MARION DÖNHOFF WORKING PAPER 2017

Qualitative and quantitative assessment of rangeland restoration extent in sandy deserts of Uzbekistan (case study in Surkhandarya province)

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2017

Imprint

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Cite as: Utkurovich, R. D., 2017, Qualitative and quantitative assessment of rangeland restoration extent in sandy deserts of Uzbekistan (case study in Surkhandarya province), Marion Dönhoff Fellowship Working Paper, Michael Succow Foundation

About

Davlat Rasulov pursued his master thesis "Qualitative and quantitative assessment of rangeland restoration extent in sandy deserts of Uzbekistan (case study in Surkhandarya province)" at the Faculty of Biology of the University of Samarkand/Uzbekistan.

As a Marion Dönhoff Fellow, he pursued studies in geographic information systems, remote sensing and statistical analyses related to the project area.

Keywords: rangelands, deserts, Uzbekistan, Central Asia, restoration, biomass

CONTENT

Abbreviations

ASTER - Advanced Spaceborne Thermal Emission and Reflection Radiometer

EOS - Earth Observing System

GIS - Geographical Information Systems

METI - Ministry of Economy Trade and Industry

NASA - National Aeronautics and Space Administration

NDVI - Normalized Difference Vegetation Index

NIR - Nearinfrared

R - Red wavelengths

RS - Remote Sensing

SWIR - Shortwave Infrared

TIR - Thermal Infrared

VNIR - Visible and Near-infrared

1. Introduction

Problem statement. Around 57% or 23,3 million ha of Uzbekistan are covered by rangelands of different ecological zones (deserts, foothills and mountains). Seventy-eight % of the rangeland is located in desert and semi desert plains [11]. They have traditionally been used as common grazing lands for livestock. The majority of farming in Uzbekistan's desert rangeland regions is Karakul sheep husbandry, followed by goat, camel and horse husbandry. The total number of head is greater than 12 million of small ruminants (sheep and goats) and 7 million of cattle. More than 2,3 million people are entirely dependent on livestock production for food and economic security in desert zones [60,61].

The natural rangelands are the main grazing lands for sheep and goats, and have been through history. Rangelands have low productivity and vegetation biomass with annual production varying from 0,15 to 0,36 t DM/ha-1. However, vegetation cover of arid and semi arid rangelands is recognized as a basic forage source for livestock sector in Uzbekistan. Ninety-five percent of their total diet comes directly from the grazing and the remaining is harvested by the farmers and local herders and used when no grazing is available. Anthropogenic impact, on top of abiotic disturbances, is thus a part of the disturbance regime this area has been exposed to through the times. High localized anthropogenic impact often results in a rapid land degradation and even desertification, hence altering the native vegetation cover of rangeland areas. The footprint of humans has increased with the ever growing human population as can be seen in the expansion of degraded rangelands of Uzbekistan.

Currently, the vegetation cover changes under direct and indirect anthropogenic impact. Natural aboriginal plants communities replaces to anthropogenic changed plant communities. The main factor of anthropogenic transformation is destruction of habitat places, cutting shrubs and trees, unregulated grazing and another factors associated with human activity. Increasing anthropogenic transformation of natural rangelands leads to decreasing forage productivity. The worsening of natural structure of rangeland vegetation can lead to threat for livestock development, which based on forage resources of natural rangelands and characterized relatively low productivity and unstable yield on seasons and years.

At present, degraded rangelands continue to grow and this process accelerating. Often, tree and shrubs vegetation changes to invasive, unpalatable, annual rangeland communities which lead to complete degradation, especially near of settlements and water source. Exactly unsustainable economic activity of men, excessive concentrations of livestock on rangelands negative impacts to native structure condition and forage productivity of all types of rangelands [52].

Similar signs of rangeland degradation can be also observed in desert rangelands in south part of Uzbekistan. Sandy rangelands of Surkhandarya province also are characterized by progressive worsening which caused by impact of overgrazing which leads to alteration of vegetation cover and low forage value of rangelands. The regular grazing of livestock leads to changing of sandy deserts vegetation and landscape. Under the effect of overgrazing number of unpalatable plants tends to increase in the vegetation composition. All this dictates necessity of realizing urgent radical measures, which directed to restoration degraded rangelands of rangeland and save the natural resources that helps to stable functioning all ecosystem and safe local biodiversity of flora and fauna. Realizing timely and conformity events guarantees removing processes of disappearing native structure of vegetation and growing degraded rangelands. At the same time, restoration of degraded and low productive rangelands, assessment current condition of native rangelands remains as one of the acute problem in sustainable rangeland management in the country. Rangeland degradation in Uzbekistan covers large spatial and temporal scales which are impossible to assess using traditional field data approach. Application of Remote Sensing (RS) data may enable covering large regions and retrospectively assessing past decades. From this point of view current master research work is dedicated to study the current state of sandy desert rangelands in Djarkurgan district of Surkhandarya province and to assess the restoration processes of vegetation cover using traditional and modern research methods.

Research object and subject. Rangeland vegetation and plant species of the restored vegetation communities of the study area were served as a research object. Research subject – geobotany, phytocoenology, GIS and RS based vegetation mapping, restoration of degraded rangeland vegetation.

Research purpose is to assess trends of vegetation restoration in degraded rangelands of sandy desert of Surkhandara province using integrated Geographical Information Systems and Remote Sensing methods.

Research objectives were as following:

- to justify degraded condition of vegetation cover of the study area;
- to perform ground truth based assessment of restoration process of vegetation cover;
- to establish plant indicators of vegetation regeneration in restored rangelands;
- to conduct comparative analysis of rangeland condition before and after adoption of restoration measures;
- to detect rangeland restoration processes using Geographical Information Systems and Remote Sensing methods.

Scientific novelty of the research. For the first time comparative analysis of rangeland restoration processes and improvement of vegetation composition was conducted in the condition degraded sandy desert in Surkhandarya province. Changes of botanical composition, projective cover, plant density and green biomass of restored vegetation were assessed. The trend of rangeland restoration starting from degraded state to restored state was studied by remotely sensed data. Normalized Difference Vegetation Index (NDVI) was used to detect fine-scale vegetation restoration in the study area. NDVI values derived from ASTER multispectral images was performed high accuracy to differentiate the changes of vegetation state before and after restoration measures were taken.

Main research issues and hypothesis. In the current work as a main research issues were determination of regeneration of botanical composition, projective cover, plant density and biomass of the vegetation were as a main research issues. In addition, differentiation of vegetation condition before and after restoration and its detection by remotely sensed data was in the center of attention of current research.

Literature review on the topic of the research. The literature on assessment of the vegetation restoration processes in the condition of sandy deserts in Uzbekistan is limited. Monitoring the current state of the rangeland condition using comprehensive and integrated methods as GIS and Remote Sensing techniques are performed [1, 56, 40], but wide application of these methods as conducted in the condition of other regions [38, 22, 57, 35] are required. The state of the research topic in the condition of study area is well analyzed using recent literature sources [18, 44, 58].

Research methods. Ground truth measurements of vegetation restoration of study area was performed by traditional geobotanical methods [15]. Systematic position of plants from study area was determined by "Flora of Uzbekistan" [10], "Determinant of plants of Central Asia" [7]. Some nomenclature changes were specified according to S. K. Czerepanov [6]. Remote Sensing based assessment of current condition of restored and degraded rangelands was done by calculation of Normalized Difference Vegetation Index (NDVI) values [43].

Scientific and practical importance of research results. Obtained research results prove successful restoration of degraded rangelands in the study area. Such restoration practices have high potential to be outscaled in other degraded rangelands of Uzbekistan. Multidisciplinary approach of vegetation studies using a combination of GIS and RS and ground-based methods opens up the way towards accurate assessment and development implication measures for sustainable rangeland management. A future remote-sensing based rangeland monitoring program is an important step towards strategic planning in a modern rangeland management of Uzbekistan. From practical point of view, RS based monitoring and assessment of the current state of desert rangelands and their carrying capacity can be widely applied to cover large rangeland areas.

Approbation of the research. The results of the research were presented in the conference of bachelor and master students at Samarkand State University during 2016-2017. During the two-month research stay of the author at Griefswald Univesrity (Germany), obtained results were presented at the

Scientific Seminar of the Institute of Botany and Landscape Ecology and main issues of the research were discussed by the scientists of this institution.

Content of the dissertation. The dissertation consisted of 56 pages and includes introduction, three chapters, conclusion, recommendations and references. In the dissertation 3 tables and 28 figures are given. References include 61 sources 38 of which belong to foreign publications.

2. Background

2.1. Desert Rangelands and Problems with its Sustainable Management

2.1.1. Characteristics of desert rangelands

The desert ecosystem of Uzbekistan covers the Kyzyl-Kum desert, Ustyurt plateau, Karshi steppe, sands of Surkhandarya and Fergana valley. The hills which situated in east of the Kyzyl-Kum desert and Ustyurt plateau shows a special landscape with different ecological niches and richest desert plant and animal variety.

Desert rangelands consist of lowlands with elevations from 100 m and 500 m. Desert has a varied environment of sand dunes, gypseous flats, clay and solonchak depressions. It experiences extreme continental arid conditions, limited and unreliable winter precipitations, a high level of transpiration, extreme daily, seasonal and annual fluctuations of air temperatures, and soils with high salinity and gypsum content. Finally, because of these extreme conditions, it has a sparse but diverse vegetation cover.

Sandy desert rangelands

The main sandy areas in Uzbekistan are- the Kyzyl-Kum ('the red sands') located between two largest rivers, the Syr-Darya and Amu-Darya; the Sudunkli sandy desert located in the southern part of Uzbekistan in Kashkadarya province [11].

The Kyzyl-Kum desert is largest desert in Uzbekistan. The Nuratau, Kuljuktau, Aminsatau, Tamdytau, Bukantau, Sultan-uyzdag hills and low mountains located in east and they are distributed over the Turanian low land. Many solonchak depressions as a Ayagakytma, Karasugursk, Minbulak, Beshbulak, Kukayaz, Kul-Karakata, Kuduk are located between sandy-loam or clay soils and sandy dune. The geomorphological diversity of soil types of Kyzyl-Kum desert: red sands, grey-brown steppe soils, grey-brown gypseous, takyr and solonchak-alkaline soils. This physico-geographical features has an impact to the unique flora and fauna of the Kyzyl-kum desert.

Sandy deserts have distinctive features which differentiate them from other types of desert. For example: a high infiltration rate of water, a movable substrate, condensation ability and low level of salinity. Furthermore, the sandy substrate differs from other substrates, because it allows a long period of plant growth with available stored water in the soil [25]. Conversely, a quantity of negative aspects affects to the vegetation cover on sandy soils such as sand mobility which limits plant growing, poor soil structure with low organic material. It is also loosened by the impact of livestock grazing. And it is subject to high temperatures in summer time when the surface of the soil can reach 60 - 70 ^{o}C.

The mean annual precipitation is 75- 130 mm. Generally, it occurs in winter season as snow and in spring as rain. The average annual temperature values between 11 ^{o}C and 14 ^{o}C.

Psammophyte type of vegetation has wide distribution and they are adapted to sandy soils of desert and include a big variety of plant forms, i.e. annual plants, shrubs and trees.

The plant diversity of the sandy deserts of Uzbekistan includes approximately 800- 950 species of vascular plant which belongs to 70 families and [12, 30]. Particularly noticeable *Asteraceae, Apiaceae, Brassicaceae, Boraginaceae, Chenopodiaceae, Caryophyllaceae, Liliaceae, Lamiaceae, Poaceae and Polygonaceae* families. From these families 226 species are endemic plants of Central Asia. In Kyzylkum desert 34 species are endemic plants [29].

In sandy desert founded approximately 60 main plant associations. The 30% of the Kyzylkum flora are ligneous associations:

- trees, over sand dunes: *Haloxylon persicum*, *H*. *aphyllum*, *Ammodendron conollyi*, *Salsola richter*; and *S. paletzkiana*.
- shrubs on fixed dunes: *Salsola arbuscula*, *S*. *arbusculiformis*, *Calligonum spp*., *Ephedra strobilacea*, *Astragalus unifoliolatus*, *A*. *paucijugus* and *A*. *villasissimus*
- semi-shrubs: *Convolvulus divaricatus*, *C*. *hamadae*, *Mausolea eriocarpa*, *Artemisia diffusa*, *Halothamnus subaphylla*, *Acanthophyllum borsczowii*, *A. elatius*, *A. turanica* and *S. orientalis*.
- ephemeroids and grasses: *Carex physodes* and *Poa bulbosa* makes a landscapes surface as a carpet over sands and dunes with a 2-4 cm. The mat with high density of *C. physodes* and *P. bulbosa* dominating the vegetation cover; also *Ferula foetida*, a large plant of the Apiaceae family.
- perennial grasses: On mobile sands dominating *Aristida pennata* and *A*. *karelinii* and they are sand-fixing plants.
- annual summer season plants: *Agriophyllum latifolium*, *A. minus*, *Salsola paulsenii*, *S. aperta*, *S. praecox*, *Corispermum lehmannianum*, *Climacoptera turcomanica*, *C. erassa* and *C. lanata*.
- ephemerals: *Eremopyrum banaepartis*, *E. orientale*, *E. distans*, *Senecio subdenlalis, Malcolmia grandif1ora, M. africana, Isalis minima; I. violascens; Matricaria lamellata, SiIetoloma desertorum, Tetracme recurvata*; etc.

