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Optimum Density and Space Structure of Kyrgyzstan's Juniper Stands for Identifying Water Protective Properties

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Abstract Central Asia including Kyrgyzstan is a disaster prone area, suffering from snow avalanches, landslides and flooding. Within the Tyan – Shan region, a mountainous region in Southern Kyrgyzstan, there is an increasing number of natural hazards over the last years. One of the possible causes of the increase in natural disasters in the region is the deterioration of the Juniper forests in the region. Juniper forests have a large economical and ecological importance for Kyrgyzstan. However, the conditions worsened for these juniper forests. Since 1980 approximately 20% of the juniper forests were lost due to intensive deforestation, forest fires and excessive cattle grazing and possibly also climate changes are affecting the juniper trees and their soil properties. The aim of this study is to investigate the impact of the juniper forest on the local hydrology and to characterize the water protective properties.

Key words Water protection, Forest Management, Juniper Species, Forest Density, Deforestation

1 Introduction

This article presents research results concerning the relationship between density and space structure of juniper stands and their water protective properties for the northern slopes of the Turkestan – Alai mountain chain. There are two exact antipodes of opinion about the impact of forest on precipitation enhancement. The first one says that forest, including mountain forest, enhances the precipitation from 1 – 3 to 15% – 20% in summer period and up to 70 – 80% in winter period. Examination of precipitation measuring accuracy detects the systematic measuring errors from 3% – 12% of liquid precipitation to 16 – 70% of solid precipitation. According to the second one, the roughness in mountain forest is 10 – 20 times as much as that in treeless areas. This intensifies the turbulent interaction and restrains the airflows what leads to extra precipitation and entrapment of horizontal precipitation, particularly in the context of high humidity[18 – 19]. Precipitation transfer in juniper stands (precipitation interception by juniper crowns, snow cover distribution and snow melting regime) is an issue of much interest[4 – 8, 14]. Forests have an important impact on snow accumulation, snow storage distribution and snow melting regime. The research works implemented in this direction mostly refer to plains; the same investigations related to mountain territories, in particular to juniper biogeocenoses of Kyrgyzstan, have not been carried out so far[3]. In mountains it is practically impossible to compare snow storage in the field and forest. Therefore, it is important to compare snow storage under shelter wood and in the nearest glade area; and for total woodland to calculate based on the amounts of these indicators with due consideration of proportion of their areas[1, 2, 9]. A peculiarity is the small number of precipitation events in the first half of winter period. The basic mass of snow is accumulated during February – March and snow storage grows to a maximum level; thereby the density of snow cover is not high. These conditions have a specific impact on the snowmelting regime of juniper stands. Snowmelt intensity is lower in forest than in glade and open areas; however, snowmelting is finished earlier here due to small snow storage[10 – 12].

Thus, protective properties of juniper stands are the extension of the snowmelting period, reduction of the intensity of water yield from snow and obstruction of production of snowmelt runoff. Juniper forests grow on steep mountainous slopes and in upstream areas where groundwater recharge occurs, they prevent soil erosion by water and wind, formation of mudflows, soil flows, mountain creeps, obstruct rapid snowmelting, destructive floods and secure groundwater runoff[15 – 17]. Moreover, forest entraps atmospheric precipitation; there is a relatively little research done on the distribution and interception of precipitation in mountain forests of Kyrgyzstan compared to the plains. The amount of precipitation interception is highly variable during vegetation period since the depth of precipitation is extremely irregular during the year. Water resources of South Kyrgyzstan sustain cross-border water supply as it supports the needs in water throughout the Fergana valley. The water supply plays an important role in maintaining environmental stability in many densely populated areas. However, the river discharge is subject to impact of climatic and anthropogenic changes, which leads to problems of increasing drought and security water as a source for drinking water supply. It also will impact irrigation issues and environmental state of water ecosystems[12, 19].

