Changes in humus content on the territory of agricultural lands in the Issyk-Kul basin of Kyrgyzstan

Tolomush Kurenkeev[1], *Gulmira* Sariyeva[1*], *Chynara* Asanbekova[1], *Nazira* Abdyramanova[1], and *Rahila* Niiazova[2]

[1]Issyk-Kul State University n. a. K. Tynystanov, Department of natural sciences, 722200 Karakol, Kyrgyzstan
[2]Issyk-Kul State University n. a. K. Tynystanov, Department of economics, finance and taxation, 722200 Karakol, Kyrgyzstan

Abstract. The Issyk-Kul valley of Kyrgyzstan has very large diversity of soil types which is developed by complex of abiotic and biotic factors including mountain-valley landscapes and different climatic conditions. We found that there is a process of significant loss of humus content in almost all studied areas of the Issyk-Kul region, both in the upper and lower layers of the soil. The humus content has been significantly decreased in the upper layer of valley soils during the past four decades. Among them, mountain-valley chestnut and dark chestnut soils, represented in the Issyk-Kul region, showed themselves to be the most depleted. Here, the difference in humus content between the top arable and non-arable layers is 40%. More stable humus content is shown in the mountain light chestnut and mountain-valley light brown soils, presented in certain areas of the Ton, Ak-Suu and Tyup districts. Apparently significant decrease in the humus content in chestnut soils is associated with intensive long-term anthropogenic use, including non-compliance with agrotechnical standards.

1 Introduction

Agriculture is one of the main sectors of the economy of Kyrgyzstan, although over the past 30 years its share in GDP has decreased from 20 to 7%. One of the reasons for the deterioration of the situation is a decrease in crop yields due to soil degradation, which is affected by both climate change and increasing anthropogenic influence. The Issyk-Kul region is located in the northeastern part of the Republic and is famous for cultivating of different agriculture crops, cereals, fruits and berries [1]. Chestnut soils occupy 2238.9 thousand hectares of the foothill plains of Northern Kyrgyzstan and the intermountain troughs of the Central Tien-Shan. During last 30 years, a transfer of agriculture land to private ownership followed by uncontrolled use of chemical fertilizers and pesticides, non-compliance with crop rotation. All these factors in recent decades have led to a decrease in

* Corresponding author: sarieva.g@iksu.kg

soil quality indicators, which is manifested in a decrease in agricultural yields and GDP [2]. At the same time, there are practically no studies of the chemical composition of arable soils in the Issyk-Kul region, so the purpose of this study was to conduct a comparative analysis of the qualitative composition of intensively used lowland arable and foothill non-arable lands.

2 Materials and Methods

The object of the study was the soils of 3 districts of the Issyk-Kul region: Ton, Issyk-Kul and Ak-Suu, as well as mountain light chestnut soils of the Kok-Moinok village administration located in the Ton region and mountain-meadow alpine soils of the "Karakol National Natural Park" of Ak-Suu district (Table 1).

The general altitude of the study area is from 1600 to 2400 m above sea level. The Issyk-Kul valley is closed on all sides by the high ridges of Terskey and Kungey Ala-Too that creates large diversity of local climatic conditions: from severe continental till mild humid [1]. Due to the dry climate of the western part of the region, gray-brown desert rocky soils are replaced by light brown, chestnut and black soils in the east of the valley, where the climate is comparatively more humid.

The soil samples were taken from genetic horizons to the entire depth of the soil profile in the spring and early summer of 2015-2016. Agrochemical analyzes were carried out in the laboratory of soil agrochemistry of the Kyrgyz Research Institute of Soil Science. To determine the content of organic matter in the soil, the amount of plant residues and humus was determined separately. Plant residues were isolated from the soil using a dry or wet method, after which their quantity was determined [3]. To determine the amount of humus, a chemical analysis of the soil determined the carbon content of decomposed organic matter in the soil. To determine organic carbon, the soil analysis laboratory used the oxidometric method of analysis. The amount of soil weighed was taken depending on the target humus content: 0.05 – 1 gram for black soils, about 1 gram for light gray soils.