From ancient times sandy desert rangeland is the main source of fodder rangeland for local livestock. The important feature of this sandy desert rangeland is stability of yield and possibility to use it all year round. Rangelands which located in eastern and western hills of the Kyzyl-Kum desert are used as autumn-winter pastures for livestock with an unreliable fodder productivity of 0.1 - 0.9 t DM/ha, and it`s depending on vegetation cover, diversity of palatable plants and annual rainfall [30].

Gypseous desert rangelands

The largest gypseous desert rangeland in Uzbekistan is Ustyurt plateau. Its extreme climatic continentality is reinforced by its flatness and geographical position. About 20% of its total annual rainfall during the summer season is unusual For Middle and Central Asia. In winter temperature of desert area are the lowest: the average temperature in January is -6 ^{o}C and absolute minimum is -

32--38 ^{o}C in Karakalpakia. The average annual rainfall is around 120-180 mm Maximum temperature in summer reach 46-48C.

Halophyte plant associations of the *Chenopodiaceae* are represented by species such as *Anabasis salsa*, *Halocnemum strobilaceum*, *Salsola arbuscula*, *S. gemmascens*, *S. arbusculiformis*, *S. orientalis* and a number of annual *Salsola spp.* in association with Artemisia. On the desert rangelands with low salinity and in years with high precipitation observes high quality and fast development of ephemerals and ephemeroids.

The species composition in the plant communities is poor and consisting of 2 - 10 species. In the takyr-like areas vegetation cover remains low [30], and these areas often flooded in winter and have a high salinity and gypsum content in summer season.

The disappointing properties of gypseous desert rangeland are their low fodder productivity between years and limitations in summer forage. *Artemisia* (*Artemisia difiusa*, *A. halophyla*) and *Salsola arbuscula* rangelands are the most valuable in terms of yielding capacity, fodder value and plant palatability. The *Artemisia* plant community produces and keeps satisfying quantity of fodder for the whole year. Despite the poor palatability of *Anabasis* pastures they are generally used as fodder reserves in autumn-winter season.

Clay desert rangeland

Clay desert is represented by the clay and loess deposits of the Kashkadarya basin (Dalvarzinskay, Fergana valley, Golodnaya steppe, Mirzachol) and includes Syrdarya and Dzhizzak provinces. The soil type of clay desert is light sierozem. But they maybe salt-affected to different degrees in depression.

The flora of the Uzbek clay deserts characterized as a poor. In spring, due to high top-soil humidity, a dense carpet of vegetation is formed. The ephemeral-ephemeroid plant associations of *Psoralea drupacea*, *Ferula foetida*, *Artemisia diffusa* and *A. turanica* appear dominant. Saline depressions are colonized by *Salsola orientalis* and several *Artemisia spp.* (e.g. *A. ferganensis, A. diffusa, A. turanica and A. halophylla*) and communities. Valuable palatable arid plants such as Anabasis, young Tamarix, rare *Kochia prostrata*, *Ceratoides ewersmanniana, Camphorosma lessingii, Salsola arbuscula, Ephedra strobilacea* and various species of small herbaceous plants are also present in clay deserts. They do not cover large areas as a rule, and usually occupy fragments, pockets or small depressions. Their standing biomass fluctuates from 0.3 t DM/ha to 5.0 t DM/ha. They are typically used as spring-summer-autumn pastures for sheep, camels and horses. The commonly accepted coefficient of use of this type of rangeland is around 40- 50%. The average productivity of the pastures does not exceed 0.4 t DM/ha, and frequently does not exceed 0.05- 0.2 t DM/ha with about 60 fodder units/100 kg DM. The economic use of pastures is limited because of the poor vegetation cover and limited seasonal grazing. Sheep and camels use these areas in autumn, but due to the occasional occurrence of spring ephemeral herbaceous plants in good years, spring grazing is recommended.

Solonchak desert rangeland

Solonchak deserts are mostly found on the central Ustyurt plateau and its slopes, near the Aidar-Arnasay lake systems which located in south-west part of Navoi and north-west part of Dzhizak regions. Solanchak depressions also founded in Kyzyl-kum desert (Ayagakytma, Karakata, Minbulak and others in the Aral region) and the present delta of the Amu-Darya river.

The contraction of the Aral Sea has not only produced a new saline desert, but the situation has been worsened by the use of river water for cultivation which has shifted salt on to newly irrigated farmlands [26]. Recurrent flooding, poor natural drainage, an old-fashioned irrigation network with a high water table, and low drainage efficiency of the irrigation system has resulted in a rise in water level, mineral composition and increasing secondary salinization of soils.

Secondary salinization is growing rapidly in this area. In these conditions, crop production under irrigation (cotton, rice, wheat. etc.) decreases quickly and becomes less sustainable each year. These type of salinization has a direct impact on the desertification process. It is destroying the vegetative cover and inducing rapid deterioration of the soil structure. The emergence of large irrigation drainage lakes during the last few decades in the Kyzyl-Kum desert, especially at the Bukhara oasis - a mosaic of sand and salt deserts - has changed fundamentally the water-salt balance in the adjoining territories. In the lowest reaches of the Zerafshan and Amu-Darya deltas, about 85% of land is now suffering from various levels of secondary salinization. The anthropogenic impact on the hydrological cycles and water regime has caused the appearance of large areas of new takyr soils (with increasing salinity) in the Zerafshan and Kashkadarya valleys [53]. Salinization is one of the most critical causes of rangeland yield reduction in the arid zone of Uzbekistan.

The main characteristics of salt-affected marshland (with solonchak-alkaline soils) are the constant wetness and humidity of the soil and temporary waterlogged areas [13].

The semi-desert rangelands

The semi-desert areas occupy isolated, small sites, usually unsuitable for cultivation. The semi-desert foothills have shallow stony soils. Each separate area takes its name from a main settlement or village [14]. Among Karakul sheep breeders, the well-known chol area is separated into the Karnabchol, the Mubarekchol, the Kanimehchol, etc. The semi-desert plains between Karshi, Kanimekh, Navoi and Bukhara are one of the largest regions for Karakul sheep husbandry. These territories between the Karnab-Zirabulak-Ziadin and Nuratau ranges are the western ends of the Pamir-Alai Mountains. They are served by small rivers, which dry up in summer or simple dry river beds, channels of temporary streams interspersed with solonchak, Shorsay being one of the largest, and takyr without vegetation.

The typical semi-desert rangelands occupy some 1.5- 2.0 million ha. The climate is typical for south regions of Uzbekistan with an annual average temperature of 15- 16 ^{o}C. The annual average rainfall is around 160- 180 mm with yearly fluctuations from 80 mm to 300 mm. The precipitation rain and snow is distributed essentially during winter and early spring. The drought period stretches from June until November. For example, the Karnabchol [27, 28] is located on the left basin of the Zerafshan River. It occupies a vast and gently rolling area on the foothills of the Zirabulak Mountains. The soils are typical grey-brown steppic sierozem with a high content of gypsum and water-soluble salts. Close to the foothills, different steppic sierozem are usually shallow and stony, with a gravel matrix. These soils are low in organic matter (less than 1.0%), lack basic nutrients and have a high content of carbonate and gypsum. The granulometric composition varies from heavy clay to loamy sands.

The main vegetation is composed of different species, but he *Artemisia*-ephemeral vegetation type is often dominant. The *Artemisia* range is closely associated with a carpet of *Carex pachystylis* and *Poa bulbosa*. It is the preferred rangeland of most shepherds. The vegetation cover consists of various shrub-ephemeral plant communities. The dominant species are *Artemisia diffusa*, *Carex pachystylis*, *Poa bulbosa*, annual *Salsola spp*., *Gamanthus gamocarpus* and *Climacoptera lanata* with annual herbaceous species such as *Bromus tectorum*, *Eremopyrum orientale, Malcolmia spp.* and others commonly present.

The Artemisia rangeland is valuable to small ruminants in autumn and winter when feed is in short supply. On the Artemisia-ephemeral rangelands, the available grazing consists essentially of Artemisia and only 15-20% ephemera ls and Salsola spp. The presence in the vegetation cover of ephemeroids and ephemerals characterizes such pastures as highly seasonal and suitable for sheep only in spring and summer. However, during favorable years, autumn grazing of Artemisia itself occurs. The fodder production of such pastures ranges from 0.1 5 t DM/ha to 0.36 t DM/ha [45, 13]. Unfortunately, this Artemisia formation tends to disappear under excessive and permanent grazing and also because currently it is heavily uprooted for fuelwood. When overgrazed, it is replaced by a poor and degraded steppe of *Iris songarica* and *Peganum harmala* and other plants such as *Cousinia resinosa, Alhagi pseudalhagi, Aegilops squarrosa, Psoralea drupacea, Phlomis bucharica, Girgensohnia oppositiflora, Ceratocarpus utriculosus,* etc., which are poorly palatable, acceptable only when feed is in short supply on the range.

However, this type of Artemisia steppe on gently rolling country with deep loess ic soils is now rapidly becoming a prime target for cereal farmers (for example, near Karnab-Samarkand province or Papanaya-Nuratau province, because of its relatively good soils and favorable climate. The steppe is quickly damaged as the native vegetation is entirely eradicated in newly cropped areas developed by private farmers or co-operatives using heavy farm machinery. Wind and water erosion can be observed in many places. This may become a major threat to the

Uzbek Artemisia steppe as has happened to similar areas in North Africa and the Middle East. Conservation measures for the Artemisia steppe are urgently needed and should be developed and implemented. It is equally important to refine methods for plant community rehabilitation and/or regeneration of degraded Artemisia formations. There is abundant literature available on Artemisia range improvement and rehabilitation in Uzbekistan [13, 45].

2.1.2. The main degradation factors of desert rangelands

During past decades grazing induced degradation is most common in rangelands of Uzbekistan. Rangeland degradation is a primary impediment of livelihood development in the region. [60] estimated that of all disturbances, overgrazing of livestock was the most serious, accounting for 44% of the total degradation, followed by uprooting and cutting of vital shrubs for fuel wood (25%). All other disturbances, including all abiotic such as droughts and wind erosion, accounted for only one third of the disturbances. The degradation process is becoming severe and needs urgent measurements to avoid the loss of rangeland productivity. This is particularly evident in areas near the villages and watering wells.

Most distributed causes of degradation of rangelands is vegetation cutting and overgrazing. Human settlements in deserts and border areas of deserts uprooting and cutting shrubs and trees for fuel. Intensive grazing of increasing number of livestock for the long period of time without recovery periods occurs to overgrazing. It may be caused by poorly managed livestock in agricultural applications. Livestock also have an effect on the plant composition by trampling and selective grazing. The animal faeces and urine change the composition of the soil organic matter. Overgrazing increases soil erosion and it`s can be a cause of land degradation [5].

The effect of grazing is often localized and is ubiquitous around watering points and settlements. Changes in vegetation cover and composition has led to the disappearance of many native fodder species. At present time the area of degraded desert rangelands continues to grow due to overgrazing. Typical impact covers a radius of 2 to 5 km around watering points, with the most intense degradation occurring closest to the wells. Grazing occurs throughout the year. The animals are kept half of the year in the mountains or other distant regions, but they are brought back to the settlements as winter approaches. It is during this winter grazing seasons that most of the degradation occurs, as grazing pressure is high due to low vegetative production [19].

The distribution of livestock is restricted by water availability. This is especially true for the summer season and creates high grazing pressures around the water sources. The grazing pressure diminish with distance, forming a gradual change in vegetative cover, species composition and soil properties as one moves away from the resource focal point.

The result of exploitation of plant resources leads to degradation of desert rangelands. The level of rangeland degradation depends on livestock composition, intensity grazing and vital vegetation cutting. Sheep graze grassy plants while camel mainly eat shrubs and semi-shrubs, but serious damage to desert rangeland vegetation inflicted by goat. It`s do harm almost to all types of vegetation [24]

3. Methods

3.1. Physical and geographical characteristics of the study area

Study area located in Kattakum sandy massif which belongs to Djarkurgan region in southern part of Surkhandarya province. The desert borders on the south-west with Termez and Angor regions, in the east with Kumkurgan region and with Qizirik and Bandikhon in north. The territory of Kattakum is main rangeland for local livestock. These desert sands forms singular natural community. In 1971, Uzdaverloyiha has released map of «Rangelands» where was presented total area of Kattakum sands – 250 km^2, but in 1994 year total area of desert decreased to 176 km^2. At present, total area of Kattakum is 147 km^2. The relief of territory presented by plains at the height of 356 m above the sea level and decreases toward the south. Soil cover of the study area is mostly represented by sandy soils with various level of dune fixation [34].

Fig. 1; Location of study area.

Green polygon represents the territory of Surkhandarya province. Triangle in black color shows the spatial location of the Djarkurgan site where research work was conducted.

