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Original Article

EVALUATION OF NORMALIZED DIFFERENCE VEGETATION INDEX IN WILD APPLE POPULATIONS GROWING IN SOUTHEAST MOUNTAIN REGIONS OF KAZAKHSTAN

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ABSTRACT

NDVI is one of the most common vegetation indices for solving various problems of assessing the state of vegetation cover and its dynamics. The purpose of the study was to evaluate the state of wild Sievers apple trees in the territory of Phenological area, Genetic Reserve of Sievers, Tauturgen and Sievers apple reserve (Zhongar-Alatau and Ile-Alatau SNNP) using the NDVI index. The period of study was season's autumn 2022 and spring 2023. Created interactive maps of the study area with multispectral reconstructions in NDVI formats let us was established the condition of the Sievers apple tree. Which was based on an analysis of the deviation of the NDVI of each tree in the study area from the average index value for the vegetation of the entire type of area. This allowed us to identify the territorial features of the state of the Sievers apple trees and identify degraded trees. The results obtained can be used for the rational management of environmental management by the Zhongar-Alatau SNNP and the Ile-Alatau SNNP.

Key words: NDVI, Sievers apple tree, multispectral reconstructions, Zhongar-Alatau SNNP, Ile-Alatau SNNP.

INTRODUCTION

Normalized Difference Vegetation Index (NDVI) is a common remote sensing calculation used to assess green biomass [1]. High-resolution aerial images also allow the calculation of the NDVI vegetation index using the built-in spectral solar sensor on the top of the drone, which captures solar radiation, ensuring maximum accuracy and consistency in data collection at different times of the day [2, 3].

Table 1. presents a scale for assessing the dependence of the NDVI index on the development of vegetation cover [2, 3]. The presence of plants in the analyzed area is determined by NDVI values from 0.1.

NDVI examines the difference/sum ratio of red and infrared radiation bands (NIR-RED)/(NIR+ RED). The general formula to calculate the Normalized Difference Vegetation Index (NDVI) is

$$\text{NDVI} = \frac{NIR_{ref} - Red_{ref}}{NIR_{ref} + Red_{ref}} \quad (1),$$

Where $Xref$ represents the reflectance value of the X band, $NIRref\ and\ Redref$ are the reflectance values of the NIR and Red bands, respectively.

If we define $Xreflected$ and $Xincident$ as the reflected light and incident light of the X band, then,

When the sunlight (i.e. the incident light) is reflected off of the target, multispectral cameras capture the reflected light of the target in the form of multispectral images, and the sunlight sensor captures the incident light to record sunlight sensor signal values [4].

NDVI was initially used to assess the presence of vegetation and this application was confirmed in many studies [1]. That is based on the strong red-light absorbance response of chlorophyll relative to a strong NIR reflectance by leaves. Other applications recognized that if chlorophyll production was reduced by biotic (disease, insect damage) or abiotic (nutrition, salinity, water stress), there would be increased red reflection and a reduced NDVI value [5-9].

The study area includes Zhongar-Alatau State National Natural Park: 1 population - Phenological area, 2 population - Genetic Reserve of Sievers and Ile-Alatau State National Natural Park: 3 population - Tauturgen, 4 population - Sivers apple reserve (Figure 1, 2).

The Ile-Alatau State National Natural Park was created by Decree of the Government of the Republic of Kazakhstan dated February 22, 1996 No. 228. In 2014, forest management work was carried out on the territory of the Ile-Alatau State National Natural Park. The total area of the Ile-Alatau State National Park as of 01/01/2023 is 200,160 hectares, of which the forested area is 69,956 hectares [10].

$$NIR_{ref} = \frac{NIR_{reflected}}{incident},\ Red_{ref} = \frac{Red_{reflected}}{incident} \quad (2),$$

Table 1. Dependence of the NDVI index on the state of vegetation cover [2].

