Improving Minimization of Cultivation of Gray-Brown Soils in Sheki- Zagatala Economic Region

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Received: 26.09.2025 Accepted: 09.10.2025 Published:25.11.2025

https://doi.org/10.54414/ZFEX8050

Abtract

The objective of this research was to determine the effectiveness of minimizing tillage in resource- saving grain production technologies in the northern forest-steppe agricultural landscape. The study focused on resource-saving tillage technologies in various field crop rotations with grain crop saturation levels ranging from 67% to 100%. The research was conducted from 2020 to 2024 on an experimental field based on a permanent field trial established in 1980. Switching from annual plowing to direct seeding reduced the microbiological activity of the topsoil. This is due to a decrease in the rate of mineralization of SOM and changes in soil microflora activity. A key factor in managing weed infestation in agrophytocenoses while minimizing soil tillage is the use of a highly effective herbicide system, which ensures weed infestation levels below the harmfulness threshold. Crop rotations combined with a combined tillage system have been found to be the most effective.

Keywords: grain, bioactivity, agrophytocenoses, tillage, agricultural landscapes

1. Introduction

Simple (normal) traditional technologies are used in Azerbaijani farms with low profitability and staffing levels and are typically designed for regions with low landscape potential, primarily steppe and arid areas. In this case, the distinctive feature of the traditional technological process is the need for plowing (Kabata-Pendias, 2011). No-tillage farming involves only one contact of tillage implements with the soil during the growing season seeding. Seeding is typically done in narrow furrows 2.6-7.6 cm wide, with one or more additional operations. Herbicides are used intensively to control weeds. With no-tillage, savings can reach 60-79%. With no-till technology, seeding is carried out in the field while crop residue is preserved and evenly distributed. Stubble helps retain snow and accumulate moisture, while chopped straw provides additional biological nutrition to soil organisms and prevents evaporation (Dobrovolsky, 1983) Crop rotation plays a particularly important role in farming under this system, reducing weed growth and crop disease, eliminating insect pest problems, and increasing soil fertility and potential land profitability (Rowell, 1999). The economic situation in Azerbaijan over the past 20 years has led to a reduction in the area of cultivated land in the country. Almost half of the arable land of the Azerbaijan Republic is unused and is largely subject to secondary overgrowth by trees and shrubs (Bunyatova et al., 2025; Ismayil et al., 2025)

The Sheki-Zagatala economic region is an important grain-growing country area, producing food grain of strong and hard varieties of spring wheat (Nasirova et al., 2022). The main direction of stabilizing grain production is the improvement of generally accepted technologies for cultivating grain crops based on resource-saving and soil-protecting soil cultivation systems in field crop rotations (Mirzezadeh et al., 2025). In modern conditions, soil cultivation remains a crucial element of zonal farming systems based on agrolandscapes. Scientists believe that we must boldly experiment with various techniques to select the best. Only in this way can we universally achieve our common goal of progressively increasing soil fertility (Biswas, 2021). The crop production industry's responsibilities include growing several tons of grain, developing and implementing measures to increase crop productivity through the use of modern technology, increasing fertilizer application, and much more. Better moisture retention when plant residues from previous crops accumulate on the surface. As the area planted using this technology increases in production, research is being conducted to study the technology in a direct seeding system and obtain objective information (Adhikari, 2017; Minasny, 2011).