Climate of the study area is represented by extreme continental character. Winter is short and worm. Precipitation is low, summer is long, dry and hot. Soil cover of the study area is mostly represented by sandy soils with various level of dune fixation. According to the data from Termez meteostation the mean annual temperature in July is 28-32 °C, in January is 2.8-3.6 °C. Sometimes, temperature of study area in summer can reach 50 °C, in winter reach -27 °C. But such high rates observes only once in 10-20 years. The mean annual precipitation is 130-146 mm and main precipitation observes in autumn, winter and spring seasons. The 82 percent of precipitation occurs from December to May. Also in these months air humidity is high.

a

b

Fig. 2; General view of study area before restoration, spring (a) and autumn (b) aspect, 2010 year

Vegetation cover basically presented by psammophyte and xerophyte type of vegetation. Before restoration measures, 60 ha of study area was represented as a degraded sandy desert rangeland with mobile and semi-mobile sands with two dominant plant communities of *Agriophyllum latifolium* and *Lagonychium farctum*.

Sands of desert complicates the livelihood of local settlement. Sand storms covers with sand buildings and gardens. People can`t work at these times. As a result we can see sands around houses. Restoration of degraded sandy desert rangelands can help to stop this process, fixate mobile and semi-mobile sands.

Fig. 3; Results of sand encroachment, 2017 May

Study area was restored after reseeding of *Haloxylon aphyllum* and preventing it from grazing and uprooting during 6 years. Currently, study area consists of 3 dominant plant communities: *Haloxylon aphyllum* plant community*, Calligonum microcarpum* plant community and *Salsola richteri* plant community. Restoration measures led to that the vegetation cover rehabilitated and mobile sands fixed by root system of plants.

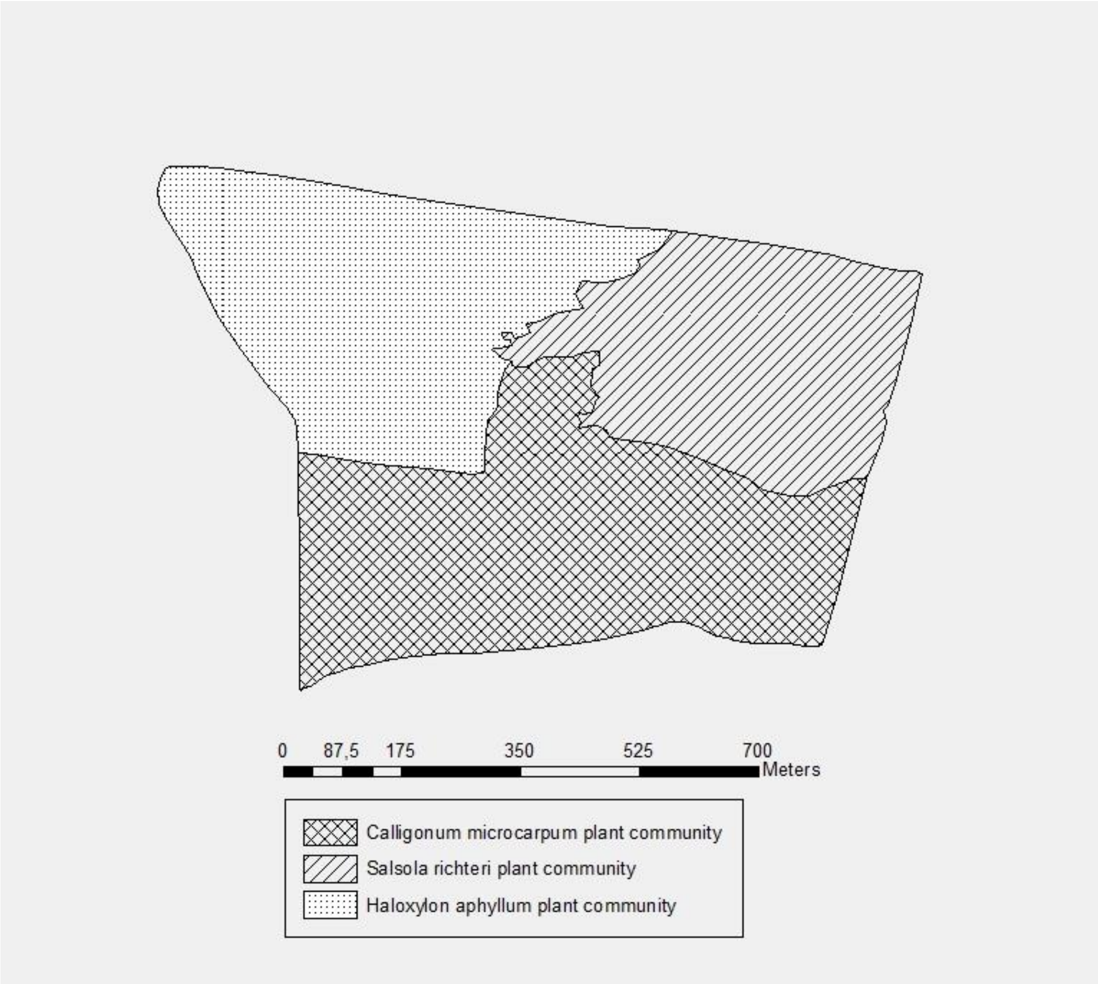

Fig. 4; Separation of study area to the plant communities

Fig. 5; General view of study area after restoration, spring aspect, 2017 year

Fig. 6; Haloxylon aphyllum plant community, spring aspect, 2017 year

Fig.7; Calligonum microcarpum plant community, spring aspect, 2017 year

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3.2. Ground truth based geobotanical methods

Vegetation data were collected within the spring seasons of 2016–2017. The measurements of study area included plant composition, biomass, projective cover and density, biomass of annual plants. Description of the vegetation cover and determination of the plant biomass was done according to Guidelines [15]. using 50 m x 2 m transects with 3 replications in each plant community. The total numbers of shrubs of each species within the 100 m^2 area were counted and separated into 3 size classes (big, medium, small) based on plant size: height and diameter. For each species within every size class, 3 representative plants were clipped at a height of 1.0 cm for determination of standing biomass (woody, green and dead tissue) in the laboratory. A total biomass for each subplot was then calculated using the density data and species biomass.

Fig. 8. Determination of projective cover and density of vegetation using transect method

The cover of individual shrub species was determined along a 100 m line intercept of the 50 m x 2 m transect.

Biomass production of ephemerals and ephemeroids was identified within 1 x 1 m frame quadrates, randomly distributed with 5 replications (Fig. 1).

Fig. 9. Collecting the biomass of ephemerals and ephemeroids

3.3. GIS and Remote Sensing methods

Traditional geobotanical methods of vegetation studies can be significantly improved by application of integrated comprehensive methods as Remote Sensing (RS) and Geographical Information Systems (GIS). These methods can help to study changes of vegetation cover in small and large scales with a practical and economical means [57]. RS and GIS data covers large areas and reject natural interrelations, allows exclusion of random or short-term changes, focusing thus on the processes of transformation of ecological state of the ecosystem under observation [54]. RS based studies allow operative assessment and repeated observations of the vegetation condition.

For the current research used ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) sensor imagery which widely used in classification of land cover and was applied to study the vegetation cover of study area. ASTER is a cooperative effort between NASA and Japan`s Ministry of Economy Trade and Industry (METI), with collaboration of scientific and industry organizations in both countries. It was launched on board of NASA`s Terra spacecraft in December in 1999. Terra is the first multi-instrument forming NASA`s Earth Observing System (EOS).

ASTER covers a wide spectral range with 14 bands from the visible to the thermal infrared. ASTER consists of 3 different subsystems (Table 1): the Visible and Near-infrared (VNIR) with 3 bands; the Shortwave Infrared (SWIR) with 6 bands; and Thermal Infrared (TIR) has 5 bands. Scene of ASTER satellite image covers an area equal to 60 x 60 km. Everyday satellite translates about 650 scenes. ASTER images has a high spatial, spectral and radiometric resolution.

ASTER images from spring seasons of 2007 and 2016 were used to calculate NDVI values to show dynamic of vegetation restoration. The atmospheric correction of images was done in FLAASH module of ENVI 4.6.1 [9] and then NDVI values were calculated by ArcMap 10.4.1. [8] Calculation of NDVI values for each plant community was performed.

Subsystem	Band No.	Spectral Range (μm)	Spatial Resolution, m
VNIR	1	0.52-0.60	15
	2	2 0.63-0.69	
	3N	0.78-0.86	
	3B	0.78-0.86	
SWIR	4	1.60-1.70	30
	5	2.145-2.185	
	6	2.185-2.225	
	7	2.235-2.285	
	8	2.295-2.365	
	9	2.360-2.430	
TIR	10	8.125-8.475	90
	11	8.475-8.825	
	12	8.925-9.275	
	13	10.25-10.95	
	14	10.95-11.65	

Table 1. Characteristics of the 3 ASTER Sensor Systems

ASTER images was obtained from online database of United States Geological Survey [55] (http://earthexplorer.usgs.gov). For obtaining images I needed to pass registration. Then, we can choose area of interest from typing the

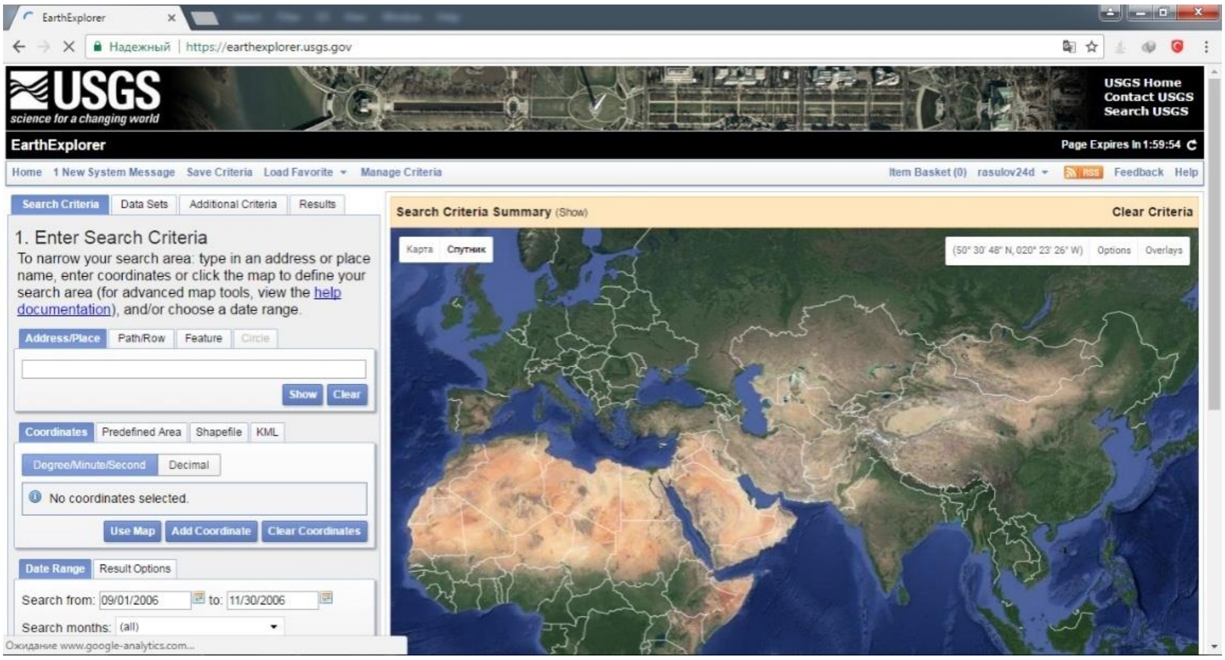


Fig. 10. Main workspace of USGS`s database

address, entering coordinates or click on map. According to the interests of research proposal we can choose a date range. Most important things is choosing data set, because we have to know about properties of satellite imagery.

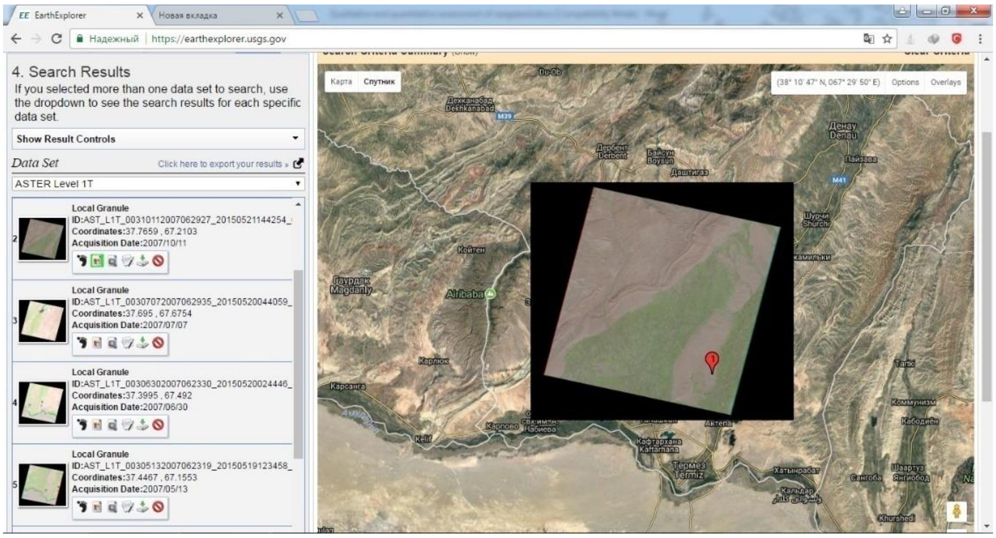


Fig. 11. Obtained results of image search

Each image from ASTER satellite covers an area equal to 60 x 60 km.