The index value of NDVI	The degree of development of green biomass
0-0.2	Lack of vegetation
0.2-0.3	The low degree of development of biomass
0.3-0.6	The average degree of development of biomass
0.6-1.0	A high degree of development of biomass

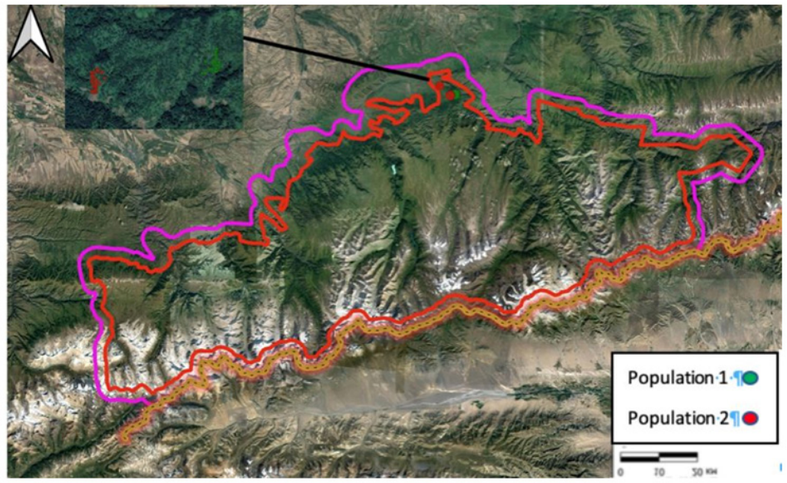

Figure 1. Zhongar-Alatau SNNP (Phenological area – 1 population, Genetic Reserve of Sievers – 2 population)

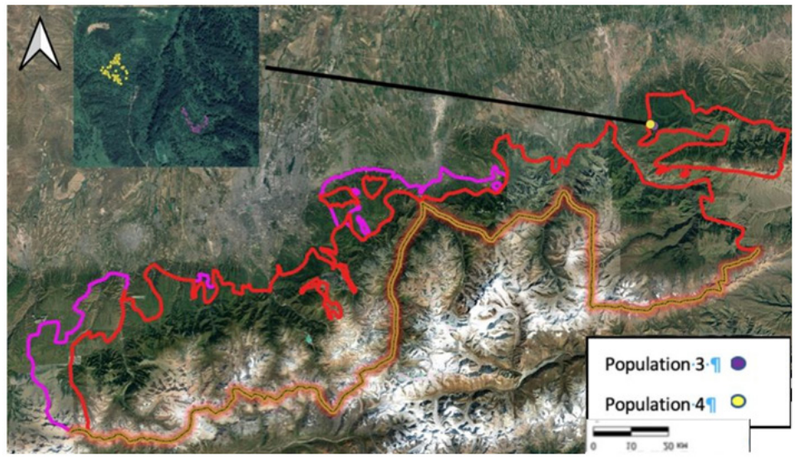

Figure 2. Ile-Alatau SNNP (Tauturgen – 3 population, Sievers apple reserve – 4 population)

At the Ile-Alatau SNNP, research is being carried out to study the soil and climatic conditions for the creation of forest crops of coniferous and deciduous forest species (Schrenk spruce, common apricot, Sievers apple tree) depending on the altitude above sea level and slopes exposure [10].

Zhongar-Alatau State National Natural Park is located on the territory of Aksu, Sarkand and Alakol districts of Almaty region. It was created in accordance with the Decree of the Government of the Republic of Kazakhstan dated April 30, 2010 No. 370. The area of the Zhongar-Alatau SNNP is 356,022 hectares. Research work is being carried out on biomonitoring of the phytosanitary state of wild fruit forests of the Zhongar Alatau, silvicultural and environmental assessment of Sivers apple tree plantings and the development of methods for its reproduction, carrying out botanical-geographical, geobotanical, population genetic and other studies in wild fruit forests of the Sivers apple tree, creating a living collection of plus (elite trees) Sievers apple trees and those created on the basis of the Zhongar population of its clone varieties, etc. [11].

