuel, seeds, agrochemicals, water, and labor [38,39]. However, the expanding body of data on productivity, economic, and environmental advantages is still based on a few studies, necessitating site-specific investigations [40,41]. Despite many positive showcases on land degradation and successful practices for their recovery/rehabilitation, NT is still not widely practised in arid regions. This is mostly because of a need for modern NT machinery, knowledge, and experience [26].

4. Conclusions

The results of this four-year study revealed that soil productivity and crop yield in response to conventional (CT) and no-till (NT) tillage practices in saline meadow-alluvial soils of arid regions has the potential to increase the sustainability of farming systems and their resilience to devasting environmental and climatic problems. Residue retention was considerably higher under NT than in CT, which was one of the main components of the soil-structure-maintenance processes, thereby improving ecosystem services in this short-term study. The effect of NT along with the legume-based crop rotation system was more pronounced on increasing crop yield and soil humus and NPK contents, and on decreasing soil salinity and temperature; thus, it may be a more resource-saving, cost-effective, and environmentally friendly method.

Our results suggest that the shift toward NT coupled with a short crop rotation system and involvement of legume can enhance crop yield and combat on-going land degradation in salt-affected arid lands.

Author Contributions: Conceptualization, A.N.; methodology, M.K.; software, M.S.; validation, M.S. and Z.Y.; formal analysis, B.K.; investigation, Z.Y.; resources, H.M.; data curation, A.N. and D.Q.; writing—original draft, B.K.; writing—review and editing, B.K. and A.N.; supervision, A.N. All authors have read and agreed to the published version of the manuscript.

Funding: This study was carried out within the GEF-funded project entitled "Integrated natural resources management in drought-prone and salt-affected agricultural production landscapes in Central Asia and Turkey" (CACILM-2).

Data Availability Statement: Data are contained within the article.

Acknowledgments: The authors thank Shavkat Shodiev and Zarafshon farm workers in Romitan district, Bukhara province, Uzbekistan, for providing technical support and collaboration.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Rustamova, I.; Primov, A.; Karimov, A.; Khaitov, B.; Karimov, A. Crop Diversification in the Aral Sea Region: Long-Term Situation Analysis. *Sustainability* **2023**, *15*, 10221. [CrossRef]
2. Conrad, C.; Lamers, J.P.A.; Ibragimov, N.; Löw, F.; Martius, C. Analysing irrigated crop rotation patterns in arid Uzbekistan by the means of remote sensing: A case study on post-Soviet agricultural land use. *J. Arid Environ.* **2016**, *124*, 150–159. [CrossRef]
3. Allanov, K.; Sheraliev, K.; Ulugov, C.; Ahmurzayev, S.; Sottorov, O.; Khaitov, B.; Park, K.W. Integrated effects of mulching treatment and nitrogen fertilization on cotton performance under dryland agriculture. *Commun. Soil Sci. Plant Anal.* **2019**, *50*, 1907–1918. [CrossRef]
4. Wang, J.; Hussain, S.; Sun, X.; Zhang, P.; Javed, T.; Dessoky, E.S.; Ren, X.; Chen, X. Effects of Nitrogen Application Rate Under Straw Incorporation on Photosynthesis, Productivity and Nitrogen Use Efficiency in Winter Wheat. *Front. Plant Sci.* **2022**, *13*, 862088. [CrossRef] [PubMed]
5. Sithole, N.J.; Magwaza, L.S.; Mafongoya, P.L. Conservation agriculture and its impact on soil quality and maize yield: A South African perspective. *Soil Tillage Res.* **2016**, *162*, 55–67. [CrossRef]
6. Li, G.D.; Schwenke, G.D.; Hayes, R.C.; Lowrie, A.J.; Lowrie, R.J.; Poile, G.J.; Oates, A.A.; Xu, B.; Rohan, M. Can legume species, crop residue management or no-till mitigate nitrous oxide emissions from a legume-wheat crop rotation in a semi-arid environment? *Soil Tillage Res.* **2021**, *209*, 104910. [CrossRef]
7. Fu, B.; Chen, L.; Huang, H.; Qu, P.; Wei, Z. Impacts of crop residues on soil health: A review. *Environ. Pollut. Bioavail.* **2021**, *33*, 164–173. [CrossRef]