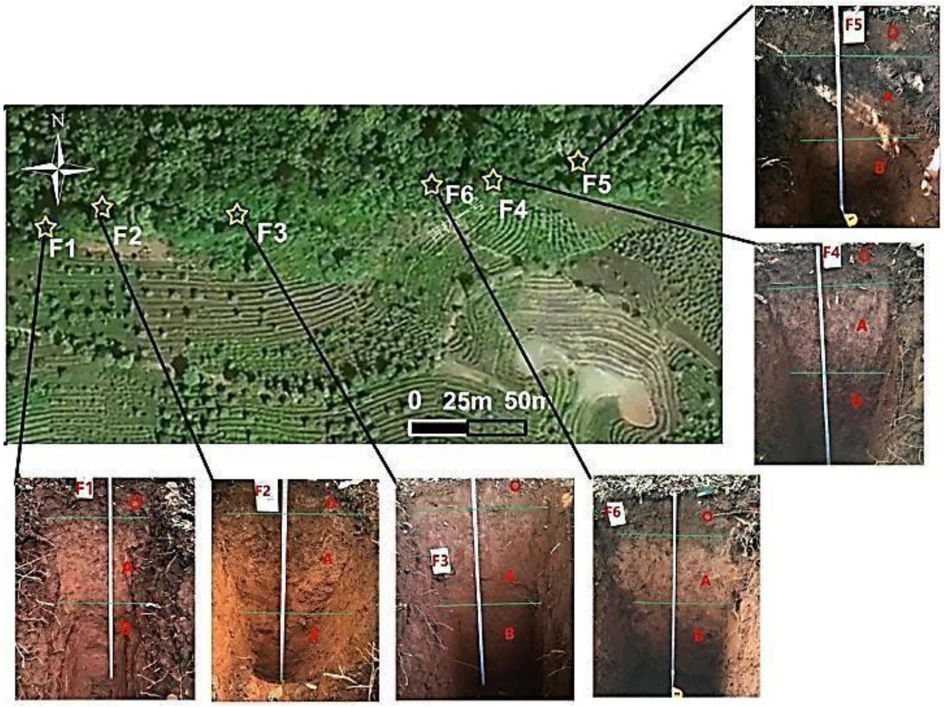
The study examined moldboard (control), combined no-tillage with plowing once per crop rotation, minimum (subsoil), and no-till tillage systems. These systems were used in a grain-fallow crop rotation with a fallow-wheat-pea-barley rotation, a crop rotation with rapeseed-wheat-pea- wheat, and a grain-fallow-grass rotation with winter rye-pea-wheat-annual grasses-barley. In the no- till system, plots were sprayed with $C_3H_8NO_5P$ 7-9 days before sowing, and an additional 16 kg of N was applied per ha of crop rotation area. During the tillering phase, grain crops in all experimental variants were treated with a tank mixture of recommended herbicides. The obtained results allowed us to determine the impact of various tillage systems on soil fertility and grain production efficiency in resource-saving technologies. Minimizing tillage in a grain-fallow crop rotation, particularly no- tillage, while maintaining stubble and a mulch layer of chopped straw, promotes the accumulation of available soil moisture. Soil bulk density measurements indicate an optimal range of 1.1-1.2 g/cm in the 0-30 cm layer for the growth and development of grain crops. The porosity of the leached gray- brown topsoil corresponded to a satisfactory estimate, amounting to 54-56%.

The studied resource-saving soil cultivation systems, focusing on minimizing the use of direct seeding in field crop rotations with varying grain abundances, are characterized by objective characteristics. Improving these elements of the farming system guarantees high yields and economic efficiency in crop production, as well as the preservation and enhancement of soil fertility in the forest-steppe.

2. Methods

To evaluate the effectiveness of various resource-saving tillage systems, including no-till, in field crop rotations, we are conducting a field study under State Contract No. 0771-2019-006: "Develop resource-saving crop cultivation technologies for sustainable crop production and land conservation." The research has been conducted since 2024 based on a permanent field experiment established in 1980 on a test field. The soil of the test plot is shallow, medium-loamy leached gray- brown soils with a humus content of 6.9-7.7%. Tillage systems are studied according to the following classification: moldboard (control) with plowing, combined with a combination of no-till and plowing once per crop rotation, minimum (subsurface), and no-till. Tillage systems were applied in three field crop rotations: grain-fallow (fallow-wheat-pea-barley), crop rotation (rapeseed-wheat-pea-wheat), and grain-fallow-grass (fallow-winter rye-pea-wheat-annual grasses-barley) with grain saturation from 67% to 100%. In all field crop rotations, the fertilizer system applied 20-30 kg of N and 20-35 kg of P per hectare of arable land, differentiated by crop type depending on their cultivation technology and placement in the rotation. With the no-till system, an additional 15 kg of active ingredient N is applied per hectare of crop rotation area. The total plot area was 650 m^2, the plot size was 122 m^2, the replicates were fourfold, and the placement of the variants was randomized. Crops were sown using an SS-6 seeder equipped with disc coulters and a special attachment (turbo discs) for direct seeding. The no-till system included glyphosate application 7-8 days before sowing. The plant protection system included spraying field crops with a tank mix of herbicides, fungicides, and insecticides when the pesticide threshold was exceeded. The study utilized generally accepted methods for determining agrophysical properties: soil moisture using the thermostat-weight method; soil bulk density using a Kachinsky auger with a 500 cm^3 cylinder; agrochemical parameters: total humus according to

Tyurin, NO3-N and available P according to Chirikov, and pH potentiometrically in a salt extract; soil microbiological activity using the flax cloth method; crop weed infestation by specific gravity in the agrophytocenoses using the Milashchenko method (Fig. 1); crop yield measurements using direct combining with a Sampo 500, the data from which were subjected to variance analysis according to Dospekhov in the Snedeko program (Flynn et al., 2019; Malone et al., 2017)