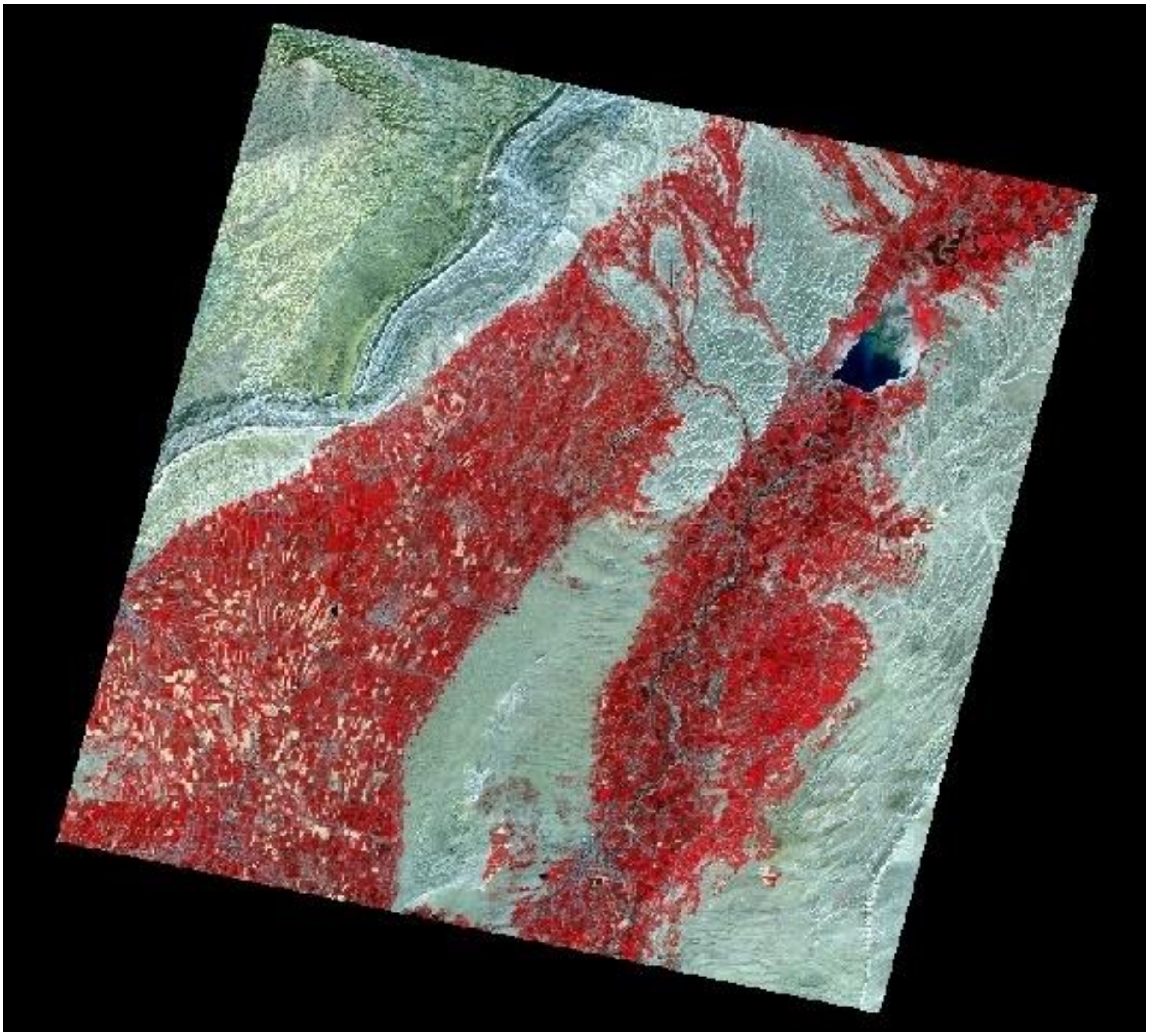


Fig. 12. General view of ASTER image

For detecting restoration stages of vegetation cover was used Normalized Difference Vegetation Index (NDVI) [43] which derived from ASTER multispectral images. NDVI is recognized as a most appropriate to monitor various types of vegetation cover with different thematic objectives [39]. In multispectral images green vegetation is characterized by a high reflectance in the nearinfrared (NIR) domain (typically 50 to 80%), which contrasts with a very low reflectance in the red wavelengths (R), because of absorption of chlorophyll bodies. R and NIR is digital counts obtained through the red and the near infrared bands of a multispectral imagery. The NDVI, expressed as:

$$NDVI = \frac{R-R}{NIR+R}$$

and equation produces values ranging from –1 to 1. Negative values are indicative of nonvegetated non-reflective earth`s surfaces, clouds, snow, water and other. Positive values shows vegetated or reflective surfaces and if the NDVI values is high than vegetation cover is greener or photosyntheticly active [4].

R and NIR bands available on most satellites (ASTER, Landsat, SPOT, etc.) and the NDVI tool is popular in remote sensing studies [41].

ASTER images passed Atmospheric correction in ENVI`s FLAASH Module. The NDVI values calculated in ESRI`s ArcMAP software.

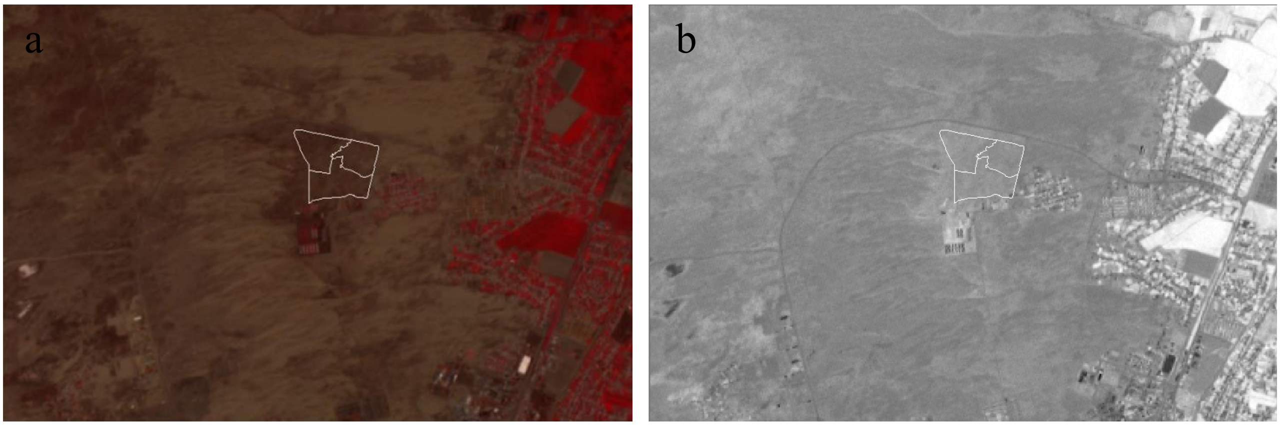


Fig. 13. View of ASTER image in ArcMAP software before NDVI calculation (a) and after calculation (b)

4. Qualitative and Quantitative Assessment of Rangeland Restoration

4.1. Botanical composition and its comparative analysis

Before restoration measures, the species composition of study area was represented by 2 dominant plant communities: 1) *Agriophyllum latifolium* – plant community on the dunes and hills in related to relief. 2) *Lagonychium farctum* – plant community on lower places. Geobotanical description was conducted on each of the plant communities.

Fig. 14. Spring aspect of *Agriophyllum latifolium* plant community

Despite the fact that, vegetation of study area characterize as a relative large variety of species structure. Meeting of species at the vegetation cover is not equal. During the geobotanical description, was fixed 29 species of perennial and annual plants which belongs to 15 family. The total number of ephemeras and ephemerides plants forms 14 species of which 50 percent is weeds.

Species	Family	Life form
Agriophyllum latifolium Fisch. & C.A. Mey.	*Chenopodiaceae*	annual
Astragalus villosissimus Bunge	*Fabaceae*	shrub
Alhagi pseudalhagi (Bieb.) Fisch	*Fabaceae*	perennial grass
Calligonum leucocladum (Schrenk) Bunge	*Polygonaceae*	Shrub
Convolvulus hamadae (Vved.) V.Petrov	*Convolvulaceae*	semi-shrub
Ceratocarpus arenarius L.	*Chenopodiaceae*	annual
Salsola paulsenii Litv.	*Chenopodiaceae*	annual
Lagonychium farctum (Banks & Solander) Bobrov	*Fabaceae*	Semi-shrub
Stipagrostis karelinii (Trin. & Rupr.) Tzvelev	*Poaceae*	perennial grass
Cousinia dichotoma Bunge	*Asteraceae*	
Heliotropium dasycarpum Ledeb.	*Borraginaceae*	annual
Echinops sp.	*Asteraceae*	perennial grass
Xanthium spinosum L.	*Asteraceae*	annual
Eminium lehmannii (Bunge) O.Kuntze	*Araceae*	perennial grass
Carex physodes M. Bieb.	*Cyperaceae*	perennial grass
Bromus tectorum L.	*Poaceae*	annual
Hordeum leporinum Link	*Poaceae*	annual
Trigonella orthoceras Kar. & Kir.	*Fabaceae*	annual
Schismus arabicus Nees	*Poaceae*	annual
Ceratocephala falcate (L.) Cramer	*Ranunculaceae*	annual
Veronica campylopoda Boiss.	*Scrophulariaceae*	annual
Vulpia ciliata Dumort.	*Poaceae*	annual
Holosteum umbellatum L.	*Caryophyllaceae*	annual
Koelpinia linearis Pall.	*Asteraceae*	annual

Hypecoum parviflorum Kar. & Kir.	Hypecoaceae	annual
Alyssum desertorum Stapf	*Brassicaceae*	annual
Erodium cicutarium (L.) L'Her.	*Geraniaceae*	annual
Eremopyrum bonaepartis (Spreng.) Nevski	*Poaceae*	annual

Table 2; The list of identified plants and their systematic position

The main builders of species composition at the upper tier of vegetation cover is *Agriophyllum latifolium*, *Lagonychium farctum* and *Alhagi pseudalhagi*. Another perennial plants greets at the individual specimen. Abundance of background plants changes on space according to relief. Their percent proportions and describes leaded lower.

Fig. 15. Spring aspect of *Lagonychium farctum* plant community

After restoration measures quantity of *Lagonychium farctum* and *Agriophyllum latifolium* decreased. Quantity of annual *Hordeum leporinum* also was high but it`s decreased after restoration. Currently, dominant plant communities and it`s vegetation composition changed to the healthy sandy desert vegetation. Preventing study area from grazing allowed natural self-restoration of vegetation cover. Instead of *Agriophyllum latifolium, Lagonychium farctum*, *Hordeum* *leporinum* and etc. presently growth native plant species as a *Haloxylon aphyllum, Salsola richteri, Calligonum microcarpum, Alhagi pseudalhagi, Poa bulbosa, Carex physodes* and etc.

Description of forage value of dominant plants before and after restoration. A large number of species encountered in the study areas in the forage is very unequally, and due to the low quality forage. Among 27 plants only 7 eaten well, 9 species - satisfactory, 4 are unpalatable, and 8 species are eaten bad for robustness and low food quality, or are eaten only in winter after a rainfall, when their hard stems become soft (Table 3). Eatable plants found in very sparse amount and percentage of the total productivity of rangelands has a slight performance. Below are the comparative information about the nutritional value of some plants background study area based on the literature, since the vegetation cover is mainly represented by these species.

Agriophyllum latifolium - annually psammofit and endemic of Middle Asian deser ts. It is the pioneer of moving sands plant. It is eatable only in the early stages of the growing season in the absence of other forage plants. Since the flowering phase of the plant become rough and spiky thus not eaten until the end of their growing season. After vegetation it is eaten only during wet weather, when the stems and leaves are soft. Pastoral importance is limited. Grazed when green in spring season by livestock because of high protein content. Not eaten by livestock after drying during summer as it becomes rough and prickly.

Alhagi pseudalhagi belongs to the family of legumes, prickly perennial herbaceous plant with rough stems. Distributed in different soil conditions, including, and in sandy deserts. As forage, depending on the phase of vegetation, is is a well-eating plant. Readily eaten by early spring, with completion of the flowering phase coarsens it strongly and eaten satisfactorily. In the autumn-winter precipitation his coarse stems became soft and then animal again begins to eat it well. One of the most valuable forage plants for camels, Karakul sheep, lambs and cattle all year round with young stems, leaves, fruits and seeds are considered a fattening feed. Fruits are eaten by large herbivores, especially cattle and horses. Collected intensively by farmers and livestock owners for making hay for winter season feed. Hay is considered to be as good as the best cereal straw.

Expected yield is about 0.06- 0.20 t DM/ha; 0.35- 0.40 t DM/ha in favourable years, or when growing on a high water table.