MATERIALS AND METHODS

Data. The data used for this study were the Google Earth images, the multispectral reconstructions of 4 populations (Phenological area, Genetic Reserve of Sievers (Zhongar-Alatau SNNP), Tauturgen, Sievers apple reserve (Ile-Alatau SNNP)) in NDVI formats data from Dji phantom 4 pro drone. The software program that was used include QGIS 3.28 (Firenze) and Netlify (web development platform). All data for autumn 2022 (October) and spring 2023 (May) years.

Methods. The maps were created in QGIS. The qgis2web plugin was used for creating an interactive map. This module allows to create an HTML page. In Layers and Groups, we selected the layers that we needed or, conversely, those that needed to be excluded. The Open Layers interface type was selected. The map displays zoom buttons, rulers, a search window, and when you click on any sampling point of the Sievers apple tree, the infectious status of each tree for the study period is displayed (Figure 3, 4).

Multispectral reconstructions in NDVI format were also added for each population for the fall 2022 and spring 2023

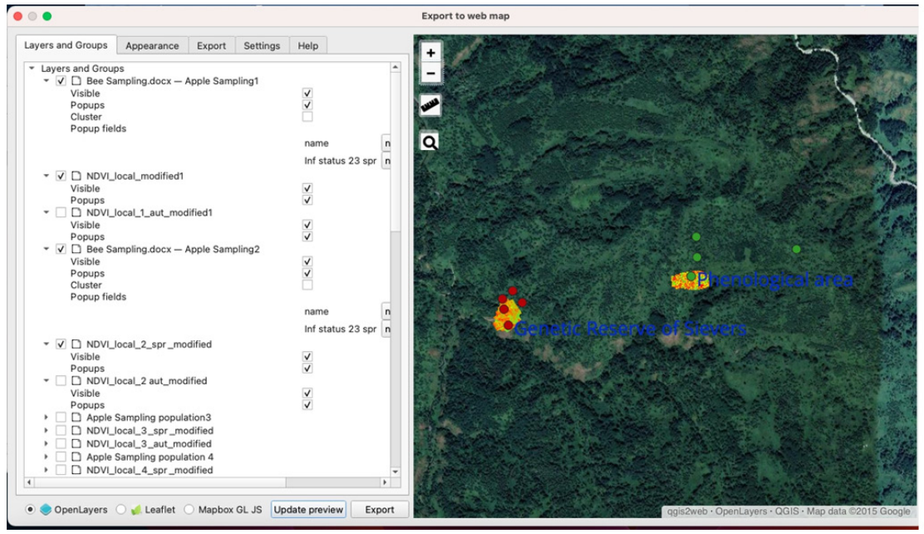

Figure 3. Export map to web map in plugin qgis2web in populations Phenological area, Genetic Reserve of Sievers (Zhongar-Alatau SNNP)

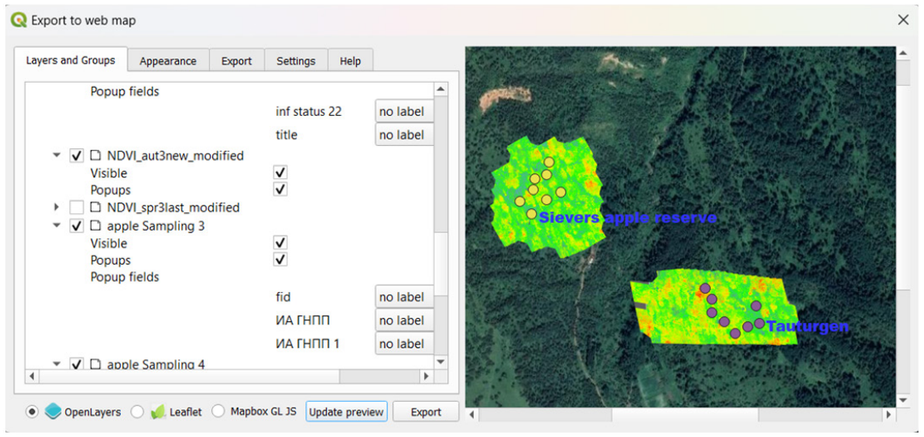

Figure 4. Export map to web map in plugin qgis2web in populations Tauturgen, Sievers apple reserve (Ile-Alatau SNNP)

