

# Assessment of carbon store by spruce plantations in forest ecosystems of Kyrgyzstan

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**Abstract.** High-altitude spruce forests of Kyrgyzstan are the main part of the forest system of Kyrgyz Republic. Due to the high ability of spruce for C (carbon) storage, the forests of Northern Kyrgyzstan (the Issyk-Kul and Naryn regions) accumulate a large amount of C in their bark and wood. The total C stock in the forests of three regions with the largest area covered by the Tien-Shan spruce (Issyk-Kul, Naryn and Chui) is about 1901415 t. Additionally to the C storage the high-altitude spruce forests can fix a large amount of C per year, for example, only in the Issyk-Kul region the forests with the total area of 142360 ha and annual growth rate of 868396 m<sup>3</sup> absorb approximately 514872 t C/year. These values indicate that spruce forests in Kyrgyzstan play a major role in C uptake and should be protected and continuously recovered by plantation and introduction. Further analysis of storage ability, emission and fixation of CO<sub>2</sub> by the forests ecosystems of Kyrgyzstan should be provided.

## 1 Introduction

The territory of Kyrgyzstan, like Central Asia as a whole, is in fact not a so-called forest region. However, despite the fact that the forested area in the country is limited, the forests of Kyrgyzstan are not only a source of timber, fruits and other valuable products, but also play an extremely important protective, environmental and climate-regulating role. Due to their rich biological diversity, their importance extends far beyond national boundaries, and some are of global importance.

The climate-regulating role of forests is associated with the deposition of atmospheric C, which allows, to some extent, to balance CO<sub>2</sub> emissions into the atmosphere. Forests are land use systems with high tree population, which play a major role in C sequestration. Forest ecosystems store more than 80% of all terrestrial aboveground C and more than 70% of all C [1, 2]. At the last decades, forests are being considered as the main factor of climate change mitigation, as they are at the same time a source and sink for C [3-5]. The accumulating role

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of forests is studied in different ecological regions of the world [6-8], however in Kyrgyzstan such kind of analysis is performed partially, in different types of forest [9-10]. For estimation of the amount of C contained and sequestered in spruce forests of Kyrgyzstan, were carried out additional studies related to the assessment of plant biomass. The purpose of the current study was to assess C reserves in the wood of Tien-Shan spruce (lat. *Picea schrenkiana* subsp. *tianschanica*) in the different forest ecosystems of Kyrgyzstan.

## 2 Materials and Methods

The spruce samples were collected in three climatic zones of Kyrgyzstan; Issyk-Kul, Naryn and Chui. Due to the mountainous landscape the spruce forests there grow within 3 altitudinal forest belts: lower (from 800 m to 1500 m), middle (1500-2500 m) and the upper sub-belt, over 2500 m above the sea level (Fig. 1).

### 2.1 Forest growing areas of Kyrgyzstan

In accordance with the sharp difference in environmental and climatic conditions and in the composition of forest-forming tree species, the territory of Kyrgyzstan is divided into the regions – northern and southern, with the following forest growing areas identified in them:



**Fig. 1.** Division of Kyrgyzstan into climatic and forest regions. I. Turkestan-Alai; II. Fergana-Alay; III. Fergana-Chatkal; IV. Chatkal; V. Talas; VI. Chui-Kemin; VII. Issyk-Kul; VIII. Internal Tien-Shan.

The distribution of forest growing areas of the republic relative to climatic regions is as follows:

Southwestern – Turkestan-Alay (I), Fergana-Alay (II), Fergana-Chatkal (III), Chatkal (IV) – Fergana and Alai valleys with their mountain frame, walnut-fruit, juniper and partially floodplain forests;

Northwestern – Talas (V), Chui-Kemin (VI) – Talas, Chui and Chon-Kemin valleys with their mountain frame, coniferous and floodplain forests;

North-eastern – Issyk-Kul (VII) – Issyk-Kul valley with a mountain frame, spruce forests;

Inner Tien-Shan – Inner Tien-Shan (VIII) – mountainous areas lying south of the Talas, Kyrgyz, Terskey Ala-Too ridges and east of the Fergana ridge with spruce, fir and floodplain forests.

## 2.2 Spruce forests

The main species of mountain forests in Kyrgyzstan is the Tien-Shan or Schrenk spruce (*Picea schrenkiana* Fish. et Mey.).

