ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 9, Issue 11 , November 2022

Assessment of Natural External Influences on Pasture and Forages in the South Aral Sea Regions using Remote Sensing and Geoinformation Technologies

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ABSTRACT: This article is aimed at assessing the condition of pasture lands and natural external influences in regions with severe natural conditions. One of the main indicators in the assessment of pasture lands is paid attention to vegetation cover. Having the necessary information on the use of pasture lands in areas with severe natural conditions help to use these lands effectively. Remote sensing is one of the most effective ways to obtain reliable and quality information about environmental conditions in a short period of time. In this study, the condition and changes of vegetation in the research area were studied using remote sensing and geographic information systems. The research was conducted using ArcGIS software from the family of modern GIS technologies using Landsat 8 data. Among the external natural influences on pasture lands, soil salinity and precipitation conditions were studied together with vegetation cover. The effect of natural external factors on vegetation cover was evaluated. In the study, changes in the location of plants, productivity, soil salinity and precipitation were studied over the last 10 years. Based on the obtained data, the use of pastures, the period of fodder collection and the level of productivity were determined. Using these methods, we can make the necessary predictions about pasture use.

KEYWORDS: Pasture, Remote Sensing (RS), Geoinformation System (GIS), Normalized Difference Vegetation Index (NDVI), Salinity Index (SI), precipitation.

I. INTRODUCTION

Pasture is land with a natural cover of plants that are fodder for livestock. Regions may have different norms and methods of using land as pasture. Because the productivity of pastures, the period of use is determined based on the inventory of pastures and geobotanical research materials. Pasture productivity and forage quality vary dramatically not only from year to year, but also from season to season. The amount of feed in some pastures decreases by 2.5 times by the winter season. It has been determined that the amount of precipitation in pastures is 80% in average years, 55-60% in low-yielding years, 30-40% in very low-yielding years.

In recent years, global climate change processes have also negatively affected pasture productivity in non-montane arid zones with desert vegetation and semi-arid areas with summer livestock pastures. Temperature changes in the region lead to disruption of the hydrological cycle. The vegetation composition of pastures used for livestock grazing is expected to change significantly, affecting forage production and grazing. This, in turn, makes it necessary to regularly monitor the land. Earth observation gives us geospatial information [22].

Continuous monitoring of the state of pastures in the desert regions allows timely reporting on the processes of transformation in the natural complexes of the region.

Land cover change is causing a loss of biological productivity and biodiversity in many terrestrial and aquatic ecosystems [4]. In the Central Asian region, plants are shrinking every decade due to growth trends during the growing season [6].

Climate is a major driver of vegetation cover change [4]. Vegetation dynamics plays an important role in the assessment of environmental processes due to the close relationship between the biosphere and global ecological parameters [1]. Plant growth largely depends on the interaction of environmental factors. There are direct and indirect effects of seasonal climate change on plant growth [14]. In general, plant growth is often promoted by increased

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 9, Issue 11 , November 2022

