PMAS

Vol. 64 No 03(251) 2024

DOI: https://doi.org/10.5564/pmas.v64i03.3778

ARTICLE

Legumes and cereal crop rotation effect on soil fertility under selected agronomic practices in central farming region, Mongolia

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ARTICLE INFO: Received: 02 Apr, 2024; Accepted: 09 Sep, 2024

Abstract: The experimental study aimed at identifying the effects on soil fertility and resources using five different treatments, fallow, non-cultivated land, serial plants, leguminous plants, and grass, was conducted in a central agricultural region of Mongolia. The findings highlight the beneficial effects of cooperative agriculture for food and fodder on the restoration of soil fertility and its resulting useful effect on wheat crop yield. To ensure the stability of soil fertility in the central agricultural region, the key results of the suggest that mobile macro element nitrogen in the soil increased by 45-75.9 per cent over a 3-year rotation with spring soft wheat as the major crop grown along with leguminous plants. Furthermore, the implementation of a two-year rotation of Melilotus albus as intercropping for fodder and food purposes has been found to enhance the rate of soil cellulose decomposition. Furthermore, it has been observed that the continuation of favorable weather conditions and availability of moisture directly correlate with the extent of cellulose decomposition. The aggregate structure of the soil with a diameter of 1-3 mm, which is crucial for growing perennial grass (*Agropyron cristatum*), is improved by 11.87 per cent to enhance the field's soil structure and reduce erosion. In our research, it was found that legumes have a high protein content and are important role in meeting the needs of livestock and human food, while enriching the soil with nitrogen and increasing the yield of other crops. However, the practical importance of our research lies in the fact that it was established that perennial plants improve the structure of the soil. Legumes, according to our research, are rich in protein and contribute significantly to the provision of food for humans and livestock, as well as to the enhancement of soil nitrogen levels and the growth of other crops. Nevertheless, our study holds practical significance because it proves that grasses enhance the soil's structure as well.

Keywords: *macro element, soil erosion, cereal crop and legumes, soil fertility, aggregate structure;*

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DOI: https://doi.org/10.5564/pmas.v64i03.3778

INTRODUCTION

Fertility resources present in soil are significantly impacted by its chemical, physical, and biological features. These resources serve as primary factors for evaluating and assessing the relative and economic value of land. In recent years, vegetation growth period for plants has shortened, growth and crop have become sparse, soil fertility has decreased, and the amount of organic matter in soil has continued to decline due to severe temperature of our country, global warming, and other negative natural and climatic phenomena. Consequently, the fertility of soil has decreased in 45 per cent of the arable cultivated land in our country, that is, in more than 560 thousand hectares [1]. of land. Major cropping practices, such as frequent mechanical soil cultivation significantly reduce the moisture content and nutrient balance in the soil. Therefore, the process of organic matter decomposition has been observed to occur at an accelerated interval, resulting in a significant decrease in soil humus content resources, which serve as a fundamental component of soil fertility. Recent studies have indicated to substantial decrease of 28.9 to 37.9 per cent in soil humus content [7]. The decrease in plant growth can be explained by slower cycling of essential resources and an insufficient supply of organic matter throughout the soil. Based on a study carried out by the Institute of Plant and Agricultural Sciences in 2010, it was found that soil fertility has experienced a decline after the introduction of intensive agricultural farming practices in the country. Furthermore, it was observed that more than 60 per cent of the overall agricultural land has been impacted by erosion and resulting soil damage. Further actions are required to restore fertility to over ninety per cent of the cultivated land. The Soil-Agrochemical Laboratory surveyed 579,300 hectares; 80.6 per cent of which are affected by severe erosion, 34.9 per cent by moderate erosion, and 4.5 per cent by minor erosion. In the last 20 years, the area of mass erosion has increased by 56.6 per cent [2]. Hence, the core concept of this study consists of maximizing the rotational use of high-quality annuals, perennials, and legumes for short-term products in order to reduce soil erosion and also improving soil fertility at the same time.