Due to the climate and landscape conditions, the spruce forests are concentrated mainly in the northern part of Kyrgyzstan on the slopes of Kungey and Terskey Ala-Too ridges, as well as in the Naryn river basin. This spruce species is distributed throughout all sub-zones of the mountain forests, and their upper zone can reach 3500 m above the sea level. The small part of Tien-Shan spruce is located on the slopes of Kyrgyz ridge, in the south of the republic.

## 2.3 Trial areas (PP)

Trial plots were laid out in accordance with the “Guidelines for forest inventory of the State Forest Fund of the Kyrgyz Republic”, as well as in accordance with the “Instructions for assessing forest stands and inventory during the forest management work”, approved by the State Agency for Environmental Protection and Forestry of the Republic of Kazakhstan [11,12].

Model trees were cut down at the level of the root collar. The total length of the tree from the cut and the length of the crown were measured. Then the age of the tree was determined by the number of growth rings on the stump. The trunk was marked by relative lengths – 0; 0.05; 0.1; 0.2; ... 0.9 N (where N is the total length of the tree). Disks were cut out near the marks. Laboratory analysis of the dry matter and C content in various parts of the tree (roots, trunk, bark, needles) was performed using standardized methods link.

## 3 Results and Discussion

C content in different part of spruce tree growing on the same exposure, but in different altitude is presented in Tables 1, 2. In the middle altitude of 2000-2040 m above the sea level the highest content of C is in the wood without bark, needles and shoots of trees, but at the higher altitude this parameter has decreased for needles and shoots and remained stable in bark and wood. This data demonstrates that C content in the bark of plantations increases with the altitude above the sea level. The carbon content in the wood and bark of Tien-Shan spruce in the range of 50-51 0% corresponds well with the numerous researches of coniferous tree species [8].

**Table 1.** Chemical analysis of different parts of Tien-Shan spruce, north-northeast exposure, altitude 2000-2040 m above sea level.

No.	Weight, mg	C, %	H, %	Ash	Part of the tree
26 (6.1)	5,010	43.96	6.24	5.18	bark
31 (6.2)	5,000	46.72	6.08	2.60	bark
36 (6.1)	4,250	45.53	6.55	0.94	wood without bark
41 (6.2)	4,800	52.47	6.73	2.08	wood without bark
35 (6.3)	4,680	49.51	6.86	0.21	wood without bark
28 (6.4)	4,890	51.06	6.08	4.09	needles
44 (6.5)	4,760	50.62	6.09	3.78	shoots
43 (6.6)	5.110	48.17	6.38	3.33	roots

**Table 2.** Chemical analysis of the different parts of Tien-Shan spruce, north-northeast exposure, altitude 2510-2562 m above the sea level.

No.	Weight, mg	C, %	H, %	Ash	Part of the tree
32 (7.1)	5,980	51.43	6.53	3.01	bark
27 (7.2)	5,660	46.05	5.80	2.47	bark
40 (7.1)	5,180	50.26	5.95	1.01	wood without bark
29 (7.2)	4,370	51.34	6.17	3.20	wood without bark
34 (7.3)	4,230	51.55	6.84	4.96	wood without bark
19 (7.4)	5,310	47.91	6.49	3.77	needles
38 (7.5)	5,540	45.67	5.47	0.54	shoots

It is well known that C reserves in the existing forests of the world are distributed according to the territorial and administrative divisions, regions, and predominant species. In this research we have determined C content in the spruce forests of Kyrgyzstan (Table 3). Based on the data obtained on the biomass in various parts of selected in Northern Kyrgyzstan spruce trees, the ratio of underground and aboveground parts, C content in them, was determined.

**Table 3.** BEF, R and CF values for the main dominant breed – pine.

Regions of Kyrgyzstan	BEF	R	CF, t C/t of dry weight
Issyk-Kul	1.21	0.34	0.49
Naryn	1.21	0.34	0.49
Chui	1.27	0.34	0.47

Where: BRF, biomass expansion factor; R, ratio of belowground biomass to aboveground biomass; CF, fraction of C in aboveground forest biomass.

The density of absolutely dry wood (D) and the biomass expansion factor (BEF) depend on the type of the forest, the age of the trees, growing conditions, tree stand density and climate [10]. Based on the data obtained on the biomass in various parts of selected trees, the ratio of underground and aboveground parts, C content in them and the average annual increment, C content in the spruce forests of three main growing regions was determined.