2 Overview of Juniper and Walnut forest ecosystems in Kyrgyzstan

The important challenge of global climate change is the as-

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sessment of "forest – water" interaction systems; therefore detailed investigation of the "forest – water" system is an important issue of this research work (Fig. 1). One of the problems within the "forest – water" system is connected with the threat of a possible reduction of potential snow storage in mountainous areas, which is expected to occur under global warming. The consequence will be a changed hydraulic regime of snowmelt and runoff. Climate in mountainous areas is different from the climate in the plains due to their high variability caused by the diversity of the landscape. Characteristic is the higher altitude, the lower temperature of water and soil and the increasing number of precipitation events up to a certain level, while the vegetation period decreases[13]. The main climatic peculiarity in the juniper forests belt is drought in the second half of the vegetation period. The average annual air temperature is 4.30 ℃ and annual amplitude is 20 ℃. The summer is comparatively cool, with June being the warmest month with an average temperature of 14.9 ℃ and a maximum temperature of 29.2 ℃. The coldest month is January with on average −5.1 ℃, absolute minimum −22 ℃. The warmest one is June.

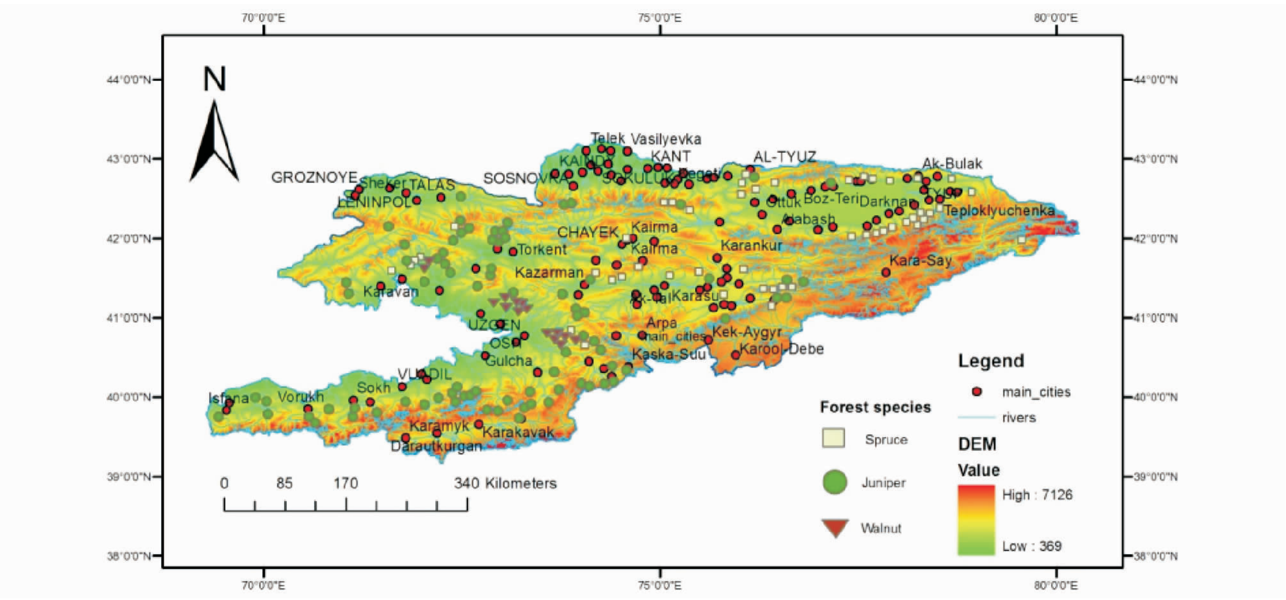

Fig. 1 Overview of occurrence of Juniper and Walnut forest ecosystems in Kyrgyzstan

The duration of the frostless season is 180 days on average April – September. Positive average daily temperatures are common from the middle April to the middle October, but cold spells occur frequently in late spring and early autumn. The soil moisture regime is completely dependent on the intensity of the precipitation distribution during the year. The average annual precipitation is 615 mm, most rainfall is observed in spring and the first half of summer (47% of annual amount). August – September, the second half of vegetation period is the period with minimal precipitation. After September the precipitation increases. The winter precipitation is 26% of the annual amount, and snow cover is observed from November to April and reaches 35 cm and rarely up to 70 cm. All rivers originating from the mountains flow into valley part of the Nookat region and belong to the Syr-darya river basin. In early spring some of them have manifold flow of temporary streams. The rivers are mainly glacier – and – snow – fed with a water regime that is typical for mountainous regions. The annual discharge regime of the rivers is distinctively divided into two periods: spring – summer floods and autumn – winter low discharges. The start of the flood season changes from year to year depending on the weather conditions of the year. Floods on the rivers of the Turkestan – Alai mountain chain start on average in early April and end in the second half of August. The maximum runoff is usually observed in June. Increase of runoff during the flood season depends on the dryness of the year and on average it ranges from 40 – 70 sm. The minimum runoff is observed in the pre – flood period.