Research objectives: The objective of this study is to maximize agricultural productivity through the use of climate change adaptation strategies and ensuring of stable crop yields per unit area. The aim is to improve soil reserve fertility and active fertility by intercropping cereal and legume crops in alternate seasons. The overall objective and aims are as follows:

- Determine the effects of cereal crops on the concentration of mobile macro elements in the soil.
  - Investigate the effects of legumes and cereal crops on soil physical properties and aggregate soil structure.
  - Analyze the impact of cultivation practices on specific biological parameters that are associated with soil fertility.

MATERIALS AND METHODS

Experimental work was carried out at the Tree Breeding Ecology Research Center, which is associated with the Ministry of Knowledge and Economy of the Republic of Korea (Figure 1). The representative office of Mining Rehabilitation Corporation in Mongolia, "Mireko MJL LLC" in "Zuun Mod" Soum, Central Province, additionally took part in the study.

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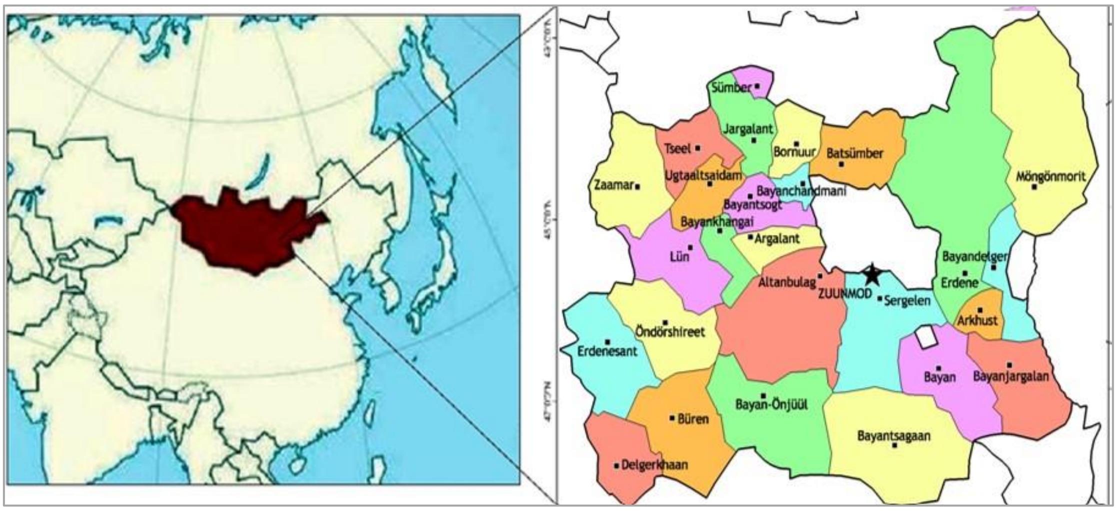

Figure 1. Study area.

Experimental design: The research approach involved conducting a field experiment that included seven treatments: fallow and fallow/control. Experiment treatments used included: **(1)** Non-cultivated-virgin land, (2) Fallow field/control, (3) Wheat */Triticum aestivum/ - (Variety name: /Darkhan -74/,* (4) Pea – */Pisum sativum/ - Variety name: (Aksainsky usatiy\),* (5) White clover */Meliotus albus/ - Variety name: (Sretensky-1),* (6) Alfalfa – */ Medicago sativa.L / - Variety name: (Burgaltai,* (7)Crested wheatgrass – */Agropyron cristatum/ - Variety name: (Sumber-1)* (Fig 2). Each treatment consisted of repeats of four replicates and a plot size of 12 square meters, with an estimated area of 11.2 square meters (Fig 2). The experimental version involved cultivating cultivars that had been introduced in our country using the most common agrotechnical methods for a 3-year rotation (2014-2016).