3 Results and Discussion

The results showed the maximum humus content in the upper layer of both non-arable and arable lands of only three places - Zhergalan, San-Tash and Karakol National Park (Figure 1). In all other places we found a decrease of humus content in the top layer compare to non-arable lands: the most significant humus loss was shown in the mountain-valley chestnut soils around Ananyevo and Chon-Sary-Oy villages (Issyk-Kul district) - to 40%. In the Ak-Suu district, the humus content in arable lands decreased by 29%, in three other agriculture areas - Kok-Moinok (Ton district), San-Tash (Tyup district) and Zhergalan (Ak-Suu district) the humus loss was 12-14% and the smallest difference in this parameter was established by light brown mountain-valley soil of the Ton district (Bar-Bulak), which amounted to only 3-5% between arable and non-arable soils (Figure 1).

Table 1. Territorial distribution of the studied soils of the Issyk-Kul basin

Slit ,№	Soil type	Location	Character of use	Depth, cm
1	Light brown mountain-valley soils	Ton district Bar-Bulak village	Foothill non-arable land	0-20
				20-50
2			arable land	0-20

				20-50
3	Brown mountain-valley soils	Issyk-Kul district Ananievo village	non-arable land	0-30
				30-59
4			arable land	0-30
				30-59
5	Dark brown mountain-valley soils	Issyk-Kul district Chon-Sary-Oi village	non-arable land	0-22
				22-52
6			arable land	0-22
				22-52
7	Dark brown mountain-valley soils	Ak-Suu district Kerege-Tash village	non-arable land	0-17
				17-29
8			arable land	0-17
				17-29
9	Soils of mountain slopes. Mountain light chestnut soils	Ton district. Kok-Moynok village	non-arable land	0-10
				10-30
10			arable land	0-10
				10-30
11	Soils of the forest-meadow-steppe belt of the middle mountains. Mountain black soils	Ak-Suu district Zhergalan village	non-arable land	0-15
				15-30
12			arable land	0-15
				15-30
13	Mountain meadow-steppe subalpine soils	Tyup district San-Tash village	non-arable land	0-12
				12-32
14			arable land	0-12
				12-32
15	Mountain meadow alpine soils	Ak-Suu district National Natural Park “Karakol ”	non-arable land	0-6
				6-21
16			arable land	0-6
				6-21

For comparison, in the territory of the Karakol National Natural Park, where the land is not used for growing crops, the humus content in the upper layer remains consistently high (Figure 1).

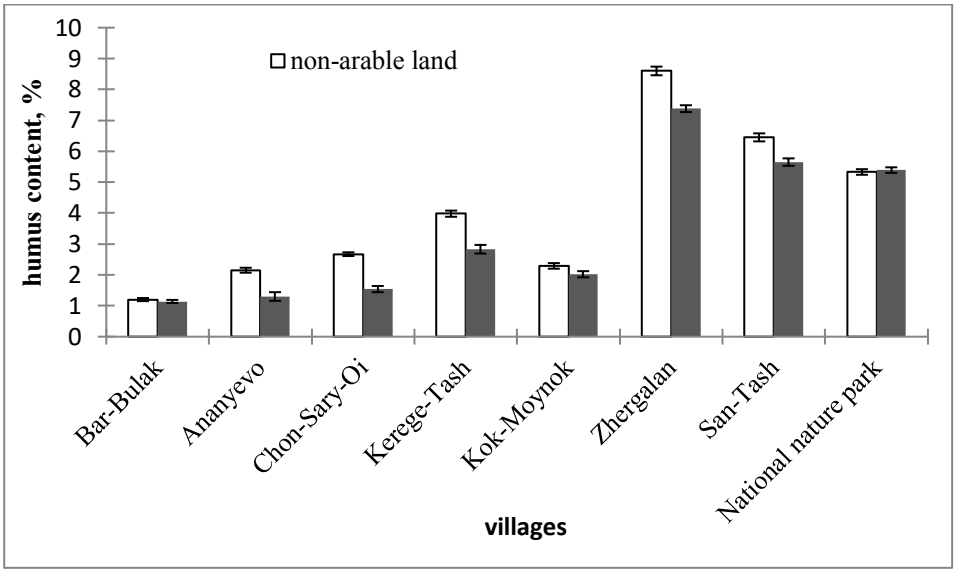

Fig. 1. Humus content in the top layer of soil in the villages of the Issyk-Kul region.