8. Ibragimov, N.; Djumaniyazova, Y.; Khaitbaeva, J.; Babadjanova, S.; Ruzimov, J.; Akramkhanov, A.; Lamers, J. Simulating crop productivity in a triple rotation in the semi-arid area of the Aral Sea Basin. *Int. J. Plant Prod.* **2020**, *14*, 273–285. [CrossRef]
9. Duval, M.E.; Galantini, J.A.; Iglesias, J.O.; Canelo, S.; Martinez, J.M.; Wall, L. Analysis of organic fractions as indicators of soil quality under natural and cultivated systems. *Soil Tillage Res.* **2013**, *131*, 11–19. [CrossRef]
10. Amoakwah, E.; Arthur, E.; Frimpong, K.A.; Parikh, S.J.; Islam, R. Soil organic carbon storage and quality are impacted by corn cob biochar application on a tropical sandy loam. *J. Soils Sediments* **2020**, *20*, 1960–1969. [CrossRef]
11. Ghorbi, S.; Ebadi, A.; Parmoon, G.; Siller, A.; Hashemi, M. The Use of Faba Bean Cover Crop to Enhance the Sustainability and Resiliency of No-Till Corn Silage Production and Soil Characteristics. *Agronomy* **2023**, *13*, 2082. [CrossRef]
12. Jahangir, M.M.R.; Islam, S.; Nitu, T.T.; Uddin, S.; Kabir, A.K.M.A.; Meah, M.B.; Islam, R. Bio-Compost-Based Integrated Soil Fertility Management Improves Post-Harvest Soil Structural and Elemental Quality in a Two-Year Conservation Agriculture Practice. *Agronomy* **2021**, *11*, 2101. [CrossRef]
13. Anastasi, U.; Scavo, A. Cropping Systems and Agronomic Management Practices of Field Crops. *Agronomy* **2023**, *13*, 2328. [CrossRef]
14. So, H.B.; Grabski, A.; Desborough, P. The impact of 14 years of conventional and no-till cultivation on the physical properties and crop yields of a loam soil at Grafton NSW, Australia. *Soil Tillage Res.* **2009**, *104*, 180–184. [CrossRef]
15. Nurbekov, A. Conservation agriculture in Uzbekistan—Status and perspectives. *Agro Inform* **2022**, 27–32. Available online: https://cyberleninka.ru/article/n/conservation-agriculture-in-uzbekistan-status-and-perspectives (accessed on 26 September 2023).
16. Ryan, J.; Estefan, G.; Rashid, A. *Soil and Plant Analysis Laboratory Manual*, 2nd ed.; International Center for Agricultural Research in the Dry Areas (ICARDA): Allepo, Syria, 2001.
17. NIAST. *Method of Soil and Plant Analysis*; National Institute of Agricultural Science and Technology (NIAST): Suwon, Republic of Korea, 2000.
18. Zimmer, S.; Messmer, M.; Haase, T.; Piepho, H.-P.; Mindermann, A.; Schulz, H.; Habekuß, A.; Ordon, F.; Wilbois, K.-P.; Heß, J. Effects of soybean variety and Bradyrhizobium strains on yield, protein content and biological nitrogen fixation under cool growing conditions in Germany. *Eur. J. Agron.* **2016**, *72*, 38–46. [CrossRef]
19. Lal, R. Climate change and soil degradation mitigation by sustainable management of soils and other natural resources. *Agric. Res.* **2012**, *1*, 199–212. [CrossRef]
20. Malobane, M.E.; Nciizah, A.D.; Mudau, F.N.; Wakindiki, I.I. Tillage, crop rotation and crop residue management effects on nutrient availability in a sweet sorghum-based cropping system in marginal soils of South Africa. *Agronomy* **2020**, *10*, 776. [CrossRef]
21. Schröder, P.; Beckers, B.; Daniels, S.; Gnädinger, F.; Maestri, E.; Marmiroli, N.; Mench, M.; Millan, R.; Obermeier, M.M.; Oustriere, N.; et al. Intensify production, transform biomass to energy and novel goods and protect soils in Europe-A vision how to mobilize marginal lands. *Sci. Total Environ.* **2018**, *616*, 1101–1123. [CrossRef]
22. Zuber, S.M.; Behnke, G.D.; Nafziger, E.D.; Villamil, M.B. Crop rotation and tillage effects on soil physical and chemical properties in Illinois. *Agron. J.* **2015**, *107*, 971–978. [CrossRef]
23. Li, Z.; Yang, X.; Cui, S.; Yang, Q.; Yang, X.; Li, J.; Shen, Y. Developing sustainable cropping systems by integrating crop rotation with conservation tillage practices on the Loess Plateau, a long-term imperative. *Field Crops Res.* **2018**, *222*, 164–179. [CrossRef]
24. Boselli, R.; Fiorini, A.; Santelli, S.; Ardenti, F.; Capra, F.; Maris, S.C.; Tabaglio, V. Cover crops during transition to no-till maintain yield and enhance soil fertility in intensive agro-ecosystems. *Field Crops Res.* **2020**, *255*, 107871. [CrossRef]
25. Haruna, S.I.; Nkongolo, N.V. Tillage, Cover Crop and Crop Rotation Effects on Selected Soil Chemical Properties. *Sustainability* **2019**, *11*, 2770. [CrossRef]
26. Nurbekov, A.; Akramkhanov, A.; Kassam, A.; Sydyk, D.; Ziyadaullaev, Z.; Lamers, J.P.A. Conservation Agriculture for combating land degradation in Central Asia: A synthesis. *AIMS Agric. Food* **2016**, *1*, 144–156. [CrossRef]
27. Piva, J.T.; Dieckow, J.; Bayer, C.; Zanatta, J.A.; de Moraes, A.; Pauletti, V.; Tomazi, M.; Pergher, M. No-till reduces global warming potential in a subtropical Ferralsol. *Plant Soil* **2012**, *361*, 359–373. [CrossRef]
28. Ogle, S.M.; Alsaker, C.; Baldock, J.; Bernoux, M.; Breidt, F.J.; McConkey, B.; Vazquez-Amabile, G.G. Climate and soil characteristics determine where no-till management can store carbon in soils and mitigate greenhouse gas emissions. *Sci. Rep.* **2019**, *9*, 11665. [CrossRef] [PubMed]
29. Blanco-Canqui, H.; Shaver, T.M.; Lindquist, J.L.; Shapiro, C.A.; Elmore, R.W.; Francis, C.A.; Hergert, G.W. Cover crops and ecosystem services: Insights from studies in temperate soils. *Agron. J.* **2015**, *107*, 2449–2474. [CrossRef]
30. Nyambo, P.; Thengeni, B.; Chiduza, C.; Araya, T. Tillage, crop rotation, residue management and biochar influence on soil chemical and biological properties. *S. Afr. J. Plant Soil* **2021**, *38*, 390–397. [CrossRef]
31. Namozov, F.; Islamov, S.; Atabaev, M.; Allanov, K.; Karimov, A.; Khaitov, B.; Park, K.W. Agronomic Performance of Soybean with Bradyrhizobium Inoculation in Double-Cropped Farming. *Agriculture* **2022**, *12*, 855. [CrossRef]
32. Page, K.L.; Dang, Y.P.; Dalal, R.C. The ability of conservation agriculture to conserve soil organic carbon and the subsequent impact on soil physical, chemical and biological properties and yield. *Front. Sustain. Food Syst.* **2020**, *4*, 31. [CrossRef]
33. Sun, W.; Canadell, J.G.; Yu, L.; Yu, L.; Zhang, W.; Smith, P.; Huang, Y. Climate drives global soil carbon sequestration and crop yield changes under conservation agriculture. *Glob. Change Biol.* **2020**, *26*, 3325–3335. [CrossRef] [PubMed]