temperature where water is not a limiting factor, but this increase in temperature has the opposite effect in arid and semi-arid regions [1].
When evaluating land, a comparison of many factors affecting the studied indicator is made. It is necessary to characterize the nature of the problem and the range of effects on vegetation through field sampling, and it is difficult to determine the geographic extent and location of disturbed areas using traditional field methods. Remote sensing of the ground offers an alternative approach to spatial coverage, which, combined with field sampling, has proven to be very useful in monitoring plant health [10].
The Normalized Difference Vegetation Index (NDVI) has proven to be a useful index in describing vegetation distribution and phenological seasonal variation. Thus, NDVI is the most widely used remote sensing dataset for vegetation and land degradation monitoring [15].
Remote sensing-based NDVI is widely used to monitor and assess vegetation dynamics and terrestrial net primary production, mainly focusing on long-term environmental and eco-physiological changes [14]. NDVI derived from satellite data is often used to analyze the growing conditions of green plants and determine the response of vegetation dynamics to climate change [5]. Remote sensing vegetation indices have the potential to assess crop growth variability by quantifying relative growth and crop health condition [2].
NDVI is a remote sensing index used to measure vegetation health and differentiate green vegetation from non-green vegetation. NDVI helps determine whether the condition of vegetation in different areas has deteriorated, remained unchanged or improved [18].
It should be noted that drought is generally recognized as one of the most destructive meteorological disasters. The agricultural sector is the first victim of drought, since agricultural drought is mainly caused by a lack of precipitation, which ends up with a shortage of water in the soil and the difference between actual and potential evaporation [13].
Therefore, the role of rainfall in providing livestock with fodder, underground and surface water sources in pasture lands is very important. Because precipitation is considered to be the main climatic factor that causes changes in vegetation [23]. It should be noted that NDVI also increases as precipitation increases. This means that NDVI is sensitive to rainfall events [13].
Some studies show that the weather has become more variable over the past half century, with more frequent and more intense precipitation events, and changes in the timing and location of precipitation [24].
According to research, climate change is already having serious effects on human society and the natural world, and is expected to continue to do so for decades to come [12].
Given the importance of land surface conditions in the water cycle, many researchers have focused on the relationship between precipitation and vegetation, especially in semiarid environments [8].
In studies of precipitation estimation using satellite data, PERSIANN (Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks) precipitation products have been shown to provide better precipitation estimates [9]. PERSIANN-CCS algorithms estimate precipitation from geosynchronous Earth orbit infrared (GEO-IR) imagery using artificial neural networks (ANNs) and cloud classification system techniques [17]. The PERSIANN-CCS system allows categorization of cloud-patch features based on cloud height, area level, and texture variability estimated from satellite imagery (http://chrsdata.eng.uci.edu/). Data from the PERSIANN family of algorithms is provided in various raster formats (ArcGrid, TIFF, and NetCDF) and is available for request on-site for instant download using the Download tool. Data requests for spatial coverages smaller than global scale come with ESRI shapefiles for easy importation into Geographic Information Systems (GIS) programs [16].
One of the factors limiting the productivity of plants is soil salinity. Soil salinity leads to a decrease in plant productivity. This process is mainly related to drought and climate change [20].
Soil salinization is an environmental disaster. Saline soil not only leads to a decrease in soil hardness and fertility, but also can lead to the loss of resources in agricultural production, which poses a serious threat to the biosphere and ecological environment [25].
Today, for various reasons, the saline areas of the world are increasing by 10% every year. In particular, low rainfall, high surface evaporation, irrigation with saline water lead to soil salinization. According to research, by 2050, more than 50 percent of cultivated land will be saline. In the fight against soil pollution, salinization and desertification, research on plant and soil fertility is vital to ensure food security in the face of a growing world population. In such conditions, not only increasing the productivity of plants, but also improving the condition of the soil through the interaction of plant roots and soil microorganisms requires appropriate modern technologies [20].

ISSN: 2350-0328
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Vol. 9, Issue 11 , November 2022

II. MATERIAL AND METHODS

A. Study area

The southern Aral Sea region of the Republic of Karakalpakstan was selected as the study area. The Republic of Karakalpakstan is located in the northwestern part of the Kyzylkum Desert, southeastern part of the Ustyurt Plateau and in the Amudarya delta. The climate is sharply continental, with dry summers and relatively cold winters, with little snowfall. As a result of the study of the vegetation condition of the Republic of Karakalpakstan, the area closest to the Aral Sea was selected as a study area. Because most of the negative consequences of the drying up of the Aral Sea are the first to affect the regions closest to the Aral Sea. In addition, plants are a key indicator in determining environmental changes.