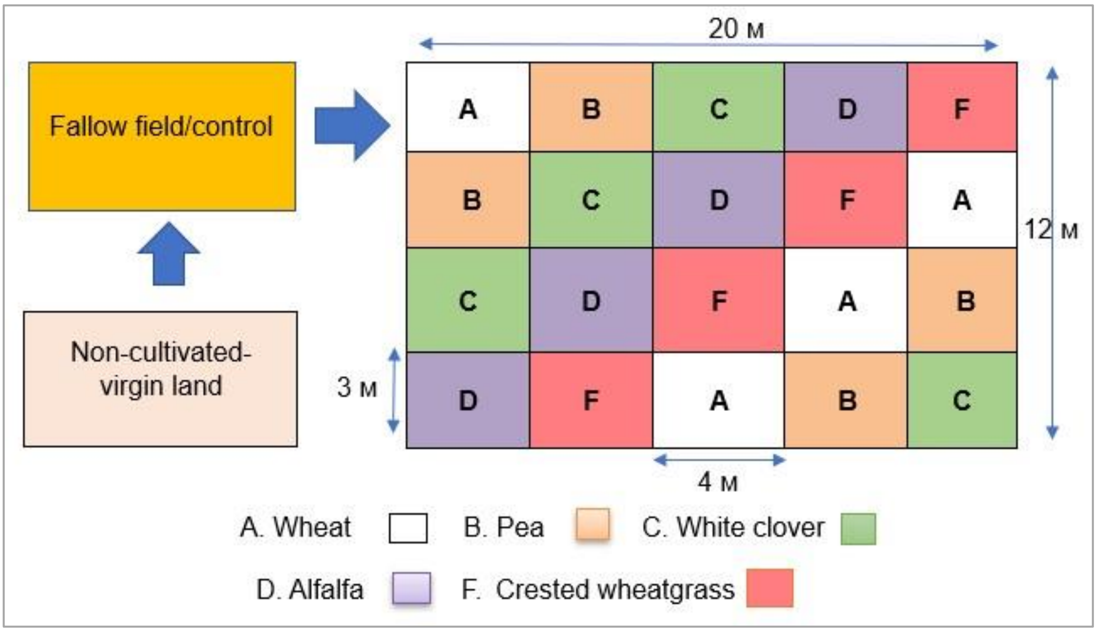

Figure 2. Diagram showing randomized block design used in experimental layout

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Field research methodology: Field research was carried out according to current agrotechnical procedures, soil and weather conditions of the study year, phenomenological observations of the growth and development stage of cultivated plants, and plant biometric measurements were carried out every year during the growing season. Field research was conducted according to the typical agrotechnical standards, soil, and weather conditions of the study year. Plant biometric measurements were performed annually throughout the growing season, and phenomenological observations were recorded concerning the growth and development stage of experimental cultivated crop plants. It included the weather conditions over several years and the result was created using the Walter Gossen method; the method developed by I. N. Beidman for phenomenological observation during plant growth through an experimental running period. In addition, soil nutrient analysis samples were collected from depths of 0-15 cm and 15-30 cm using a manually operated soil borer in each trial.

Laboratory analysis was carried out by the soil-agrochemical laboratory of the School of Agroecology of the Agricultural University [14]. Soil analysis was performed according to standard laboratory methods.

Statistic analysis: The quantitative processing of experimental research materials was conducted by integrating the findings from the field and laboratory research materials. This was accomplished through the utilization of several statistical techniques, including B .A. Dospekhov's analysis of variance, Commander-Dataset-Statistics, Craphs, TukeyHSD, and pairwise.t.test, all implemented within the R studio software package.

RESULTS AND DISCUSSION

In our study, the summary of analysis shows that 2.47-3.1 per cent of the soil nutrient supply was compared to the control or compacted fallow scenario, which revealed a regular decrease of 0.1-0.53 per cent from the control (Table 1) scenario. Still, the fallow indicated a nitrate nitrogen content of 2.2 mg/100g, above the control scenario at 3.87 mg/100g or 1.67 mg/100g. According to the soil phosphorus and potassium content, phosphorus and potassium were -1.5 mg/100g and potassium -21 mg/100g in the control treatment, while phosphorus and potassium were -0.47 mg/100g and potassium -6.5mg/100g respectively in the experimental area (Table 1).

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Table 1 Effect of soil nutrient supply on legumes and cereal (2014 to 2016).