3 Landsat image and land use of southern Kyrgyzstan Kara-darya basin

The data collected during the research allowed to prepare cartographic material. Landsat image demonstrates the state of tree, shrub and grassland vegetation, soil and other conditions (Fig. 2, 3). This allows using a differentiated approach for assessing natural resources and planning of actions in the investigated zone.

Studying the hydraulic peculiarities in the "forest – water" system requires modern research methods. Formation of snow cover, interception and distribution of solid precipitation and snow melting regime were defined on the basis of snow survey methods with the use of snow sampler and snow stake since the first permanent snow cover (October) once a month, and during the snow melting period more frequent every 3 – 5 days. Interception of liquid precipitation by the crown layer of junipers and shrubs was measured by use of precipitation gauges. The water-protective and water-regulating role of juniper stands is the conservation of soil moisture on the mountain slopes. By preventing formation of over-

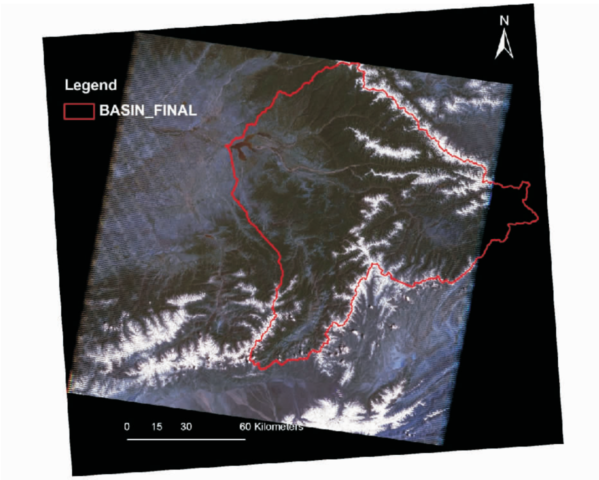

Fig. 2 Landsat image of southern Kyrgyzstan Kara-darya basin

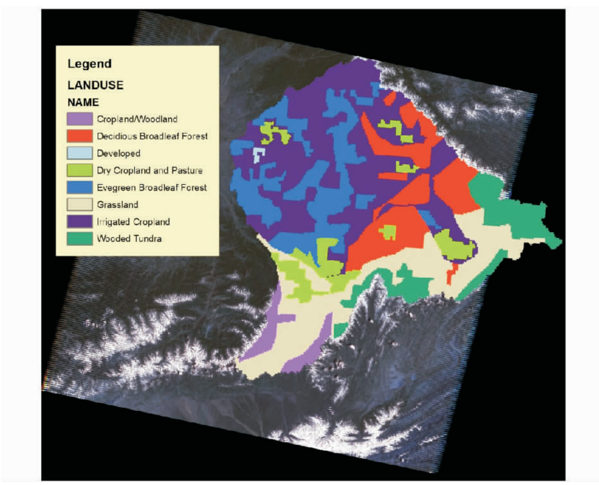

Fig. 3 Land use of southern Kyrgyzstan Kara-darya basin

land runoff and its transfer into deeper soil layers, they contribute to moisture accumulation in the soil and its use during the dry part of vegetation period. Also the slope-protective role of juniper stands is significant; it depends on the water and physical characteristics of the soil not only in high-density stands but even in open forests. Juniper forests have the strongest impact through mineralization of forest floor outputs and removal to lower areas by fertilizing soil with soil nutrients elements and improving soil structure. The soil types in the main areas of the juniper stands, which are more concentrated in middle – mountain and high – mountain subbelts, are distinguished by higher infiltration capacities compared to the treeless areas which influence the snow melting regime of juniper stands. The duration of the snow melting period depends on the weather conditions and varies from 0.5 to 1.5 month. The snow melting period in juniper stands extends up to 20 days compared to slopes which are treeless. The maximum rate of water loss from snow is balanced what prevents formation of snowmelt surface flow. There is no wind-driven snow resedimentation in the belt of juniper forests, even in open forests, what contributes to bedding snow cover and prevents descent of snow slips. This phenomenon is practically not observed when canopy density is already 0.3 – 0.4. Hence, also juniper stands reduce chance of avalanche formation. All this demonstrates the high adaptability of juniper to arid conditions and significant positive impact of juniper stands on hydraulic regime.

3 Conclusions

Forests play a key role in water resources production. Trees are water consumers but on the other hand they protect soils and increase water productivity. Our findings show that the slope-protective role of juniper stands to a considerable extent depends on the water and physical characteristics of the soil both in close and open forests. Juniper forests have the strongest impact through mineralization of forest floor outputs and removal to lower areas by fertilizing soil with soil nutrients elements and improving soil structure.