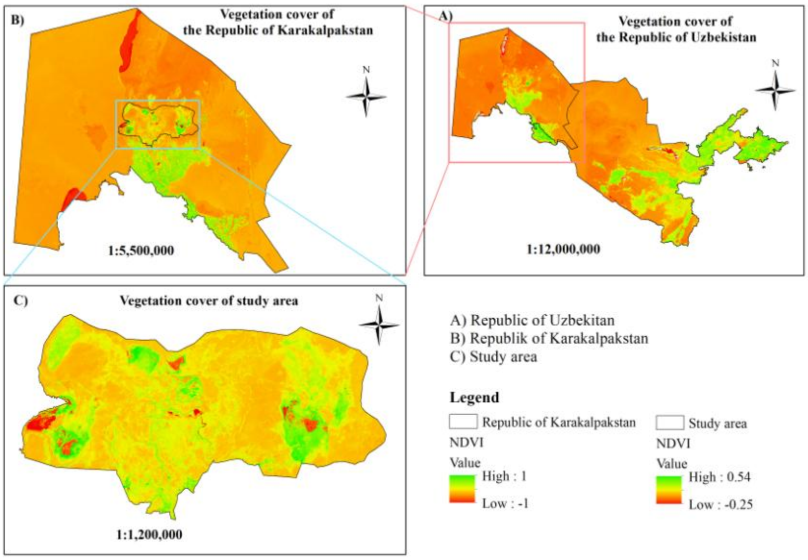


Figure 1. Location of the study area forest

Since 1960, the water level of the Aral Sea has started to decrease significantly, and it continues to this day, leading to drastic changes in the climate around the Aral Sea [7].

In order to prevent or mitigate the negative consequences of the environment, this situation requires timely understanding of the events taking place in the area, based on scientifically based proposals and conclusions.

The use of NDVI is one of the most effective indicators for obtaining information about the state of vegetation.

NDVI is associated with the physiological state of the plant and the process of photosynthesis. It helps to find information about the state of the soil in terms of greenery, chlorophyll content, water content and etc. NDVI is a remote sensing index used to distinguish green plants from non-green plants [18] and is calculated as follows [19].

$$NDVI=NIR-RED/NIR+RED$$

here: NDVI – Normalized difference vegetation index, NIR - close to the infrared of the spectrum and RED – reflection of the spectrum in red. NDVI values range from -1 to +1. Healthy green vegetation normally has the highest positive values while surfaces without vegetation, such as bare soil, water, snow, ice or clouds usually have low NDVI values that are near zero or slightly negative [21].

PERSIANN-CCS estimates real-time global precipitation at high spatial resolution using a cloud clustering algorithm and infrared (IR) data, the resolution is 0.04° x 0.04° or 4km x 4km. PERSIANN-CCS system enables the categorization of cloud-patch features based on cloud height, areal extent, and variability of texture estimated from satellite imagery (http://chrsdata.eng.uci.edu/).

PERSIANN-family datasets are utilizable for projects and research anywhere there is a demand for precipitation estimates over time and space between 60°N and 60°S [13].

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 9, Issue 11 , November 2022

Data from the PERSIANN family of algorithms is provided in various raster formats (ArcGrid, TIFF, and NetCDF) and is available for request on-site for instant download using the Download tool. Data requests for spatial coverages smaller than global scale come with ESRI shapefiles for easy importation into Geographic Information Systems (GIS) programs [24].

Data for soil salinity assessment and mapping are collected using traditional soil sampling and laboratory analysis methods. However, these methods are time-consuming, so research is limited to small areas. Several methods for estimating soil salinity have been developed to overcome this limitation. One such method is based on remote sensing, which has shown great success in mapping and estimating soil salinity [3].