Year	Soil depth /cm/	Salt, %	Electrical conductivity ,ds,m	pH	Humus, %	Mobile macro element mg/100 g			The sum of adsorbed bases in 100 g/soil mg/eq	
						NO_3	P_2O_5	K_2O	Ca	Mg
Non-cultivated-virgin land	0-30	0.03	0.09	7.7	3.6	3.2	2.4	29	32.25	15
Fallow field/control	0-30	0.06	0.2	7.8	3.0	2.2	1.5	21	30.75	9.75
Wheat - *(Triticum aestivum)*										
2014	0-30	0.08	0.250	7.2	2.9	4.2	1.8	24	28.75	12.5
2015	0-30	0.01	0.395	7.4	2.5	3.1	1.8	21.5	28	9
2016	0-30	0.01	0.296	7.93	2.6	2.7	0.9	23	24.32	7.55
Average		0.06	0.313	7.5	2.67	3.3**	1.5	22.8**	27.02*	9.98*
Pea - *(Pisum sativum)*										
2014	0-30	0.07	0.240	7.7	3.2	2.6	1.9	27.5	33	10.5
2015	0-30	0.08	0.246	7.6	2.6	3.6	2.1	23.5	35	11.5
2016	0-30	0.08	0.244	8.5	3.06	3.5	1.3	22	28.1	5.1
Average		0.05	0.243	7.9	2.94	3.2**	1.77	24.3**	32.03*	9.03*
White clover -*(Melilotus albus)*										
2014	0-30	0.07	0.220	7.1	3.4	2.6	2	27	30.25	12.5
2015	0-30	0.06	0.212	6.6	2.2	3.3	1.65	16	39	13.3
2016	0-30	0.13	0.406	7.8	2.4	4.6	1.2	22	25.2	8.6
Average		0.07	0.279	7.1	2.66	3.5**	1.61	21.6**	31.48*	11.5*
Alfalfa - *(Medicago sativa.L)*										
2014	0-30	0.03	0.288	8.2	3.5	2.4	1.65	20	28.75	12.75
2015	0-30	0.05	0.171	7.5	2.6	3.8	1.8	29	37	13.6
2016	0-30	0.09	0.280	8.1	3.2	5.4	1.1	21	26.9	7.2
Average		0.04	0.246	7.9	3.1	3.87**	1.52	23.3**	30.88*	11.2*
Crested wheatgrass - *(Agropyron cristatum)*										
2014	0-30	0.04	0.120	8.1	3.01	1.3	2.08	30.5	26	13.75
2015	0-30	0.004	0.150	7.5	2.1	1.7	2.75	27	32.7	17.4
2016	0-30	0.12	0.368	7.8	2.6	3.1	1.07	25	22.5	7.5
Mean		0.05	0.212	7.8	2.57	2.03**	1.97	27.5**	27.06*	12.88*

(Statistical Analysis: * - (P value≤0.05); **- (P value≤0.01))

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As shown in (Figure 3), nitrogen content of the soil is comparable to that of the legume crop, ranging from 3.28 to 3.85 mg/100g. However, in contrast, nitrogen content of the crop of beans is notably lower at 2.1 mg/100g. This pattern confirms that nitrogen is accumulated and increased in the soil by leguminous plants (p=0.0026).