Lagonychium farctum - Shrub with stems studded with thorns, height 50-60 cm belongs to the group of drought-resistant plants. Due to the robustness and prickliness cattle do not eat it. The roots and the fruits are able be used as a fertilizer.

Name of plants	**Type of distribution of species**	**Degree of eating**
1. *Agriophyllum latifolium* (Lam.) Moq	typical	bad
2. *Lagonychium farctum* (Banks & Solander) Bobrov	pastoral weed	bad
3. *Alhagi pseudalhagi* (Bieb.) Fisch	typical	good
4. *Calligonum leucocladum* (Schrenk) Bunge	typical	satisfactorily
5. *Convolvulus hamadae* (Vved.) V.Petrov	typical	good
6. *Ceratocarpus arenarius* L.	pastoral weed	bad
7. *Salsola paulsenii* Litv.	typical	bad
8. *Astragalus villosissimus* Bunge	typical	good
9. *Stipagrostis karelinii* (Trin. & Rupr.) Tzvelev	typical	satisfactorily
10. *Cousinia dichotoma* Bunge	typical	bad
11. *Cousinia* sp.	typical	bad
12. *Heliotropium dasycarpum* Ledeb.	pastoral weed	satisfactorily
13. *Echinops sp.*	pastoral weed	unpalatable
14. *Xanthium spinosum* L.	pastoral weed	unpalatable
15. *Carex physodes* M. Bieb.	typical	good
15. *Bromus tectorum* L.	typical	satisfactorily
16. *Hordeum leporinum* Link	pastoral weed	bad

17. *Trigonella orthoceras* Kar. & Kir.	pastoral weed	satisfactorily
18. *Schismus arabicus* Nees	typical	satisfactorily
19. *Ceratocephala falcate* (L.) Cramer	weed, poisonous	unpalatable
20. *Veronica campylopoda* Boiss.	typical	satisfactorily
21. *Vulpia ciliata* Dumort.	pastoral weed	bad
22. *Holosteum umbellatum* L.	typical	good
23. *Koelpinia linearis* Pall.	pastoral weed	satisfactorily
24. *Hypecoum parviflorum* Kar. & Kir.	pastoral weed	unpalatable
25. *Alyssum desertorum* Stapf	typical	good
26. *Erodium cicutarium* (L.) L'Her.	pastoral weed	satisfactorily
27. *Eremopyrum bonaepartis* (Spreng.) Nevski	typical	good

Table 3; Degree of eating and type of distribution of species in study area

After restoration measures vegetation composition changed. Was formed 3 dominant plant communities. They are considered native plant species. Below are given descriptions of dominant species.

Haloxylon aphyllum or Black Saxaoul`s is xero-psammo-halophyte with height 4-10 m and deep root system penetrating to depth 9-16m. Life span of *H. aphyllum* is 50-90 years. One of the most important rangeland plants in Central Asia. Palatable parts of plant is young vegetative stems, leaves and fruits. Extensively used for the creation of long-term rangelands, for restoration of degraded desert rangelands with sandy, takyr, solonchak soils. Fodder, useful for sand-fixing, soil-improving, fuel, coal-making (up to 40%). Local people extract acetone, alcohol and vinegar from the wood.

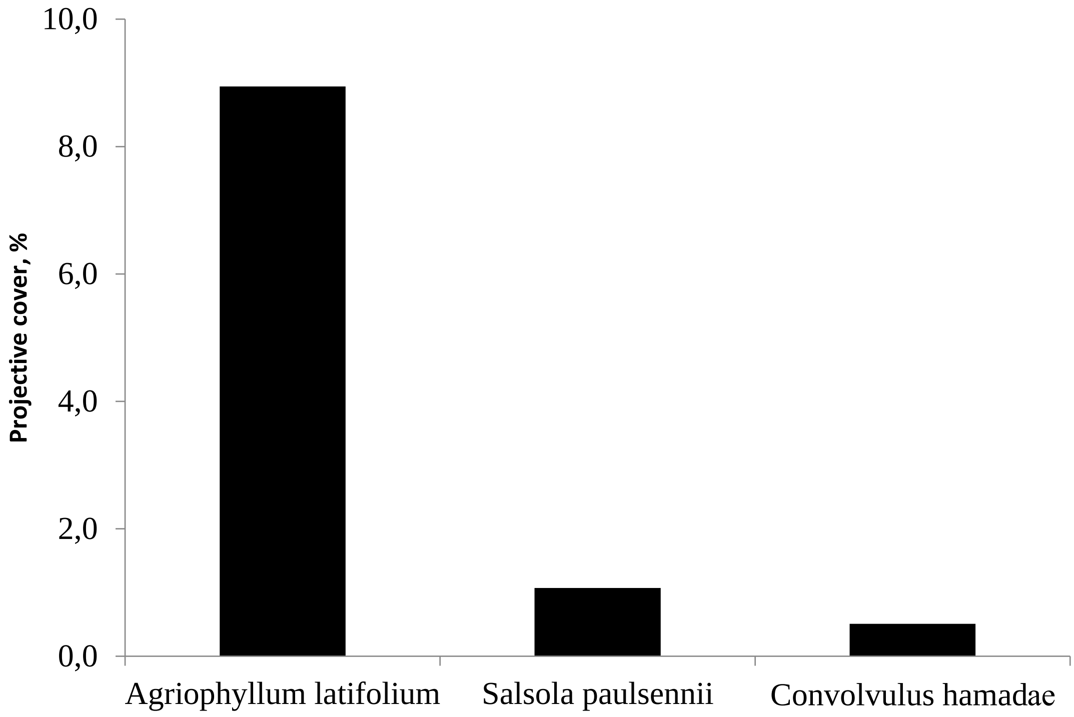
Salsola richteri is tree-like bush with height 1.5-2 m. Roots penetrating to depth 5-12 m. Life span 25-30 years. Stems, leaves and fruits are well grazed by sheep, camels and goats. Used for creating agro-phytocoenoses and rangeland improvement of sandy soils. These plant good sand-fixing. Biomass of forage about 0.6-1.3 t DM/ha. Plant rich in protein. *S. richteri* is psammo-xerophyte and it is usually grows on sands and barkhans, as well as on grey-brown soils in southern Kyzyl-kum.

Calligonum microcarpum perennial shrub with height 1 m. In spring, young stems and fruits well grazed by all livestock. Helps to improve sandy desert rangelands. Also psammo-xerophyte.

Poa bulbosa is perennial ephemeroid grass. Height of *P. bulbosa* is 3-8 cm and forms green carpet in rangelands. Has a spring vegetation cycle. Important resource of forage in Central Asian rangelands. Grows from early February to middle of April. On good soil, expected biomass is up to about 0,5-1.0 t DM/ha. Rich in carotin, crude protein and cellulose.

Carex physodes is also perennial ephemeroid grass with height 15-20 cm. Has a short growth period. Great grazing in spring and summer. Excellent fixing mobile and semi-mobile sands. Keeps roots in the end of vegetation. Forage values is about 0.01-0.2 t DM/ha. Often growth with *Poa bulbosa*. During flowering contains up to 19% crude protein and 25% cellulose.

Fig. 16. Indicators of the projective cover of separate plants at



***Agriophyllum latifolium* plant community; b – Lagonychium farctum plant community**

4.2. Changes in projective cover and density of vegetation.

Results of geobotanical describes shows that the projective cover of *Agriophyllum latifolium* vegetation community forms on average 10,53%. Most high performance of projective cover at this community accounted for *Agriophyllum latifolium* (Fig. 16.). Another species as a *Salsola paulsenii* and *Convulvulus hamadae* characterize with low projective cover

Lagonychium farctum plant community have a highest performance of projective cover and forms 20,67% unlike the *Agriophyllum latifolium* plant community (Fig. 16.). Its explains as a species composition of Lagonychium community more variable than the previous, because here meets another species as a *Lagonychium farctum* and *Alhagi pseudalhagi*. The highest performances of vegetation cover at this vegetation community accounted for *Lagonychium farctum*. *Agriophyllum latifolium* is subdominant plant. Its lobe lowering to 7,14%. After summarizing received data about both vegetation communities, we can get average of studying areas vegetation projective cover. Thus, in the autumn season vegetations projective cover of studying area forms average 15,6%, 8% for *Agriophyllum latifolium* and for *Lagonychium farctum* 4,4%.

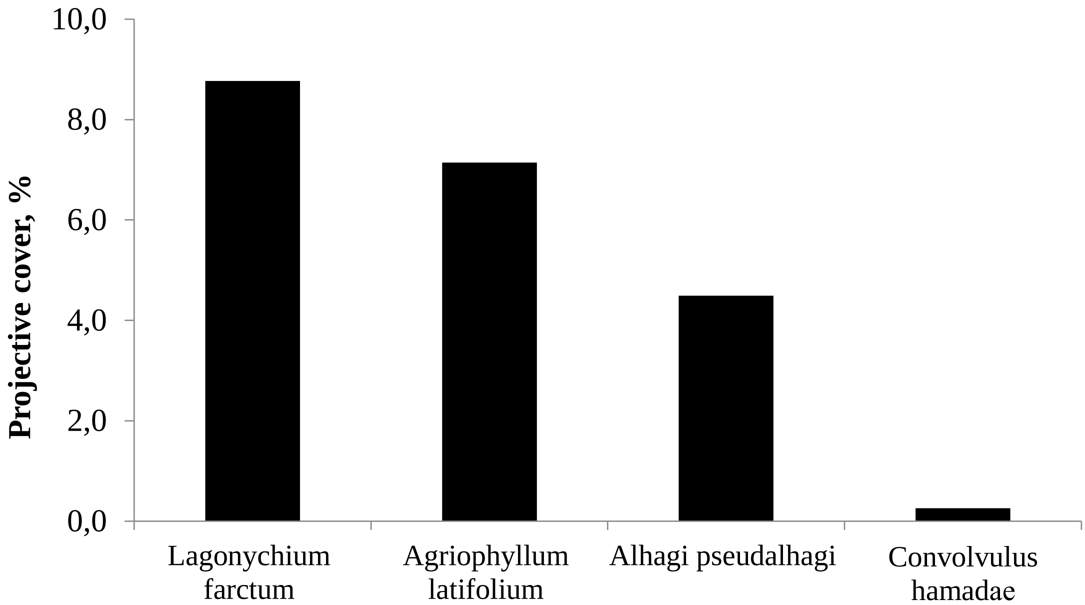


Fig. 17. Indicators of the projective cover of separate plants at *Lagonychium farctum* plant community

After restoring of study area was formed 3 dominant plant communities of *Calligonum microcarpum, Salsola richteri* and *Haloxylon aphyllum.* Projective cover of these plant communities represented by high values.

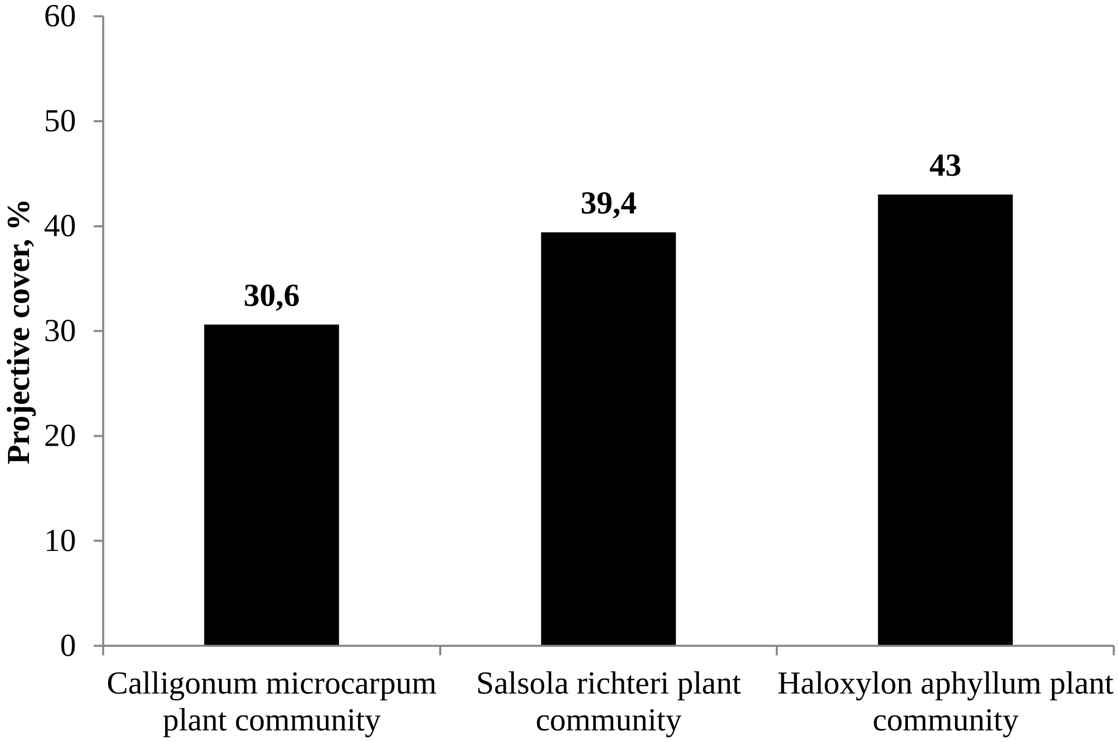


Fig. 18. Projective cover of 3 dominant plant community in study area

According to the obtained results of projective cover of study area we can see that the projective cover of *Haloxylon aphyllum* plant community is highest and consists of 43%. The lowest value of projective cover observes in *Calligonum microcarpum* plant community and it is consists of 30,6 %. This results shows that the coverage of area is increasing.