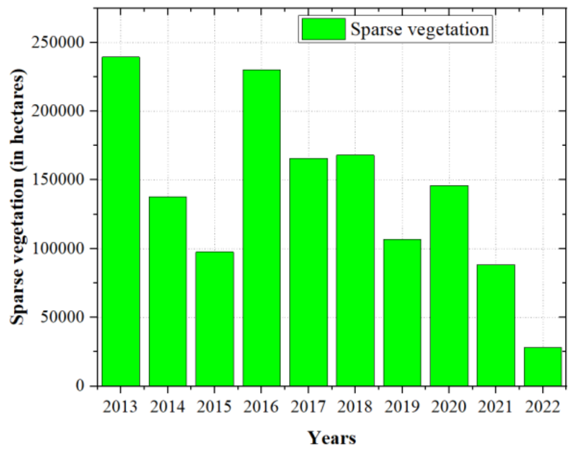
The salinity index is determined using the following formula: [11]

$$SI = (NIR*RED)^{1/2}$$

Here: SI – salinity index, NIR - close to the infrared of the spectrum and RED – reflection of the spectrum in red.

III. SIMULATION&RESULTS

Based on the above information, research was conducted on the lands used for pasture and fodder collection. As a result, it was determined that the development of plants in the region begins in March-April, and the highest point of development corresponds to the end of June and the beginning of July. As a result, we were chosen the month of June to study the condition of plants in pastures and fodder areas. Studies have shown that in the last ten years, the area of sparse vegetation has decreased by 90%, and we can see that dense vegetation almost did not remain. This, in turn, means that low-quality pastures have appeared in the regions, and the areas for fodder cultivation have decreased sharply. The result is a decrease in the amount of fodder collected for livestock (Figure 2).



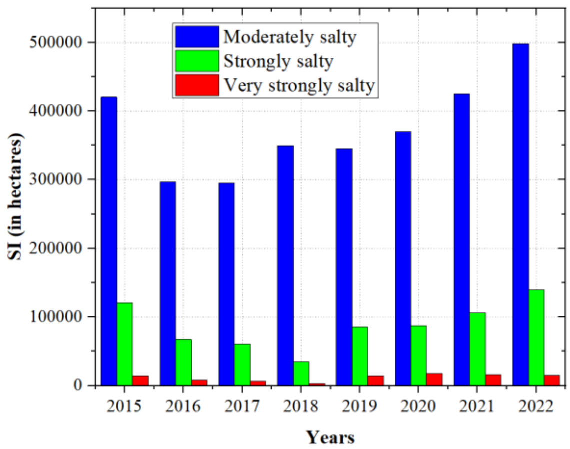


Figure 2. Changes in sparse vegetation areas (in June) Figure 3. Changes in saline soil areas (in July)

Along with the reduction of vegetation cover in the study area, it was found that the salinity of the soil is also increasing. The research work was studied as a state of July. From the categories of soil salinity, it was known that the average amount of salinity increased by one and a half times. We can also see that the area of highly saline and very high saline areas is constantly increasing (Figure 3).

ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 9, Issue 11 , November 2022

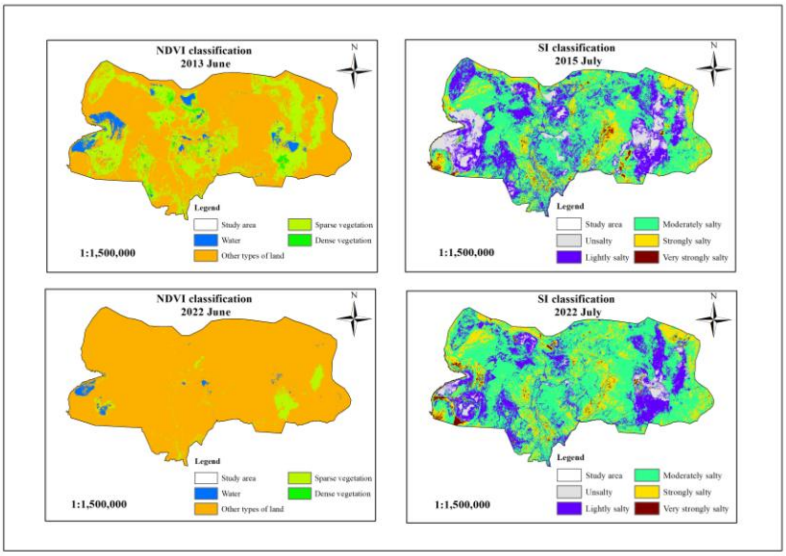
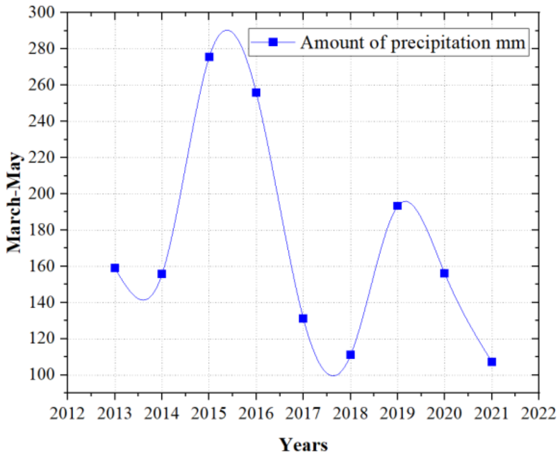