The results of comparing the humus content in the lower horizon (from 6 to 50 cm) are shown in Figure 2. The greatest decrease in humus in arable lands was found in the Chon-Sary-Oy village (by 44%), Zhergalan and San-Tash (by 23% and 14%, respectively).

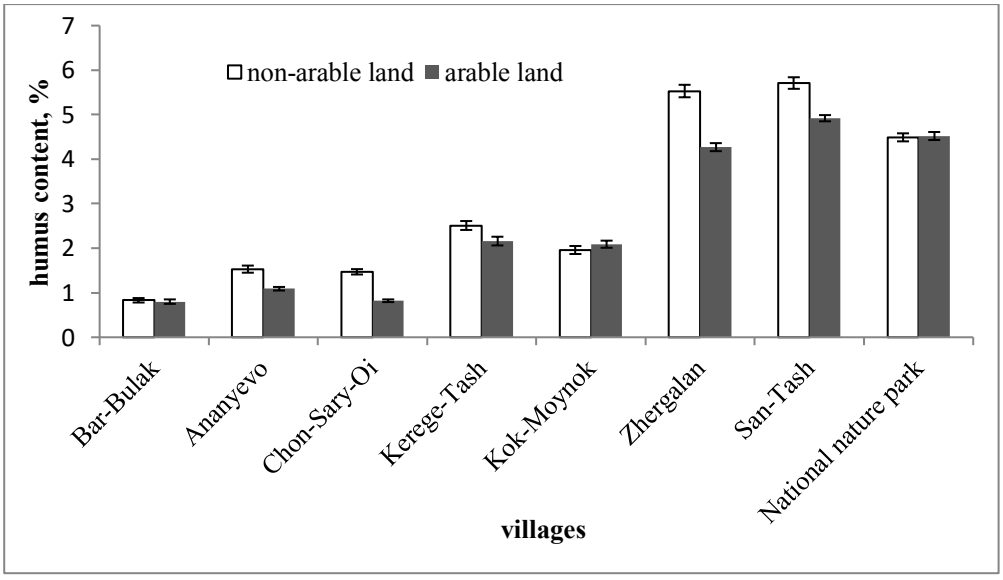

Fig. 2. Humus content in the lower horizon of soil in the villages of the Issyk-Kul region.

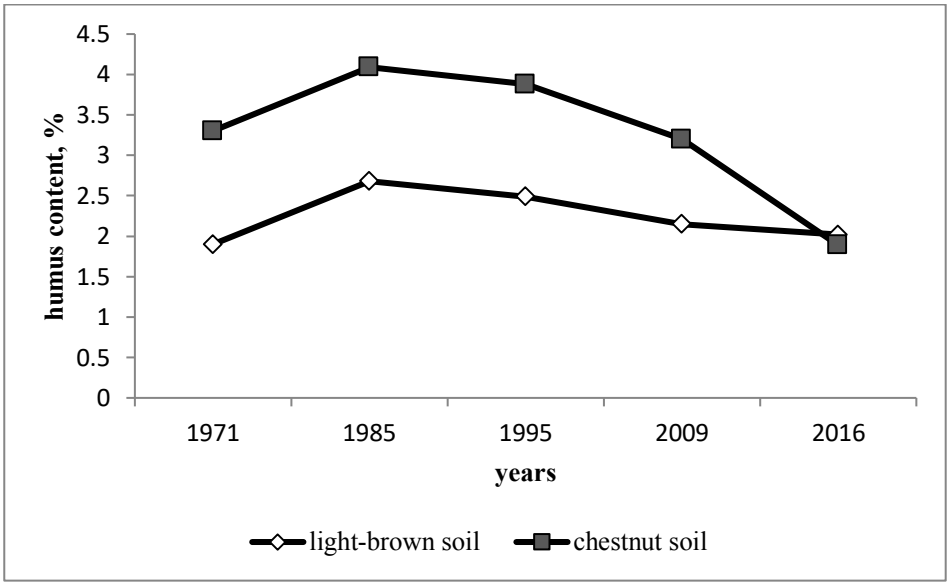

Fig. 3. Long-term dynamics of humus content in the upper arable layer in the Issyk-Kul region. Data for 1971-2009 were taken from source [4].