Investigations of plants density in study area before restoration shows that the in *Agriophyllum latifolium* plant community dominates *Agriophyllum latifolium* with 73% of coverage, then, subdominant - *Convulvulus hamadae* – 19% (in 3767 ha). Lowest quantity shows *Salsola paulsenii* and *Astragalus villosissimus*, which forms percent proportions 7% and 2% (Fig. 19.)

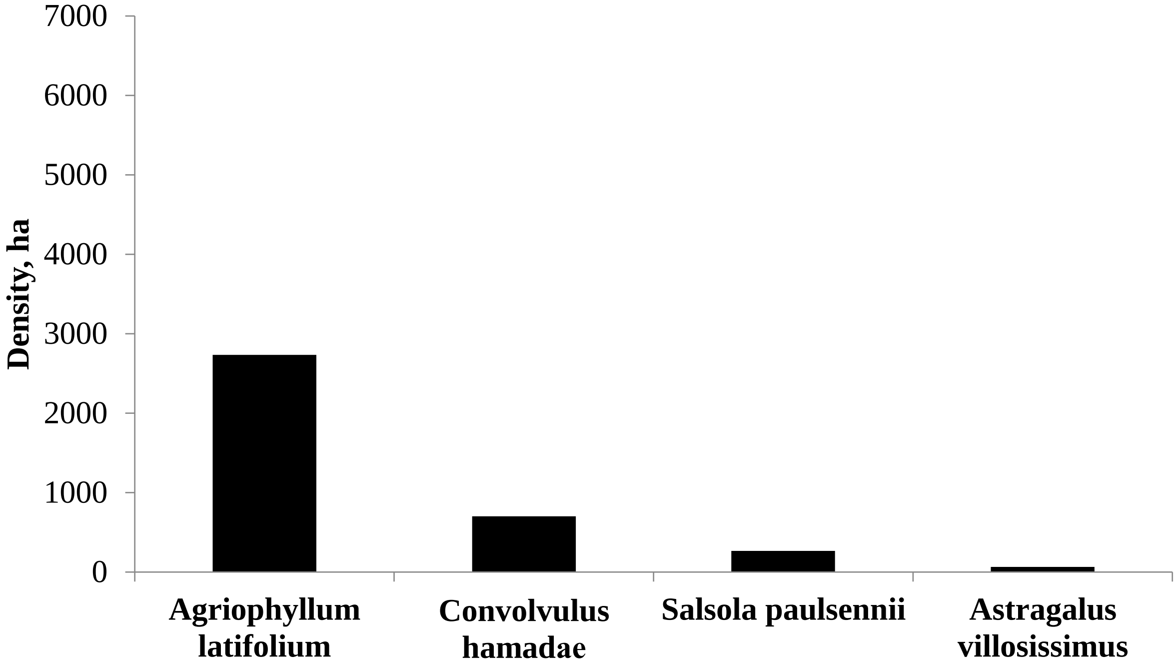


Fig. 19. Density of plants in *Agriophyllum latifolium* plant community

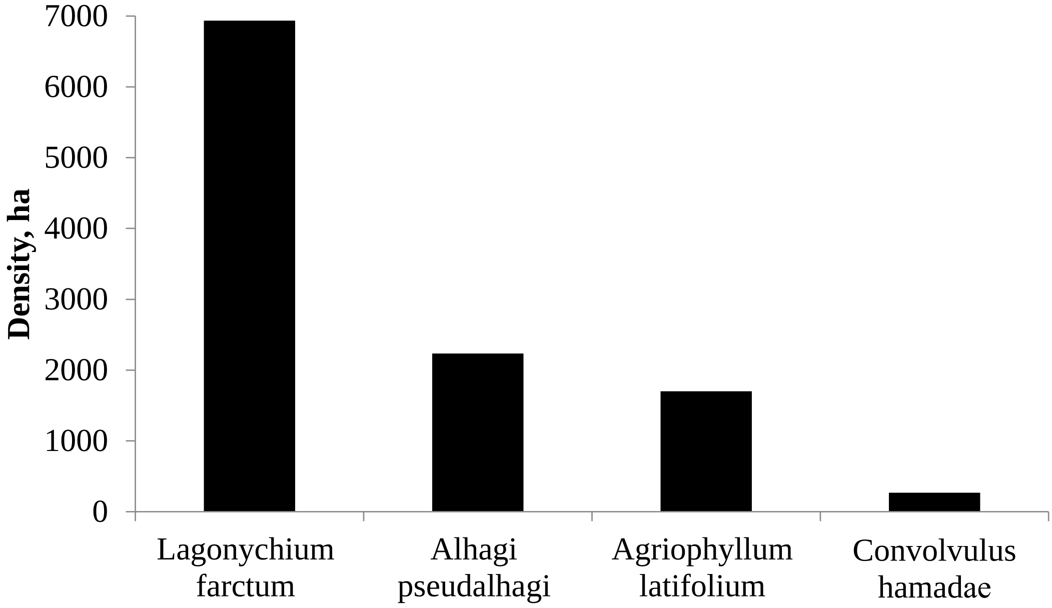


Fig. 20. Density of plants in *Lagonychium farctum* plant community

On the second vegetation community dominant plant is *Lagonychium farctum* with 62% from the total number. *Alhagi pseudalhagi* as a subdominant plant in that plant community with 20%. In addition, observed lowering quantity of

Agriophyllum latifolium (15%), its explains with presence of *Lagonychium farctum* as a competitor specie in this plant community.

Lagonychium farctum and *Alhagi pseudalhagi* plants in plant community basically spreaded at lower places against to relief. Observed that the large number of *Lagonychium farctum* semi-shrubs growth on vested sands among the borders of that study area.

After restoration, in *Calligonum microcarpum* plant community often meet such plant species as a *Convolvulus divaricatus*, *Astragalus villosissimus*, *Aristida pennata*, subdominant *Heliotropium dasycarpum* and dominant *Calligonum microcarpum.*

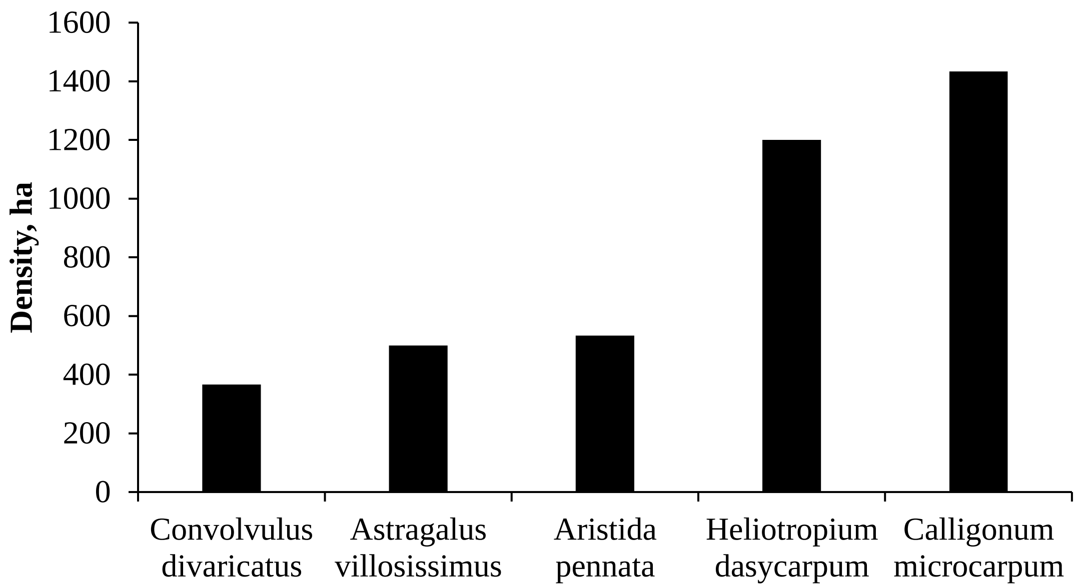


Fig. 21. Density of plants in *Calligonum microcarpum* plant community

Salsola richteri plant community consists of *Alhagi pseudalhagi, Astragalus villosissimus* and dominant *Salsola richteri.*

In *Haloxylon aphyllum* plant community only 2 wide spreaded species: *Alhagi pseudalhagi* and *Haloxylon aphyllum*.

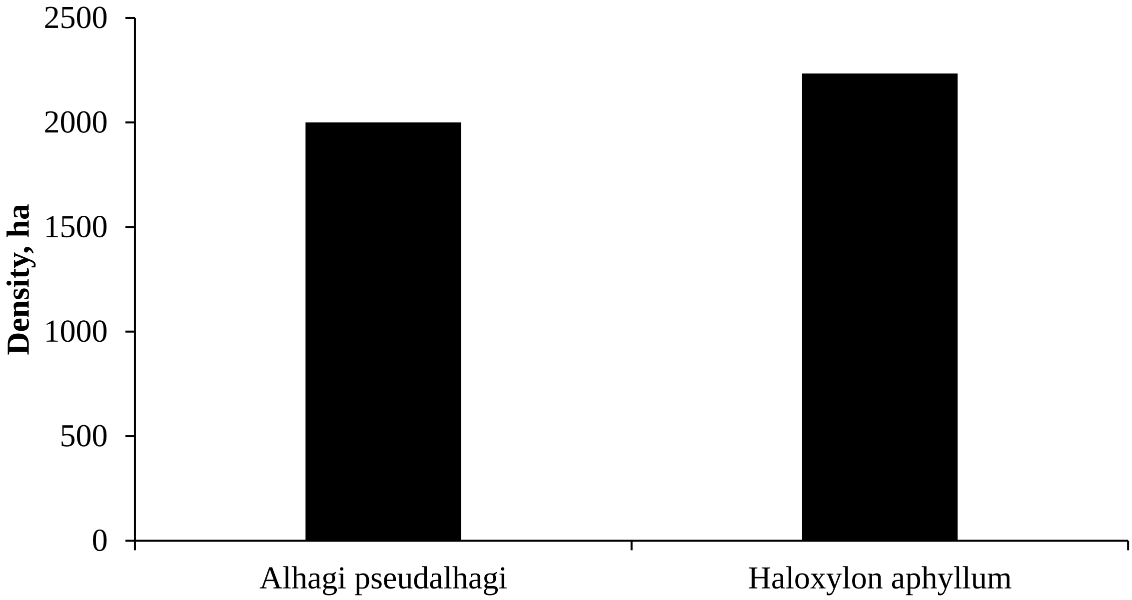


Fig. 22. Density of plants in *Haloxylon aphyllum* plant community

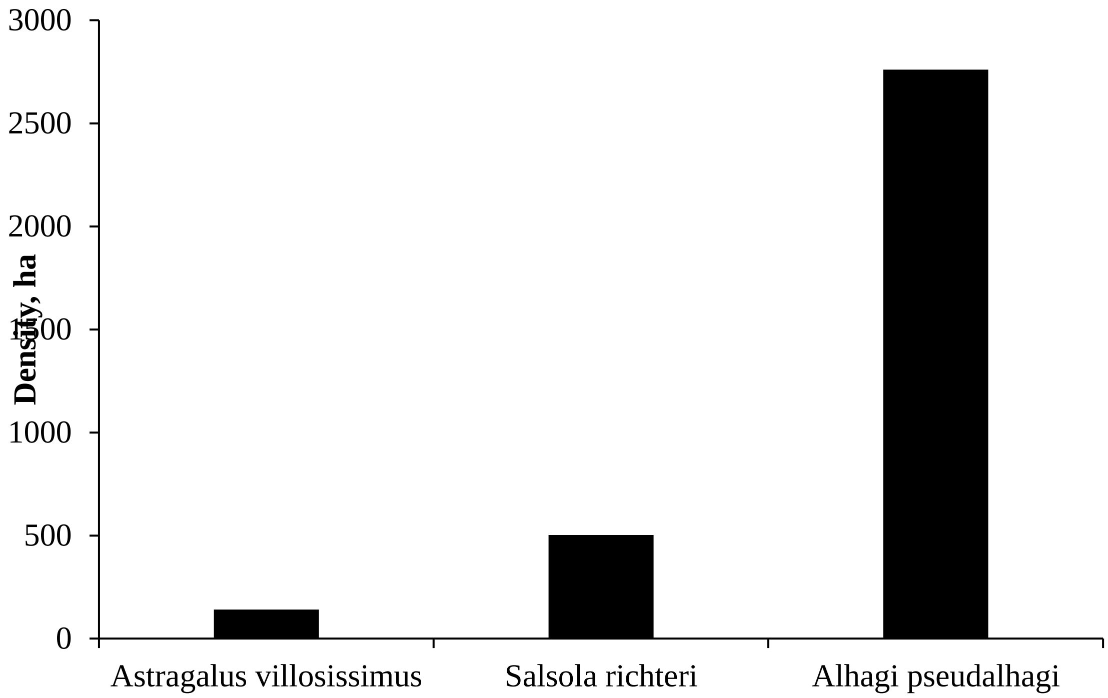


Fig. 23. Density of plants in *Salsola richteri* plant community

Currently, vegetation at the project site is showing important signs (plant species as phytoindicators) of pastures in the process of restoration. Before introduction of the measures, the project area was represented by two main plant communities which had very low forage values. After the adoption of phytomelioration measures, which were running for ive years, these plant associations naturally gave way to other characteristic plant species. They formed a healthy pasture with more characteristic sandy dryland vegetation communities with high economic value. Restoration and development of different plant communities (*Astragalus, Aristida* species, etc.) contributed to consolidation of sand and thus formed the necessary conditions for development of other annual and perennial plant species.