Figure 4. Changes in vegetation cover and soil salinity using Landsat 8 satellite images

PERSIANN-CCS data was used to assess the impact of precipitation on the change of vegetation cover in the area. The data showed that the amount of precipitation has decreased in recent years and the areas where precipitation is observed have also changed (Figure 5).



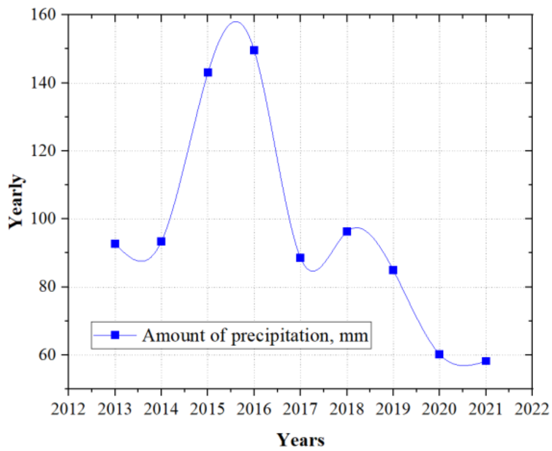


Figure 6. Changes in the amount of precipitation for March-May (Hydrometeorological station data).
Figure 7. Changes in average annual precipitation (Hydrometeorological station data).

Precipitation was mainly observed in the southeastern part of the Ustyurt Plateau, but in recent years, the precipitation in this area has decreased. If we take into account that large parts of the territory of Karakalpakstan belong to non-irrigated lands and are arid regions, the productivity of pastures will decrease in the years of low rainfall in these regions. Lack of rainfall in this region poses a great threat to livestock farming.

In terms of geographical location, green vegetation is mainly present around the Amu Darya delta in spring, summer and autumn. In the remaining parts of the Republic of Karakalpakstan, southeastern part of the Ustyurt Plateau, the

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 9, Issue 11 , November 2022

southern parts of the Aral Sea, and northwestern part of the Kyzylkum Desert, ephemeral plants grow mainly in the spring, and these plants dry up as the temperature rises. Therefore, the amount of precipitation observed in these parts of the Republic of Karakalpakstan plays a key role in the use of pasture lands.
In the work carried out to determine the accuracy of the PERSIANN-CCS data, the data was shown to be correct when compared with the data of the hydrometeorological station.