Procession of the research results corroborated that soil in the main areas of juniper stands is distinguished by higher infiltration rates compared to treeless areas. Juniper stands have a significant influence on the snow melting regime. Experimental works proved that wind-driven snow resedimentation is not observed in the belt of juniper forests and open forests. In its turn this contributes to proportional snow cover and prevents descent of avalanches. This phenomenon is practically not observed when canopy density is already 0.3 – 0.4.

Thus, conducted researches show that juniper stands of Kyrgyzstan carry out all environment-protective and water-protective functions. Therefore, we conclude that juniper forests adapt to different natural conditions and have a positive impact on the hydraulic regime of mountain ecosystems.

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not increase with increasing phosphorus content because *Brassica chinensis yield first increases and then decreases*, *but Brassica chinensis* yield is more in biomass charcoal treated soil than no biomass charcoal (Tr0%) soil. The K and P contents and concentration in *Brassica chinensis* show similar regularity. Increasing K absorption in *Brassica chinensis* improves its nutritional quality.

Table 7 Effect of biomass carbon on major nutrient content and concentration in *Brassica chinensis*

Treatment	N uptake mg/plant	N content mg/kg	P uptake mg/plant	P content mg/kg	K uptake g/plant	K content g/kg
Tr0%	50.06	328.61	1.44	9.45	45.51	298.75
Tr4%	55.59	317.37	1.76	10.05	70.27	401.16
Tr8%	56.72	308.00	1.93	10.49	69.76	378.85
Tr12%	34.35	265.59	1.52	11.73	68.66	530.83
Tr16%	36.97	373.71	1.53	15.43	54.49	550.83

3 Conclusions

(i) Agricultural and forest biomass carbon is rich in potassium, calcium, manganese, aluminum, iron, and other nutrients necessary for crop growth. These types of carbon are also characterized by high specific surface areas and developed pore structures (abundant microporous structure), making for strong adsorption capacity.

(ii) Agricultural and forest biomass carbon can remediate soil that is heavily contaminated by metals. Treating soil with cotton stalk charcoal diminishes bioavailability of Cd. Under mild Cd pollution, soil treated with cotton stalk charcoal treated exhibits rapid Cd adsorption. As Cd pollution increases, the adsorption rate gradually slows down, but the amount adsorbed gradually increases. Treating soil with cotton stalk charcoal (Tr4%, TR8%, Tr12%, Tr16%) significantly reduces the accumulated Cd in the edible parts and roots of *Brassica chinensis*. The Cd mass fraction of the edible portions of *Brassica chinensis* declines by 49.43% – 68.29%, and that of the roots drops by 64.14% – 77.66%.

(iii) Adding an appropriate amount of agricultural and forest biomass carbon can increase crop biomass. The *Brassica chinensis* biomass in the Tr8%-treated soil increases to 20.87%, whereas that in the Tr16%-treated soil decreases to 36.06%. Within a certain range, increasing agricultural and forest biomass carbon promotes the absorption of major nutrients in *Brassica chinensis*. When a certain amount of biochar is added, the absorption nutritional elements in *Brassica chinensis* tends to decrease.

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