Note: The satellite imagery was obtained from the OweMap Windows Client v10.1

Figure 1. *Study area and soil sampling locations in Yunnan Province, southwest China (soil profile, O. humus layer, greyish black, loose, plant debris; A. leachate, gray-brown, sandy loam; B. alluvium, reddish brown, sandy loam;). In the study area, six plots with different slopes, slope directions, and elevations were established and designated F1–F6 (Moldboard, Combined, Minimum, No-till)*

3. Results

A scientifically based transition to new resource-saving technologies based on minimizing tillage is based on the established principle that minimizing tillage in crop rotation does not degrade soil fertility parameters compared to plowing. Our research examining tillage systems in a typical field grain-fallow crop rotation with 75% grain crop saturation yielded the following soil fertility indicators (Table 1).

Table 1. *Fertility indicators of leached gray-brown soils depending on soil cultivation systems, 2020-2024*

SCS*	PMC in the 0- 100 cm layer, mm	SBD in the 0-30 cm layer, g/cm^3	NN content in the 0-40 cm layer, mg/kg	Soil bio-activity, %
Moldboard	125	1.14	13.0	43.9
Combined	122	1.13	12.3	43
Minimum	121	1.14	10.9	39.2
No-till	129	1.15	10.2	38.9
LSD*	20.1	0.04	3.86	9.86

*Note: SCS- Soil cultivation system; PMC - productive moisture content; SBD - Soil bulk density; NN – Nitrate nitrogen (NO_3-N); LSD - least significant difference

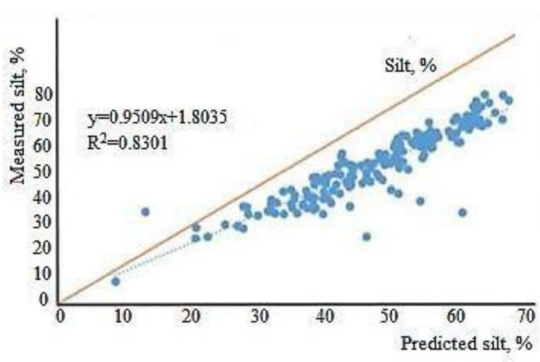
During the experimental observation period, spring moisture reserves, based on the productive moisture content in the one-meter soil layer under field crop rotation, were characterized as satisfactory. Maximum moisture accumulation was achieved with the no-till system, with mulch of crop residues left on the soil surface. The soil bulk density during equilibrium was within the optimal range for grain crop growth and development across all tillage systems (1.1-1.2 g/cm^3). This demonstrates the high resistance of gray-brown soils to compaction. The porosity of the arable layer of leached gray-brown soils corresponds to a satisfactory estimate, reaching 54%-56%. In energy- saving tillage technologies, the bulk of crop and plant residues, which provide food for soil microflora, including pathogens, is located in the upper soil layers. Observations in spring wheat crops after fallow have shown a decrease in the microbiological activity of the arable layer from plowing to no-tillage, from 43.9% to 38.8%. Minimizing tillage reduces the rate of mineralization of soil organic matter, resulting in a nitrate nitrogen (NO_3-N) deficiency, which leads to a deterioration in the nitrogen nutrition of field crops. Compensating doses of nitrogen fertilizers are required. In field crop rotations with up to 75% saturation with grain crops, the accumulation of plant residues in the form of straw amounted to 3.0 t/ha, in crop rotation - 4.2 t/ha, which in the conditions of forest- steppe agricultural landscapes is insufficient to maintain a stable state of soil fertility and to increase it. Correlation analysis between the productivity of grain-fallow crop rotations under different tillage systems and the content of NO_3-N and available P allows modeling the fertility indicators of the arable horizon of leached gray-brown soils and adjusting the application rates of mineral fertilizers depending on the preceding crops. The influence of available P content in the 0-40 cm soil layer on crop productivity in grain-fallow crop rotations averages 68-81%, with a correlation coefficient (Cc) of r = 0.82-0.89 for both moldboard and minimum tillage systems. The influence of NO_3-N content on crop productivity in minimum and no-till systems averaged 46-48%. Weed prevalence rates in various agrophytocenoses were below the harmfulness threshold for all tillage systems. Weed control of cultivated crops was achieved through the use of tank mixes of highly effective herbicides during the growing season and the application of glyphosate ($C_3H_8NO_5P$) before sowing. Minimizing soil cultivation does not worsen the fertility level of the arable layer of leached gray-brown soil and ensures sustainable productivity of field crop rotations (Table 2).