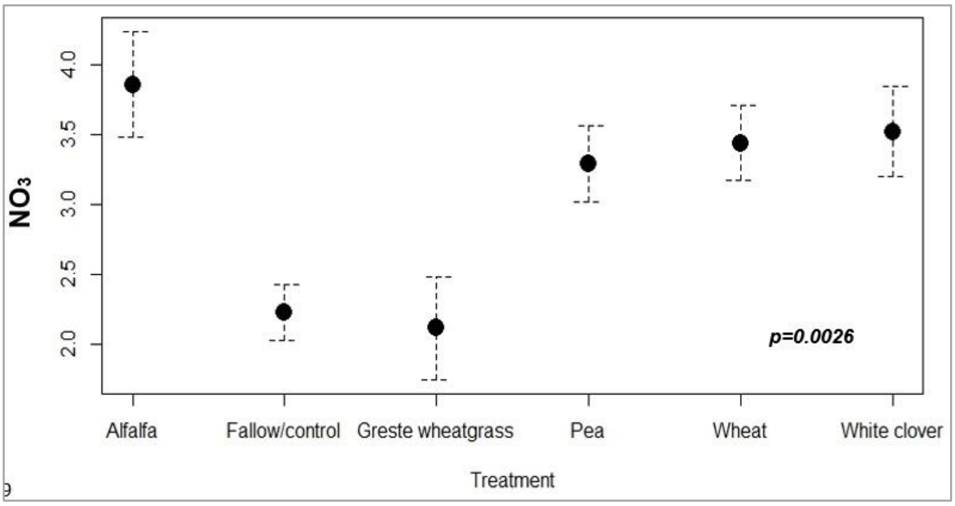

Figure 3. The effect of cultivation plants on the nitrate nitrogen content in soil mg/100g

Based on the data presented (Figure 4), the average impact of content and bean cultivation on soil mobile phosphorus content was 1.48-1.93 mg/100g. No significant variation was observed between the two crops, and their influence on mobile phosphorus levels in the soil was consistent throughout the plant growth period.

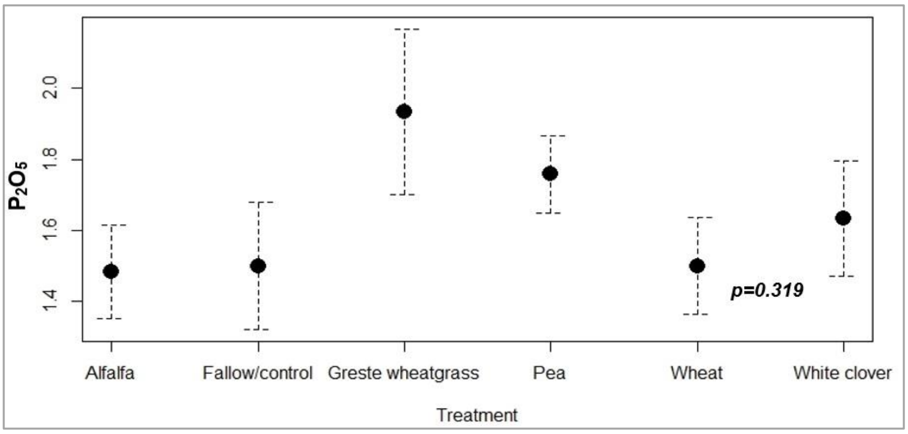

Figure 4. The effect of cultivation plants on the content of mobile phosphorus in the soil mg/100g

According to the data presented (Figure 5), potassium content in the soil is comparable to that of the soil modified with annual beans, ranging from 22.8 to 24.4 mg/100 g. However, potassium content in the soil amended with perennial sedge is 3.1 mg/100 g higher than that of the soil changed with white clover, at 21.75 mg/100 g, with a standard deviation of 7.78. The result was statistically confirmed (p=0.0098)

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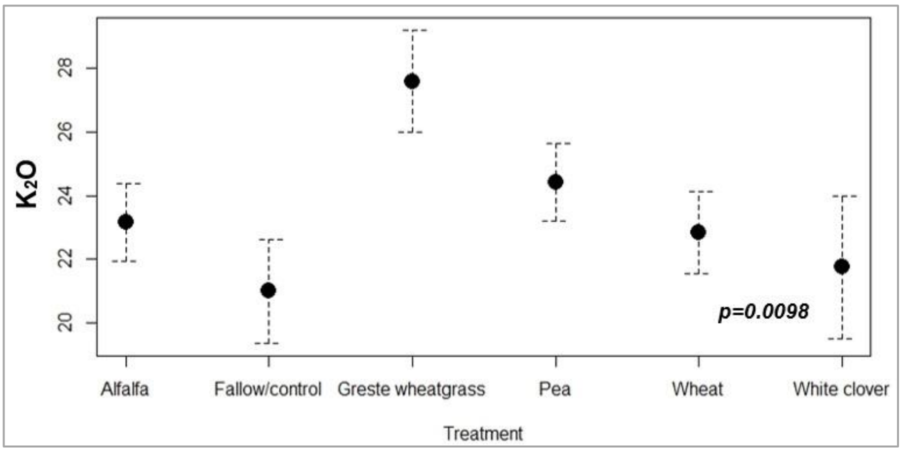

Figure 5. Effect of cultivation plants on mobile potassium content in soil mg/100g

The physical characteristics of the soil were assessed at the experimental site by measuring its density, solid density, and infiltration in both the virgin – non-cultivated site and closed fallow areas, as illustrated in Table 2.