34. Rodríguez, M.P.; Domínguez, A.; Moreira Ferroni, M.; Wall, L.G.; Bedano, J.C. The diversification and intensification of crop rotations under no-till promote earthworm abundance and biomass. *Agronomy* **2020**, *10*, 919. [CrossRef]
35. Etemadi, F.; Hashemi, M.; Barker, A.V.; Zandvakili, O.R.; Liu, X. Agronomy, nutritional value, and medicinal application of faba bean (*Vicia faba* L.). *Hortic. Plant J.* **2019**, *5*, 170–182. [CrossRef]
36. Islam, R.; Glenney, D.C.; Lazarovits, G. No-till strip row farming using yearly maize-soybean rotation increases yield of maize by 75%. *Agron. Sustain. Dev.* **2015**, *35*, 837–846. [CrossRef]
37. Pulatov, A.; Egamberdiev, O.; Karimov, A.; Tursunov, M.; Kienzler, S.; Sayre, K.; Tursunov, L.; Lamers, J.P.A.; Martius, C. Introducing conservation agriculture on irrigated meadow alluvial soils (Arenosols) in Khorezm. Uzbekistan. In *Cotton, Water, Salts and Soums—Economic and Ecological Restructuring in Khorezm, Uzbekistan*; Martius, C., Rudenko, I., Lamers, J.P.A., Vlek, P.L.G., Eds.; Springer: Dordrecht, The Netherlands, 2012; pp. 195–217.
38. Xin, X.; Yang, W.; Zhang, J.; Ding, S. Tillage and residue management for long-term wheat-maize cropping in the North China Plain: I. Crop yield and integrated soil fertility index. *Field Crops Res.* **2018**, *221*, 157–165.
39. Büchi, L.; Wendling, M.; Amossé, C.; Jeangros, B.; Sinaj, S.; Charles, R. Long and short term changes in cropyield and soil properties induced by the reduction of soil tillage in a long term experiment in Switzerland. *Soil Tillage Res.* **2017**, *174*, 120–129. [CrossRef]
40. Gura, I.; Mnkeni, P.N.S. Crop rotation and residue management effects under no till on the soil quality of a Haplic Cambisol in Alice, Eastern Cape, South Africa. *Geoderma* **2019**, *337*, 927–934. [CrossRef]
41. Yang, R.; Su, Y.; Kong, J. Effect of tillage, cropping, and mulching pattern on crop yield, soil C and N accumulation, and carbon footprint in a desert oasis farmland. *Soil Sci. Plant Nutr.* **2017**, *63*, 599–606. [CrossRef]