Table 2. *Efficiency of tillage systems in field crop rotations in, 2020-2024 years*

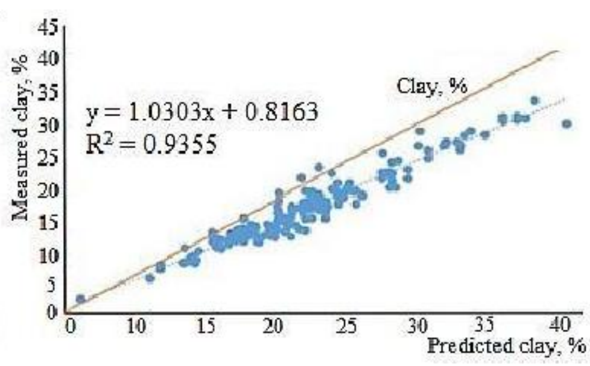
Crop rotation	SCS*	Grain crop yield, t/ha	Grain yield per 1 ha of arable land, t	Profitability, %	EEC*
Grain-fallow	Moldboard	3.17	2.35	230	3.6
	Combined	3.10	2.31	226	3.7
	Minimum	2.89	2.15	230	3.4
	No-till	2.71	2.09	148	3.6
LSD*			0.36		
Crop-replacement	Moldboard	2.31	2.48	238	2.8
	Combined	2.26	2.41	250	2.8
	Minimum	2.08	2.22	212	2.5
	No-till	2.06	2.21	132	2.6
LSD		0.23			
Grain-fallow-grass	Moldboard	3.28	2.51	210	3.5
	Combined	3.17	2.42	231	3.4
	Minimum	2.92	2.26	204	3.4
	No-till	2.93	2.28	146	3.6
LSD		$F_f > F_T$			

*Note: EEC - energy efficiency coefficient; SCS - Soil cultivation system; LSD - least significant difference

The RF-OK model refers to a predictive modeling approach that combines Random Forest (RF) with Ordinary Kriging (OK), typically used for spatial prediction tasks. This combination improves predictive performance, particularly in spatial data environments such as soil property mapping or environmental data modeling (Fig. 2 a-d).



a.



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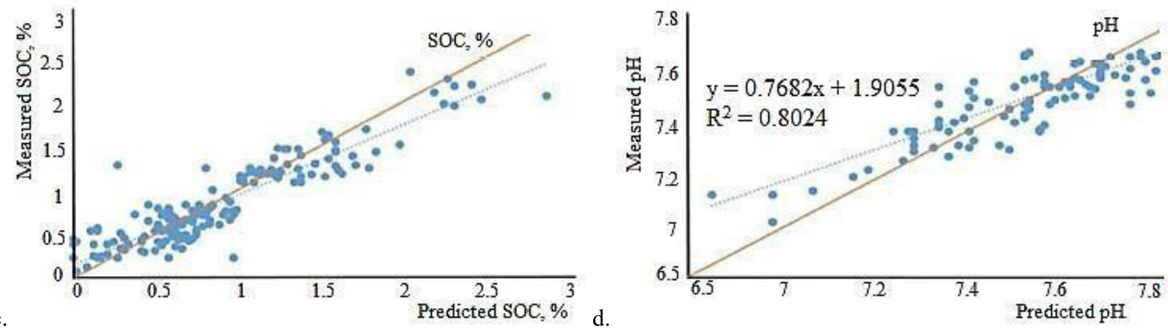

Figure 2. Scatter plots of the predicted data based on RF-OK method for: Silt (a), Clay; (b) SOC and pH (d) in minimum tillage soil cultivation areas

Research has shown that effective production of 2.31-2.40 tons of grain units per 1 hectare of arable land was achieved in crop rotations with a combined tillage system. This system proved to be the most cost-effective. The minimum tillage system was inferior to the moldboard system in terms of crop rotation productivity by 0.20-0.24 tons of grain units per 1 hectare of arable land, but was as close to it in terms of profitability. No-till technology with direct seeding in various crop rotations ensured a grain harvest of 2.08-2.22 tons of grain units per 1 hectare of crop rotation area with a profitability of 143-148%, which is economically advantageous. The EEC for grain-fallow and grain- fallow-grass crop rotations averaged 3.5 units. For crop rotations with a crop rotation, this indicator decreased to 2.7 units, due to the relatively high energy costs of producing rapeseed and peas. Growing regionally selected grain crops allows for minimal tillage, including the use of no-till systems (Fig. 3). However, in the Sheki-Zagatala region conditions, especially for forest-steppe agricultural landscapes, genotypes that are tolerant not only to drought but also to excess drought are needed. Spring wheat varieties grown on the best preceding crops (bare and chemical fallow, peas, and rapeseed) produce grain of quality that meets Class 3 Azerbaijan Standards, while maintaining optimal mineral nutrition. When switching to a no-till system, spring wheat grain was obtained with a gluten content of 26.3% for the following preceding crops: chemical fallow (26.2%), rapeseed (26.2%), and pea (26.1%).