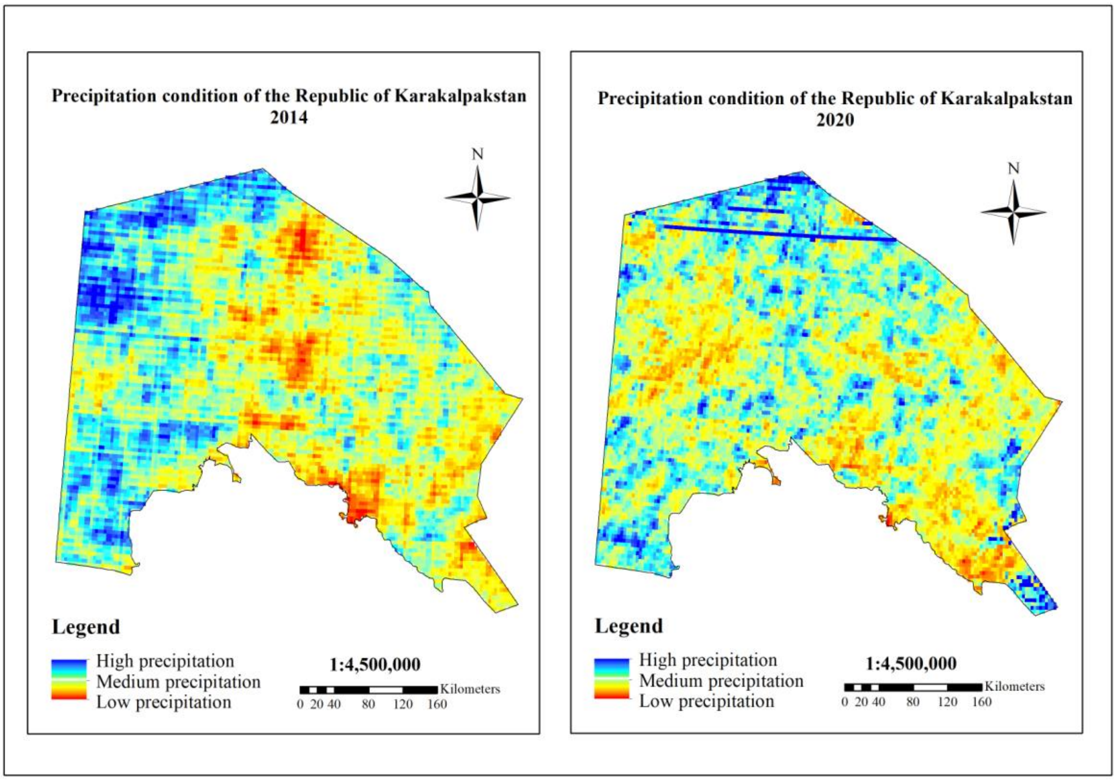


Figure 5. Changes in the amount of precipitation

Precipitation rates observed in early spring on grasslands in arid regions can determine the productivity of grasslands. The conducted research showed that in the last decade, the rainfall in March, April and May has also decreased (Figure 6). We can see that the average annual precipitation has also continued to decrease in recent years (Figure 7).

IV. DISCUSSIONS

The decrease of precipitation in the non-irrigated desert regions of the Republic of Karakalpakstan, the decrease of fodder cultivation areas, and the increase of soil salinity in the areas closest to the dry part of the South Aral Sea have a negative external effect on pastures. Therefore, in planning the use of pasture land in this area, it is very important to have information about the vegetation condition, visual observation of precipitation in early spring, and the salinity of pasture soils. Based on the amount of water collected in pastures irrigated in early spring, we will be able to estimate the area of growing pasture plants and determine productivity.
It turned out that PERSIANN-CCS data is useful for visual monitoring of precipitation in early spring. Because, a cloud-based classification system for remotely sensed precipitation estimation using artificial neural networks (PERSIANN-CCS) can provide numerical and image-based precipitation data. When we compared the data of this system with the data obtained by the traditional method, it was found that the accuracy of the images of the precipitation state of the area coincided with each other. However, due to the fact that the accuracy level of this system is 4 km, the accuracy of the data in some areas has partially decreased. But the level of accuracy of the main indicators has been proven to be high.

V. CONCLUSION

Using the above information and methods, we will be able to research pasture lands, plan the use of pastures, assess pasture productivity and soil salinity, and visualize the state of precipitation. As a result, we will be able to determine the use of pastures, fodder collection periods, and make reliable predictions about the condition of pastures in the future. Therefore, it is useful to use remote sensing methods and geoinformation technologies in the implementation of these works.

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