Comparative analysis of humus content in the upper arable layer in the Issyk-Kul region in the period 1971-2016 has shown significantly decrease (Figure 3), especially in chestnut soils, against the background of an almost unchanged humus content in light chestnut soils. Our data are consistent with the results of other authors, who also stated that the mountain dark chestnut soils of Kyrgyzstan are characterized by both low and average fertility, the humus content in the top layer of soil is in the range of 2,0–6,2% [5,8]. The chestnut and light-brown soils are different in morphology, clay fraction chemistry, mineralogy and are supposed to be very different in content, distribution, and composition of soil organic matter [9]. The high humus content in black-brown soils is attributed to the continuous organic matter input from the forest litter or grasses [6, 7]. There are also evidences in the literature that the loss of humus in the depths of arable horizon in the Issyk-Kul region of Kyrgyzstan from 1972 to 2000 ranged from 19 to 57%, depending on the degree of erosion [5]. According to this research, the chestnut soils, including soils of intermountain troughs, reduce their productivity by 1–13 points, light chestnut soils – by 1–7 points, and low-humic black soils by 10–18 points [2]. Soil fertility depends on the humus content and mineral substances in the arable layer. The loss of humus in the upper layers of soils is related to continuous decrease of input of fresh organic matter on the soil surfaces as well as lower microbial activity in the top layer of soil, which are the main factors affecting humification [6]. The decrease of microbial activity in the upper layers could be related to over-use of chemical fertilizers that is very common in Kyrgyzstan. From the other side, it was estimated that the climate change makes a significant contribution to the Soil-Ecological Index (SEI) in the Southern Kyrgyzstan [5]. As to light-brown soils, they are classified as low-productivity soils in terms of SEI, but they are more provided with elements of mineral nutrition: the amount of nitrogen is 0,10–0,25%, of phosphorus – 0,20–0,30%, of potassium – 2,0–2,5 % [3]. We have found that such kinds of soils are presented in the Ton district with an average level of fertility 1-2 %.

Thus, soil degradation causes Kyrgyzstan a great economic damage, reducing crop yields by 20–60% [2,4]. Intensive use of soils as arable and fodder lands led to their unsatisfactory condition, since 88% of lands are subjected to the degradation processes.

4 Conclusion

The present study demonstrates that there is a process of significant loss of humus content in almost all studied areas of the Issyk-Kul region, both in the upper and lower layers of the soil. The most depleted in organic matter soils are mountain-valley dark chestnut ones. The decrease in humus content in them over 45 years is almost 50%. But the humus content in light chestnut soils is almost unchanged during 45 years and still remains at a high level. Excessive use of arable land in the Issyk-Kul basin led to a decrease in the fertile state of both the upper and lower layers from 14 to 40%. Apparently, this is due to the long-term use of arable land without following the norms of agricultural technology: water erosion followed un-normed irrigation, over-use of chemical fertilizers, incorrect or in many cases no rotation, over-use of close to village's arable lands for autumn pastures. All of these factors are artificial, so, the fertility loss of arable soils in Northern Kyrgyzstan is more related to anthropogenic influence than climate change.

Taking into account the ecological situation of the Issyk-Kul basin, it is necessary to use fertilizers, preferably organically produced (biocomposts, biopreparates of microbial origin).

Authors' contribution

K.T.K. executed the study; S.G.E. prepared the manuscript, and interpreted the study; A.Ch.A. and A.N.T. contributed to the concept and study design, N.R.T. has analyzed statistical data.

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