4.3. Dynamics of rangeland productivity

Indicators of autumn productivity of separated plants shows picture, similar for the projective cover, plants quantity. Researches about determining annual increment shows that the in a both plant communities, main quantity of *Agriophyllum latifolium* species mass.

High indicators of *Agriophyllum latifolium* productivity explains as a this plant is annual grass and don`t have a perennial wooden parts. Almost all mass of *Agriophyllum latifolium* forms annual increment. But, during the calculation of its productivity excluding main stems which exceeds 3mm diameter. Also was determined that the indicators of *Agriophyllum latifolium* productivity changes according to studying areas relief. Highest indicators of annual increment of *Agriophyllum latifolium* observed in *Agriophyllum latifolium* plant community and its forms 8 centner/ha or 97 percent of the total productivity of rangelands. A slight annual increase has *Agriophyllum latifolium* and *Convulvulus hamadae*, 0,16 c\ha and 0,04 centner/ha, accordingly. The proportion of *Astragalus villosissimus* in vegetation cover is so low that plays no role in the change of the productivity of rangelands.

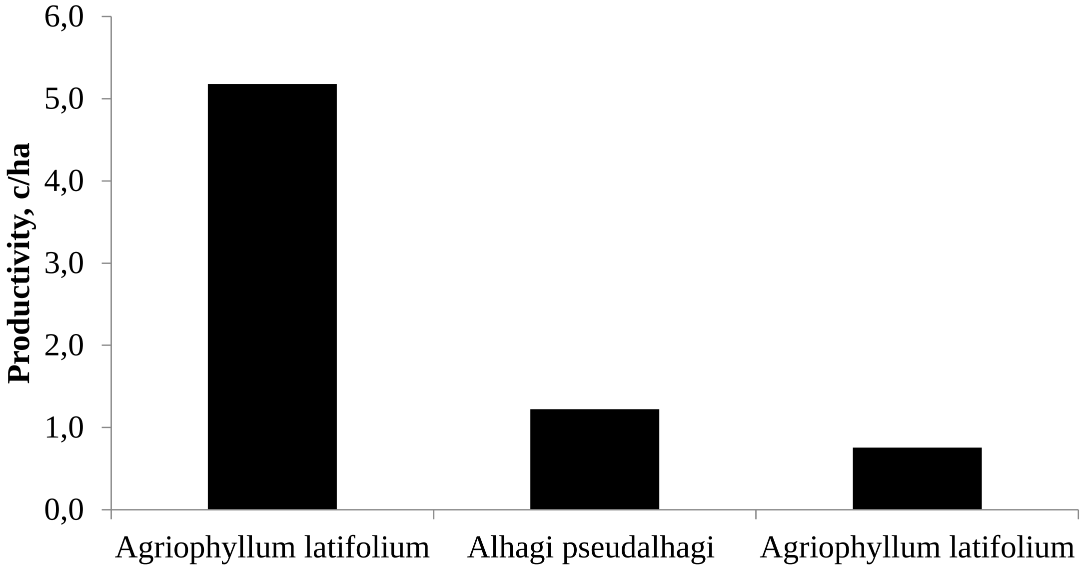


Fig. 24. Annual growth (before restoration) of separete plants in the *Agriophyllum latifolium* plant community

The annual productivity of *Agriophyllum latifolium* reduced *Lagonychium farctum* community and its forms 5,18 c\ha or 72% of the total productivity. The annual increase of *Alhagi pseudalhagi*, one of the main forage plants - is caused by low 1,22 c\ha or 17% of the total rangelands productivity. In spite of *Lagonychium farctum* is dominant character at the vegetation cover on this community has a small reserve of annual increase. If summarize all reserves of vegetation resources in a both communities then productivity of upper tier rangelands average consists 7,73 c\ha in a autumn season. Percent correlation of another plants shows that the *Agriophyllum latifolium* is main part of rangelands productivity which consists 86% of total reserves.

Remaining portion of *Alhagi pseudalhagi* and *Lagonychium farctum* number, 8% and 5% accordingly. Other species occupy an insignificant place in the vegetation. From this follows that despite the relatively high productivity of vegetation in the desert rangeland, feed palatability of existing stock is low, because it is not edible or bad grazing. Below there is a description of some of the features of the study area, feed the main plant in order to get an idea about their role in this rangeland.

After restoration measures productivity of vegetation increased because of appearance of characteristic desert plants. Preventing study area from grazing and cutting leaded to increasing of vegetation productivity and biomass.

Forage from three different types of rangeland vegetation in study area has high fodder quality values. Under natural conditions, plant species that are typical for sandy pasture, would not have such a high productivity. Once sown in the project area, however, their productivity increased compared to performance in other conditions. It should be noted that most of the forage consisted of a single plant species. Thus, in the Saxaul and Salsola dominated plant communities main fodder component (90%) accounted for such species as Black saxaul and Salsola species. Extremely high accumulation of annual growth in the project area was primarily associated with high plant density, which does not always have positive consequences. The number of Black saxaul plant individuals in Saxaul dominated plant communities was characterized by high numbers of dominant species occurrence which reached up to 2,235 individuals als per hectare. However, the optimal plant density of Black saxaul should be within the range of 800-1,000 individuals per hectare [51]. In fact, the natural rate was doubled in this case. It shows that black Saxaul can also be used sustainably for firewood (see below). This indicator in the project area is much higher than the recommended standard rate. An identical situation with high feed stocks was observed in Salsola richteri vegetation community where 94% of the annual increase was accounted for by Salsola richteri species. Dominance of one plant species in this case (despite success in species productivity) does not provide enough diversity in animal forage. From this perspective, emergence and spread of other shrub and semi-shrub plant species in vegetation composition can be a criteria for increasing the economic value of arid land in the project area.

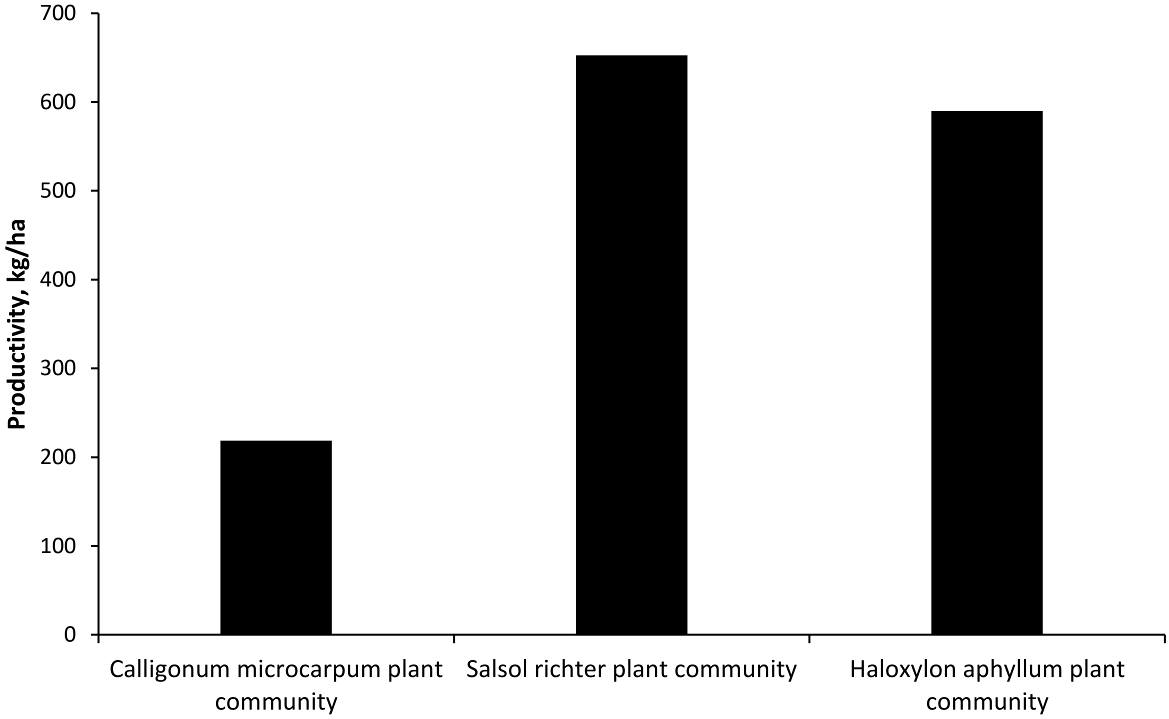


Fig. 25. Annual growth (after restoration) of dominant plant communities in study area

Forage potential was evaluated for the plant species in the study area. Sections with different dominant species can vary in their fodder values. Calligonum-dominated plant community type had a total of 18.0 centner/ha productivity of perennial and annual plants. Total productivity of Salsola richteri is 25.3 centner/ha. The highest increase in productivity was found in Black saxaul dominated plant community where the annual growth of vegetation was 57.5 centner/ha. The study area was grazed by cattle owned by one family throughout the study period. Accurate livestock population data could not be obtained. Field observations showed that lack of grazing on pastures of the project area during ive years started to affect the occurrence of some important plant species. It is another piece of evidence for the important presence of grazing animals. Lack of grazing in rangeland areas contributes to accumulation of dead plant matter. In the long term it worsens the condition of vegetation that eventually leads to pasture degradation. Balanced pasture use is essential for keeping the desert in its healthiest state.

4.4. Remote Sensing based assessment of rangeland restoration processes

Geobotanical methods of vegetation studies can be significantly improved by application of integrated comprehensive methods as Remote Sensing (RS) and Geographical Information Systems (GIS). These methods can help to study changes of vegetation cover in small and large scales with a practical and economical means [57]. RS data covers vast areas and reject natural interrelations, allows exclusion of random or short-term changes, focusing thus on the processes of transformation of ecological state of the ecosystem under observation [54]. RS based studies allow operative assessment and repeated observations of the vegetation condition.

Based on remotely sensed data several vegetation indices with different level of accuracy were developed to study vegetation cover and it`s changes in different ecological zones. For instance, Soil Adjusted Vegetation Index - SAVI [17], Perpendicular Vegetation Index - PVI [20], Transformed Soil Adjusted Vegetation Index - TSAVI [2] and many others. But, in most cases, Normalized Difference Vegetation Index – NDVI [43] is recognized as a most appropriate to monitor various types of vegetation cover with different thematic objectives [39].

In Uzbekistan rangeland vegetation studies using RS and GIS methods are limited [1, 56, 40]. Most RS based vegetation studies in past used satellite images with coarse spectral and spatial resolution. The modern possibilities of RS allow to conduct fine-scale spatio-temporal analyses of vegetation dynamics. Thus, current article sets a purpose to study dynamics of vegetation cover in sandy desert rangelands using the RS and GIS technologies. The article deals with detection of restoration succession of degraded rangelands in sandy deserts using spectral vegetation index derived from Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) multispectral satellite images.

Remote sensed based assessment of vegetation restoration of the target site is performed by calculation of NDVI values.

Analysis showed that the ASTER imagery provides reliable information about vegetation cover and its changes. Two contrasting periods (before and after restoration) was clearly detected by remotely sensed data which is represented by significant difference between NDVI values in three plant communities (Fig. 26.)