The conditions that were present in the virgin area were as follows: 3.6 per cent humidity, 1.2 g/cm^3 general density, 2.3 g/cm^3 solid part density, and 47.82 per cent infiltration. In contrast, the closed fallow area had 1.2 per cent humidity, 0.1 g/cm^3 higher general density, 0.1 g/cm^3 solid part density, and 6.34 per cent different infiltration. According to the findings, the proportion of infiltration is decreasing, and the compaction can be explained by the use of cultivation methods [8].

Table 2. Indicators of general physical properties of soil

№	Version	Moisture%	General density, g/cm3	Density of soil solids, g/cm3	Infiltration,%
1	Non-cultivated-virgin land	3.6	1.2	2.3	47.82
2	Fallow field/control	4.8	1.10	2.4	54.16
	Difference	**1.2**	**0.1**	**0.1**	**6.34**
3	*Wheat (Triticum aestivum)*	4.37	1.17	2.43	52.11
4	*Pea (Pisum sativum)*	5.27	1.22	2.42	49.77
5	*White clover (Melilotus albus)*	4.20	1.19	2.4	51.22
6	*Alfalfa (Medicago sativa.L)*	4.97	1.21	2.5	52.08
7	*Crested wheatgrass (Agropyron cristatum)*	4.97	1.20	2.4	50.49

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The results of the dry and wet methods that were used to determine the aggregate structure of the soil are presented in Table 3. In the soil at a depth of 0-30 cm, aggregate structure of leguminous and leguminous plants in the control or closed fallow treatment in 2014 was 17.3 per cent using the wet method. In the soil planted with cultivation in the experimental years 2014-2016, aggregate structure ranged from 14.67 to 29.17 per cent.

Moreover, optimal resistance to water and structure is achieved by washing the soil with water using the wet method. This results in a 29.17 per cent or 11.87 per cent increase in structure for the multi-stage plant *(Agropyron cristatum)* compared to the control. However, the structure is disrupted by the annual one-year leguminous crop plant pea (*Pisum Sativum*), which contributes to a poor structure by a range of 12.5-16.5 per cent.

Table 3. Comparison of dry and wet soil aggregate structure, in percentage

Version	Soil depth /cm/	2014		2015		2016		Average	
		Dry method	Wet method	Dry method	Wet method	Dry method	Wet method	Dry method	Wet method
Non-cultivated-virgin land		58.7	31.3	-	-	-	-	58.7	31.3
Fallow field/control	0-30	38	17.3	-	-	-	-	38	17.3
Wheat (Triticum aestivum)	0-30	33.5	23.5	24.5	10.3	21	15	26.33	16.27
Pea (Pisum sativum)	0-30	23.5	16.5	30.5	15	24	12.5	26.00	14.67
White clover (Melilotus albus)	0-30	27	12	40.5	24	48	20.5	38.50	18.83
Alfalfa (Medicago sativa.L)	0-30	26	12.5	34	21.5	45.5	24.5	35.17	19.5
Crested wheatgrass *(Agropyron cristatum)*	0-30	47.5	25	52.5	30	51.5	32.5	50.50	29.17

The data presented in Table 4 indicates that the proportion of bacteria contributing to the increase of soil nitrate nitrogen and mobile phosphorus ranged between 14.8 and 33.3 per cent respectively in the fallow field/control.

However, in the treatments containing *Pisum sativum, Melilotus albus*, and *Medicago sativa.L*, the previously mentioned percentage exhibited a notable increase, ranging from 66.7 to 85.2 per cent in comparison to the control category. The leguminous plant residues improved the fertility of the rapidly decomposing soil [10].