**Table 4.** Total C stock in the forests of Issyk-Kul, Naryn and Chui regions of the Kyrgyz Republic.

Region	General stock of spruce (m <sup>3</sup> )	Density absolutely dry wood (D), t d.w./m <sup>3</sup>	General volume of absolutely dry masses of wood by stock (tons of dry matter)	Carbon fraction in dry substance (CF), t C/t d.w.	Total carbon stock in forests, t
Issyk-Kul	4238000	0.42	1779960	0.49	872180.4
Naryn	3912000	0.41	1603920	0.49	785920.8
Chui	1294220	0.40	517688	0.47	243313.4
<b>Total:</b>	<b>9444220</b>		<b>3901568</b>		<b>1901414.6</b>

The most part of C is stored in the spruce forest of Northern Kyrgyzstan, two regions with similar climatic conditions – the Issyk-Kul (13% of total forest area) and Naryn (12%), and the small part of C is stored by the forest of Chui region (4%).

C sequestration by forest ecosystems occurs due to the growth of trees. The data in Table 6 demonstrates that the forest ecosystems of the Issyk-Kul region on an area of 142360 hectares annually absorb approximately 514872 tons of C.

**Table 5.** C fixation by spruce forest in the Issyk-Kul region with average area of spruce forest 142360 ha (according to the data of National forest inventory, 2010).

No.	Parameter	Value
1	Annual growth rate of trees, m <sup>3</sup>	868396
2	Biomass expansion coefficient (BEF)	1.21
3	Proportion of carbon in dry matter (CF)	0.49
4	<b>Annual fixation of C (<math>\Delta</math>CG), tons C/year</b>	<b>514872</b>

The data obtained in the three main forest regions of Kyrgyzstan made it possible to determine such values as the fraction of carbon in aboveground forest biomass (CF), the ratio of underground biomass to aboveground biomass (R), and the biomass expansion factor (BEF), which can be considered national.

Thus, according to the Guidelines, the CF for temperate conifers is recommended as 0.51, with a range of 0.47-0.55. According to the data obtained for Kyrgyzstan spruce, this indicator is equal to 0.49 for Northern regions – Issyk-Kul and Naryn. This value allows storage of aboveground C as approximately 1901414.6 t, which is quite high value comparing to the juniper forests located in the Southern Kyrgyzstan, the Batken and Osh regions [13]. In addition to C storage the high-altitude spruce forests can fix a large amount of C per year, for example only in the Issyk-Kul region the forests with the total area of 142360 ha and annual growth rate of 868396 m<sup>3</sup> absorb approximately 514872 t C/year. Further we should take into account carbon losses during the removal of wood and cutting.

The new data obtained makes it possible to adjust upward the default values recommended by the IPCC Guidelines related to the ability to fix and absorb C by forests of the Kyrgyz Republic. It also makes it possible to determine the contribution of forests to low-carbon development more accurately.

At the same time, it is necessary to establish additional studies of the water protection, water regulation, forest reclamation and protective functions of forests in the fragile mountain ecosystems. It is necessary to expand efforts to preserve and increase the area of forests, including plantations and gardens in the Kyrgyz Republic. These actions will provide additional opportunities for the country to determine the amount of CO<sub>2</sub> emissions reductions needed to meet its obligations under the UN Framework Convention on Climate Change.

## Conclusion

The spruce forests located on the slopes of Central Tien-Shan Mountains are distributed according to the altitude. In the middle altitude of 2000-2040 m above the sea level the highest content of C is in the wood without the bark, needles and shoots of trees, but at the higher altitude this parameter has decreased for needles and shoots and remained stable in the bark and wood. This data demonstrates that C content in the bark of plantations increases with the altitude above the sea level. C content in the wood and bark of Tien-Shan spruce is in the range of 50-51 0%. The most part of C is stored in the forest of the Northern Kyrgyzstan, two regions with the similar climatic conditions – Issyk-Kul (13% of total forest area) and Naryn (12%), and the small part of C is stored by one of Chui region (4%). The forest ecosystems of the Issyk-Kul region on an area of 142360 hectares annually absorb approximately 514872 t of C. The value of carbon factor (CF) of 0.49 allows storage of aboveground carbon as approximately 1901414.6 t, and only in the Issyk-Kul region the forests with approximately area of 142360 ha and annual growth rate of 868396 m<sup>3</sup> absorb 514872 t C/year. Thus, the high-altitude spruce forests of Kyrgyzstan contribute significantly to low-carbon development of the country and should be protected and increased for sustainable future of Central Asian region.

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