seasons. The multispectral reconstructions of 4 populations (Phenological area, Genetic Reserve of Sievers (Zhongar-Alatau SNNP), Tauturgen, Sievers apple reserve (Ile-Alatau SNNP) in formats NDVI data from Dji phantom 4 pro drone. Multispectral reconstructions were constructed using software DJI Terra Pro software. Next, the saved html pages were added to Netlify (web development platform) where they are publicly available.

RESULTS AND DISCUSSION

Interactive maps of the study area were created with multispectral reconstructions in NDVI formats.

Under normal conditions, the NDVI index has minimal values in the spring, stable values in the summer, and a gradual decrease in the intensity of the growing season in the fall [2]. The distribution of NDVI for each type of terrain indicates the leading importance of natural factors in its formation: NDVI of grass ecosystems is lower than that of forest ecosystems.

According to the results obtained, it is clear that the NDVI of Sievers apple trees of population 1 in the fall of 2022 ranges from 0.51 to 0.87. Trees at points 3, 7, 10, 13, 35, 42, 43 are sick with different intensities: their vegetation index NDVI ranges from 0.18-0.41. NDVI of the undergrowth was marked by values of 0.43-0.61, of areas uncovered by vegetation - 0.24-0.36, which is also due to the structure of the plant community itself. Locally around the existing road, a decrease in NDVI to 0.12-0.18 is noted (Figure 5a).

Figure 5. was displayed a multispectral reconstruction of the NDVI index of Sievers apple trees of population 2 for the same study period, which ranged from 0.51 to 0.88. There were areas with depressed trees and low NDVI (0.23-0.42) - these are points 1-6, 16, 18, 19, 21, 45, 46, 47. A decrease in NDVI was noted for areas not covered with vegetation - 0.21 -0.34 (Figure 5b). There was also a section of the road network around which the NDVI index is very low - 0.12-0.17.

In the spring of 2023, the NDVI vegetation index of Sievers apple trees of population 1 varied from 0.59 to 0.91. Since

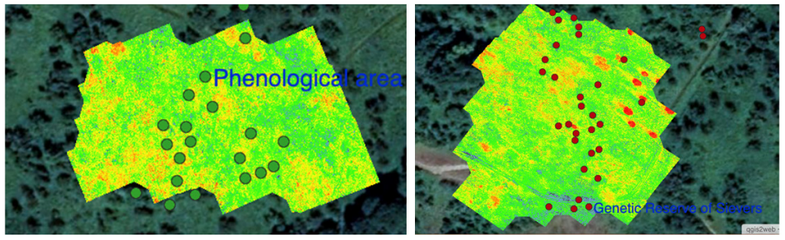

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Figure 5. Multispectral reconstructions in NDVI index of the 1 (a) and 2 (b) populations (fall 2022)

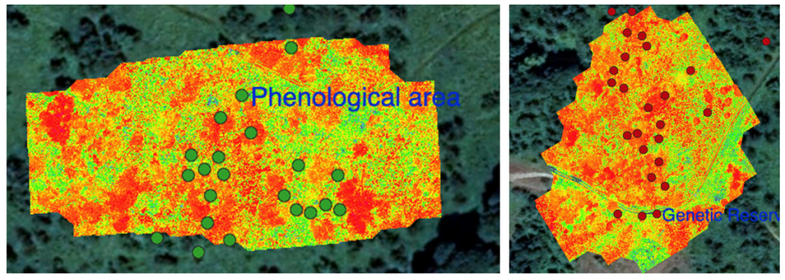

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Figure 6. Multispectral reconstructions in NDVI index of the 1 (a) and 2 (b) populations (spring 2023)

it was May, it was much more intense than in October 2022. Figure 6a shows that trees at points 3, 7, 13, 32, 35, 42, 43 were sick with different intensities: their vegetation index NDVI ranges from 0.19 to 0.33. Understory NDVI is in the range of 0.45-0.65. A decrease in NDVI were noted for areas not covered with vegetation - 0.35-0.44. Locally around the existing road, the NDVI indicator was expectedly very low - 0.12-0.19 (Figure 6a).