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Table 4. Effect of some biological parameters on soil fertility (2014-2016)

Treatments	Number of free-living soil nitrogen-fixing microorganisms, 1 g of soil	Number of microorganisms involved in soil phosphorus transformation, 1 g of soil	Total bacteria count, 1 g of soil	Number of molds and fungi, 1 g of soil,
Non-cultivated-virgin land	$2.2*10^{5}$	$5.5*10^{5}$	$7.7*10^{5}$	$2.7*10^{-1}$
Fallow field/control	$1.4*10^{5}$	$2.4*10^{5}$	$3.8*10^{5}$	$1.4*10^{-1}$
Wheat (Triticum aestivum)	$6*10^{5}$	$6.95*10^{5}$	$12.95*10^{5}$	$6.5*10^{-1}$
Pea (Pisum sativum)	$6.8*10^{5}$	$8.2*10^{5}$	$15*10^{5}$	$4.5*10^{-1}$
White clover (Melilotus albus)	$4.7*10^{5}$	$6.9*10^{5}$	$11.6*10^{5}$	$5.8*10^{-1}$
Alfalfa (Medicago sativa.L)	$9.5*10^{5}$	$6.4*10^{5}$	$15.9*10^{5}$	$11.7*10^{-1}$
Crested wheatgrass *(Agropyron cristatum)*	$4.0*10^{5}$	$3.15*10^{5}$	$7.15*10^{5}$	$7.5*10^{-1}$

Based on the findings presented in Table 5, organic residue analysis reveals that the fallow/control group exhibited an accumulation rate of 11.3 per cent. In the experimental situations, the average accumulation ranged from 10.4 to 12.26 per cent from 2014 to 2016. Notably, white clover scenario showed the highest accumulation rate, approaching almost 12.26 per cent.

Table 5. Effect of some biological parameters on soil fertility (2014-2016)

№	Treatments	Soil depth /cm/	Organic residue, %			Average
			2014	2015	2016	
1	Non-cultivated-Virgin land	0-30	13.45	-	-	**13.45**
2	Fallow field/control	0-30	11.3	-	-	**11.3**
3	Wheat /*Triticum Aestivum*/	0-30	12.5	13.32	7.6	**11.14**
4	Pea /*Pisum sativum*/	0-30	11.4	12.9	8.5	**10.93**
5	White clover /*Melilotus albus*/	0-30	13.4	13.8	9.6	**12.26**
6	*Alfalfa /Medicago sativa.L/*	0-30	11	13.3	8.2	**10.83**
7	Crested wheatgrass /*Agropyron cristatum*/	0-30	11.2	11.8	8.2	**10.4**

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A characteristic feature of the soil is its fertility. It is different from mountain rocks. Each soil is different in fertility, and fertile soil has full roots to reap bountiful harvests. The main goal of agricultural production is to increase soil fertility and use it without damaging it. "Soil fertility is the ability of the soil to provide water, air, heat, and nutrients necessary for the life of plants [9]. In our study, in the central agricultural region of Mongolia, annual and perennial soybean crops adapted to climate change were placed in 5 fields of fallow, fallow, grain, legumes, and perennial plants. They determined its effects on soil resources and active fertility. The positive effects of cooperative cultivation for food and fodder on the recovery of soil fertility on wheat yield are being determined and shared with the producers.

1. In our research, legumes have shown to have a high protein content and play an important role in meeting the needs of livestock and human food, while enriching the soil with nitrogen and increasing the yield of other crops.

Atmosphere contains between 79 to 80 per cent nitrogen, meaning that most legumes obtain more than 70 per cent of their nitrogen needs from the atmosphere [4]. After seed harvests, legumes, such as cowpeas, pigeon peas, green gram, and groundnuts generated positive net nitrogen balances of up to 136 kg N ha-1 [16]. Recently, it was discovered that biological nitrogen fixation (BNF) accounted for approximately 50 and 60 per cent of the nitrogen requirement in legumes [17]. The amount of nitrogen fixed varied widely depending on crop management conditions, with the percentage of transfer to related crops ranging from 0 to 70 per cent, as noted by several writers [3, 11]. The net nitrogen balance would decrease even more from 28 to 104 kg N ha-1, if residues were removed from the field [16]. These differences are explained by the legume's variety, maturity period, and biomass production [18]. Rhizobium inoculation could enhance this process by increasing N2 fixation, plant yield, and seed quality [5].