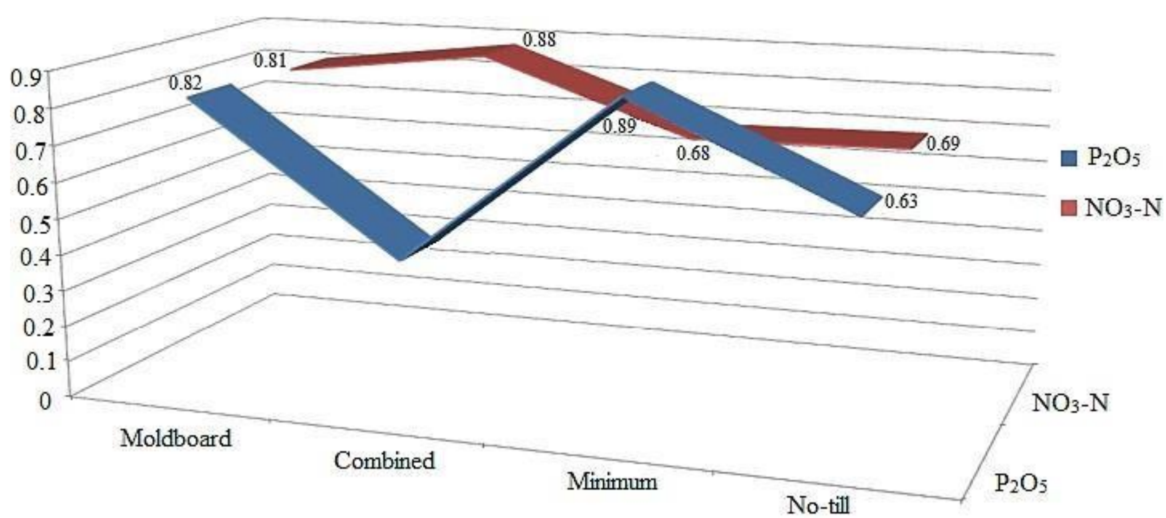

***Figure 3.** Correlation between the content of N-NO$_3$, mobile phosphorus P$_2$O$_5$ and the yield of crops in grain-fallow crop rotation depending on the soil cultivation systems*

4. Conclusions

The conducted research revealed the following: Minimizing soil tillage in field crop rotations, including no-tillage systems, promotes moisture accumulation, an optimal bulk density of 1.1-1.2 g/cm^3, and satisfactory porosity in 54-56% leached gray-brown soils; transition from annual plowing to direct seeding of field crops reduces the microbiological activity of the arable layer from 43.9% to 38.8%, and the NO_3-N content from 12.8 mg/kg to 11.0 mg/kg. This is due to a decrease in the rate of mineralization of SOM and changes in the vital activity of soil microflora; the regulatory factor for managing weed infestation of grain crops while minimizing tillage is the use of a highly effective herbicide system and the weed-clearing effect of pre-cultivation crops (bare, fallow, winter rye, and rapeseed). The proportion of weed vegetation in various agrophytocenoses was within the weed harmfulness threshold of up to 10% across all tillage systems; the accumulation of plant residues in the form of chopped straw in field crop rotations with a field of clean fallow amounted to 3.0 t/ha, in a crop rotation - 4.2 t/ha, which in the conditions of forest-steppe agricultural landscapes is insufficient to maintain a stable state of soil fertility and to increase it; The most effective were field crop rotations using a combined tillage system with a productivity of 2.31-2.43 tons per 1 hectare of arable land with a maximum profitability of 258% and an EEC of 3.7 for a grain-fallow crop rotation. Minimum and no-tillage systems ensured a grain harvest of 2.09-2.28 tons per 1 hectare of arable land, with a profitability of 145-147% and an EEC of 2.5-3.6, which turned out to be economically and energetically advantageous; Spring wheat grown after bare fallow, including chemical fallow, and the best non-fallow predecessors (peas, rapeseed), using various tillage systems, produces grain of AzStandart Class 3 quality. To produce high-quality grain while minimizing tillage, including no- till, balanced nutrition through the use of nitrogen and phosphorus fertilizers is essential.

5. Acknowledgments

This work was financially supported by the authors and the equipment provided by the Institute of Soil Science and Agrochemistry of the Azerbaijan Republic and Baku State University, Faculty of Ecology and Soil Science. Our gratitude to the colleagues of the Baku State University.

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