The NDVI index of Sievers apple trees of population 2 in the spring of 2023 has a slightly different distribution: ranging from 0.53 to 0.92. There were (Figure 6b) areas with depressed trees and an NDVI index (0.31-0.43) - these are points 2-4, 45, 46. The highest values of the NDVI index were observed in the central and northern parts of the population - the places where the Sievers apple tree grows. A decrease in NDVI was occurs for areas not covered with vegetation - 0.35-0.45 (figure 6b). There was also a section of the road network around which the NDVI is very low - 0.15-0.19.

We saw (Figure 7a) that the vegetation index NDVI of Sievers apple trees of population 3 in the fall of 2022 was distributed in the range from 0.48 to 0.79. There were areas with depressed and partly depressed trees and a low NDVI index (0.16-0.38) - these are points 10-14, 16-18, 20-23, 25, 33-36, 39. A decrease in NDVI was noted for areas not covered with vegetation - 0.15-0.29 (Figure 7a). There were also spontaneously created road sections around which the NDVI is very low - 0.10-0.19.

The NDVI of Sievers apple trees of population 4 during the same study period ranged from 0.44 to 0.88 (figure 7b). There were areas with depressed trees and low NDVI (0.19-0.37). These were points 3-4, 9, 11, 15-17, 23, 47, 49, 61, 63-65. A decrease in the NDVI vegetation index was observed for areas not covered with vegetation - 0.19-0.35 (figure 7b). We were also observing a spontaneously created road section, around which the NDVI is very low – 0.13-0.22.

Figure 8a displayed a multispectral reconstruction of the NDVI index of the Tauturgeni population in spring 2023 and was distributed between 0.55 and 0.89. We saw areas with depressed and partly depressed trees and a low NDVI index (0.19-0.47) - these were points 14, 20, 27, 29, 31, 33, 35. A decrease in NDVI was observed for areas not covered with vegetation - 0.35-0 .58 (Figure 8a). Around spontaneously created road sections, NDVI was very low - 0.19-0.39.

The NDVI index of Sievers apple trees in the population

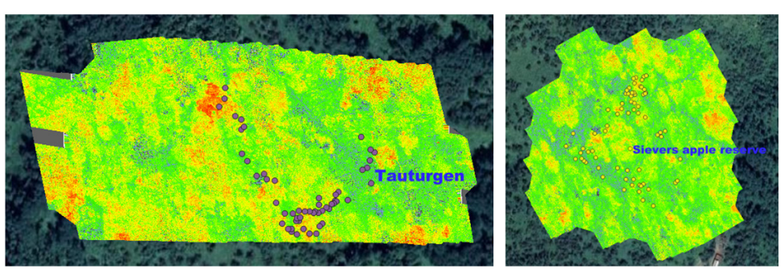

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Figure 7. Multispectral reconstructions in NDVI index of the 3 (a) and 4 (b) populations (fall 2022)

of the Sievers apple reserve in the spring of 2023 was distributed in the range from 0.55 to 0.92. In Figure 8b we observed areas with depressed trees and low NDVI (0.24-0.47) - these are points 9, 11, 15-16, 64-65, 67-69. The highest NDVI index values were observed in areas where the Sievers apple tree grows. A decrease in NDVI was observed for areas not covered with vegetation - 0.29-0.55 (Figure 8b). There was also a spontaneously created road section, around which the NDVI is 0.33-0.42.