However, according to (Graph 1) based on the outcomes of our research, the nutrient supply in the soil-cultivated field of *Fabaceae* displayed an average increase in mobile element nitrogen by 1.0-1.67 mg/100 g, or 45-75.9 per cent (p-0.0048). According to a study conducted in Buriat, Russia, the activity of soil fiber decomposition was 76.7 per cent in green-manured fallow, 72.3 per cent in plowed fields, and 50.1 per cent in clean fallow [6]. (Table. 4). The counting of nitrogen-fixing free-living microorganisms was $1.4*10^{-5}$ in the control or pre-planting fallow scenario, while the average of the 2014-2016 scenarios was $9.5*10^{-5}$ in the yellow alfalfa scenario, or b 85.2 per cent more than the control scenario. A large or significantly increased result is visible.

2. It has been found that plants improve the structure of the soil, which is of practical importance in research, as it provides an opportunity to reduce and prevent soil erosion and damage in agricultural fields.

In this study, the distribution of water-stable soil aggregates in each plant restoration phase was mainly dominated by >2 mm size. This type of filler structure is the possible resistance to hydraulic distribution, and its number and distribution indicate stability and soil structural resistance. The soil structure tended to stabilize with vegetation restoration, with surface soils having a higher degree of aggregation than underlying soils. The soil water-stable aggregates at each vegetation restoration stage were mainly larger than 2 mm, and the MWD markedly increased with vegetation restoration [20].

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However, in our research, (Table 3) the aggregate structure in the soil planted by crops in 2014-2016 is 14.67-29.17 per cent, which is the best water resistance and structure when the soil is washed with water by wet method. The perennial plant Crested wheatgrass - *(Agropyron cristatum)* increased by 29.17 per cent or it was by 11.87 per cent more than the control scenario. This is similar to the 2024 article and the above research paper. Based on this pattern, our research shows that using cultivated perennials and legumes can further increase soil fertility and improve aggregate structure stabilization.

CONCLUSIONS

The conclusions drawn from the findings of the study concerning the impact of cereals and legumes on multiple indicators of soil fertility are as follows:

- Based on the outcomes of our research, the nutrient supply in the soil-cultivated field of *Fabaceae* displayed an average increase in mobile element nitrogen by 1.0-1.67 mg/100 g, or by 45 to 75.9 per cent (p-0.0026), in comparison to the control soil. The potassium content in the *Agropyron Cristatum* field surpassed that of the control by 30.95 per cent (p-0.0098), as confirmed statistically.
- The investigation discovered that the primary factors influencing soil fertility and the improvement of the perennial *Agropyron Cristatum* structure had a statistically significant impact of 29.17 per cent, more the control scenaior by 11.87 per cent (p-0.0052).
- In the fallow field/control, the proportion of microbes that contributed to the rise of soil nitrate nitrogen and mobile phosphorus varied between 14.8 and 33.3 per cent. In contrast, this value was considerably greater in variants incorporating *Pisum sativum, Melilotus albus*, and *Medicago sativa.L*, ranging from 66.7 to 85.2 per cent greater than the control scenario. The decomposition of residues from these *Fabaceae* crops was reported to undergo rapid mineralization, leading to an improvement in the fertility of the soil.
- *Melilotus albus* demonstrated a 12.26 per cent higher level of soil fertility and organic residue compared to other crops. Furthermore, it displayed a moderate correlation with the rate of soil cellulose decomposition (r=0.51). The rate of decomposition was found to be higher in comparison to the *Poaceae* crop (*Agropyron cristatum*).

Acknowledgments

We would like to express our sincere gratitude to the peers for their guidance and judgment of the publication of this article. M. Hishigjargal, teacher of the Ecology Department of the Agricultural University and (Ph.D), and Lieutenant B. Odgerel, Head of the Department of Economics and Resources of the University of Internal Affairs.

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