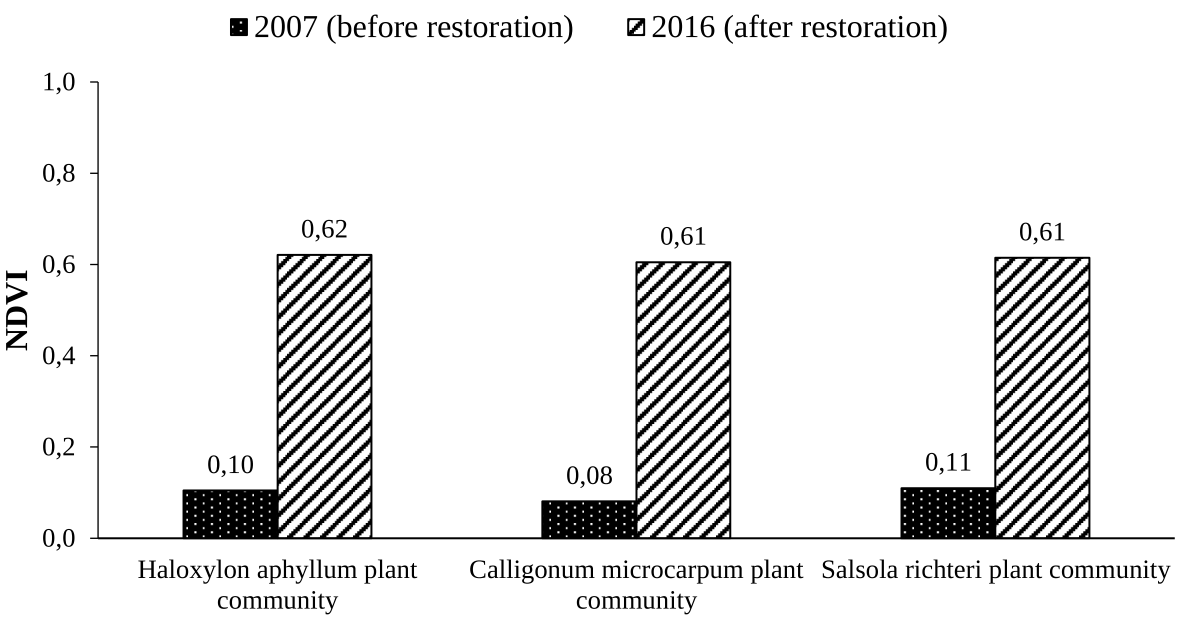


Fig. 26. Dynamics of NDVI values in degraded (2007) and restored (2016) vegetation cover

Poor vegetation stand before restoration was confirmed by low NDVI values which varied between 0,08-0,11. Scarce and unstable degraded vegetation with domination of unpalatable plants as *A. latifolium* and *L. farctum* has generated low NDVI values in the spring season of 2007. In comparison to previous degraded condition, NDVI values have significantly increased in the condition of restored rangelands by spring season of 2016. NDVI values of restored vegetation varied between 0,61-0,62 with very low difference between three plant communities (Fig. 26.). Relatively high values were observed in H. aphyllum plant community which is well compatible to ground condition of the site (high green biomass). NDVI values of other two plant communities had also relatively high NDVI values due to the accumulation of large amount of annual biomass of forage plants. As can be seen, the clear difference between degraded and restored vegetation was well detected by ASTER multispectral imagery. The qualitative and quantitative dynamics of vegetation cover of restored rangelands was well confirmed by NDVI values in the condition of three restored plant communities.

Assessment of vegetation cover and biomass by NDVI values is one of the popular methods of vegetation studies in Remote Sensing. NDVI values explains (Table 4.) current and noncurrent condition of study area [32].

NDVI	Biomass and vegetation cover
-1 – 0.10	Bare soil or no data
0.11 – 0.20	Minimum biomass and very low-standing grass vegetation
0.21 – 0.30	Middle biomass, low-standing grass vegetation
0.31 – 0.55	High biomass, high-standing grass vegetation
0.56 – 0.70	Very high biomass and high-standing grass vegetation with random shrubs
0.71 – 1.00	Maximum biomass, forests

Table 4; Assessment of biomass and vegetation cover by NDVI values

Obtained NDVI values of *Haloxylon aphyllum* plant community from 2007, 2011 and 2016 years shows that the restoration of vegetation between 2007 and 2011 increased (Fig. 27.). NDVI values before restoration (2007) equal to 0.10. This value explains that the territory of *H. aphyllum* plant community was represented as a bare soils or sands without plants. After restoration measures in 2011 year, NDVI values of territory *H. aphyllum* plant community increased and equals to 0.57. This value shows that the plant community has a good biomass and this value comply with ground-truth data.

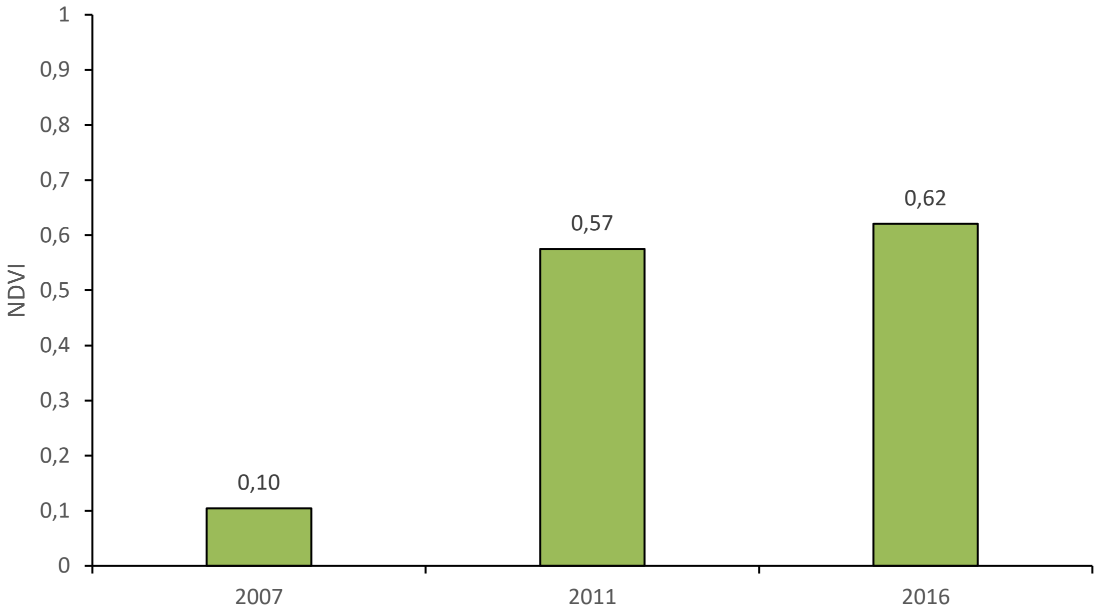


Fig. 27. NDVI values of *Haloxylon aphyllum* plant community

Values between 2011 and 2016 is trivial but presents increasing.

NDVI values in *Calligonum microcarpum* plant community has the same positive state as in *Haloxylon aphyllum* plant community. Values in 2007 is small and equals to 0.08, but after restoration increasing to 0.56 in 2011 and to 0.61 in 2016 (Fig. 28.). According to ground-truth data methods, values comply with biomass of these plant community

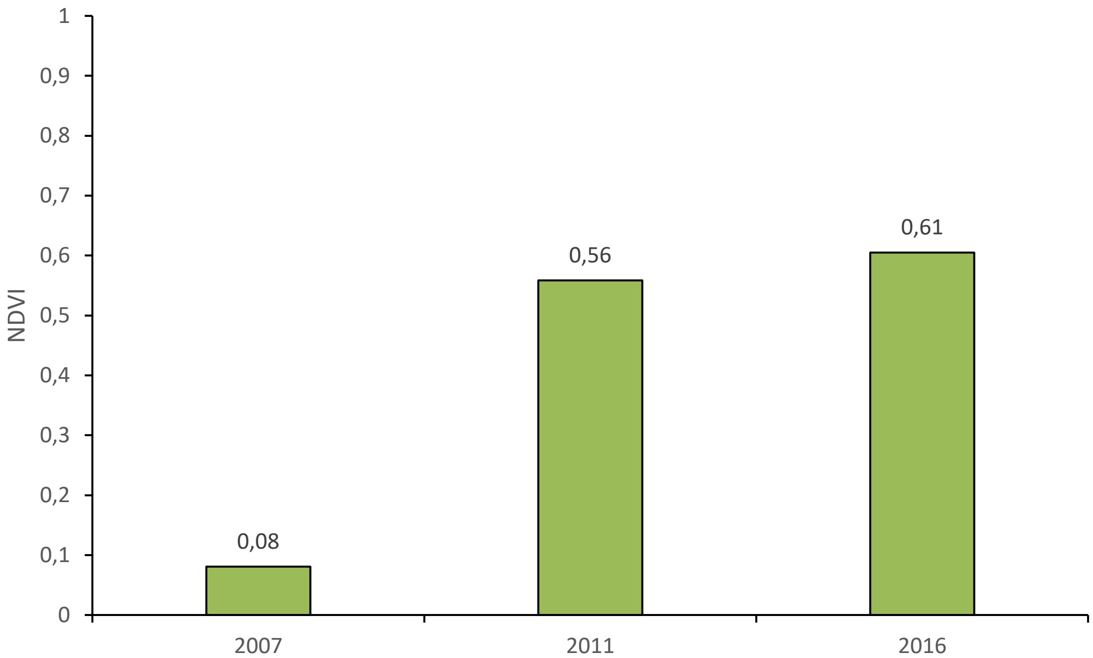


Fig. 28. NDVI values of *Calligonum microcarpum* plant community

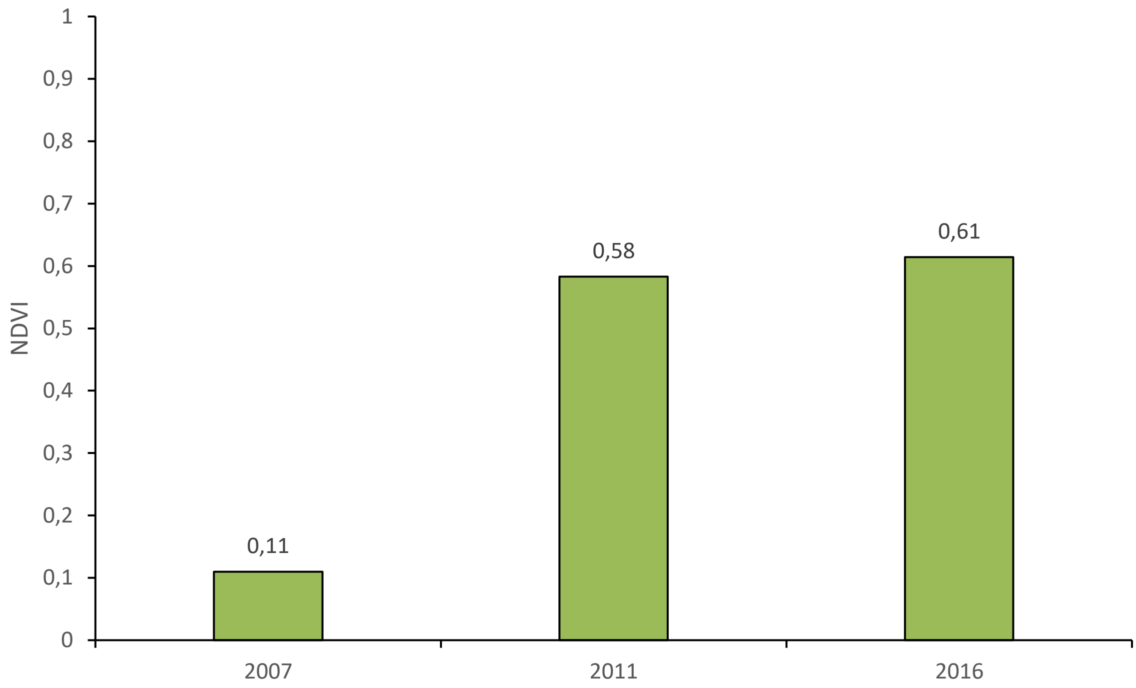


Fig. 29. NDVI values of *Salsola richteri* plant community

As showed in Fig. 29., NDVI values of *Salsola richteri* plant community is same either as in two previous plant communities. Values in 2007 equal to 0.11. This value increasing from 0.58 in 2011 to 0.61 in 2016.

Obtained results confirmed with results of biomass calculating which was conducted by ground-truth geobotanical methods.

Detection of restoration succession in study area was well performed by NDVI values derived from ASTER satellite imagery. Degraded and restored vegetation condition is apparently differentiated by remotely sensed data. Based on the research evidence we can confirm high potential of satellite imagery to use in monitoring of vegetation variations in desert ecosystems. Thus, the combination of ASTER imagery with NDVI values can be widely applied in assessment of current condition of desert rangelands which lies on the basis of sustainable utilization and management of vegetation resources.

Conclusion

1. Restoration succession of degraded rangelands in study area was consistent. Successful vegetation restoration and further self regeneration of native plant species as Astragalus villosissimus, Arisitida pennata and Convolvulus hamadae during 6 years was well promoted by exclusion of livestock grazing and other human activities in the study area.
2. Species diversity and richness is significantly improved after restoration measures were taken. This resulted in accumulation of palatable forage biomass which is increased to 64% compare to degraded state of the rangelands. Existence of this palatable biomass allows the rangelands for whole year round use under livestock grazing.
3. Detection of restoration succession in study area was well performed by NDVI values derived from ASTER satellite imagery. Degraded and restored vegetation condition is apparently differentiated by remotely sensed data where NDVI values of degraded rangelands indicated 0,41, whereas restored rangelands showed 0,61 values.
4. Based on the research evidence we can confirm high potential of ASTER satellite imagery to detect vegetation variations and to assess vegetation dynamics in desert ecosystems of Uzbekistan.

Reccomendations

1. Successful restoration practice in degraded rangelands of Surkhandarya province can be recommended to be outscaled in other degraded and low productive rangelands of Uzbekistan.
2. Combination of ASTER imagery with NDVI values can be widely applied in assessment of current condition of desert rangelands which lies on the basis of sustainable utilization and management of vegetation resources.
3. Obtained results can be recommended to use as a teaching materials for lectures and practical lessons for students of professional colleges and higher education institutions.

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