The use of the NDVI vegetation index allowed us to effectively analyze the condition of Sievers apple trees on the territory of the Zhongar-Alatau State National Nature Reserve and the Ile-Alatau State National Nature Reserve. Determination of the state of the Sievers apple tree was based on an analysis of the deviation of the NDVI of each tree in the study area from the average index value for the vegetation of the entire type of area. This made it possible to identify the territorial characteristics of the state of Sievers apple trees and identify depressed trees [12]. The distribution of the NDVI index for each type of terrain indicates the leading importance of natural factors in its formation: the NDVI index of grass ecosystems is lower than that of forest ecosystems.

The main conclusions on the state of Sievers apple trees based on the analysis of the NDVI vegetation index will be objective if they are based on an analysis of the dynamics taking into account different growing seasons.

CONCLUSIONS

Based on the created maps with multispectral reconstructions of the NDVI vegetation index, territorial features of the state of Sivers apple trees were identified on the territory of 4 populations of the Zhongar-Alatau State National Nature Park and the Ile-Alatau State National Nature Park.

The results obtained can be used for the rational management of environmental management by the Zhongar-Alatau SNNP and the Ile-Alatau SNNP.

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Conflicts of Interest: The authors have no relevant financial or non-financial interests to disclose.

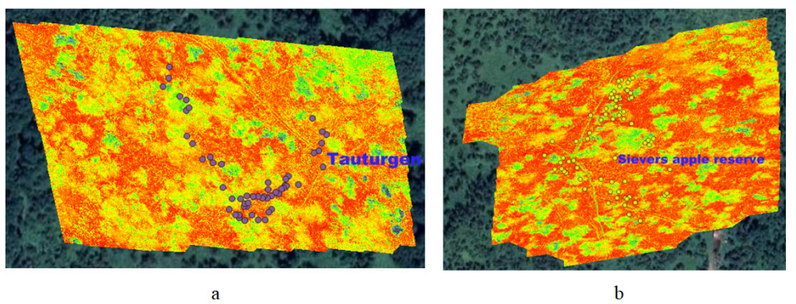

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Figure 8. Multispectral reconstructions in NDVI index of the 3 (a) and 4 (b) populations (spring 2023)

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ОҢТҮСТІК-ШЫҒЫС ҚАЗАҚСТАННЫҢ ТАУЛЫ АЙМАҚТАРЫНДА ӨСЕТІН ЖАБАЙЫ АЛМА ПОПУЛЯЦИЯЛАРЫНДАҒЫ НОРМАЛАНҒАН ДИФФЕРЕНЦИАЛДЫ ВЕГЕТАЦИЯЛЫҚ КӨРСЕТКІШТІ БАҒАЛАУ

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АБСТРАКТ

NDVI өсімдік жамылғысының жай-күйін және оның динамикасын бағалаудың әртүрлі мәселелерін шешуге арналған кең таралған өсімдік индекстерінің бірі болып табылады. Зерттеудің мақсаты NDVI индексін пайдалана отырып, Фенологиялық аумағында, Генетикалық қорық, Таутүрген және Сиверс алма ағашы қорығы (Жоңғар-Алатау және Іле-Алатау мемлекеттік ұлттық табиғи қорығы) аумағындағы жабайы Сиверс алма ағаштарының жағдайын бағалау болды. Оқу мерзімі 2022 жылдың күзі және 2023 жылдың көктемі.NDVI форматындағы мультиспектрлі реконструкциялары бар зерттеу аймағының жасалған интерактивті карталары Сиверс алма ағашының күйін анықтауға мүмкіндік берді. Бұл зерттелетін аумақтағы әрбір ағаштың NDVI көрсеткішінің аумақтың барлық түрінің өсімдіктері бойынша орташа көрсеткіш мәнінен ауытқуын талдауға негізделген. Бұл Сиверс алма ағашының жағдайының аумақтық ерекшеліктерін анықтауға және ауру ағаштарды анықтауға мүмкіндік берді. Алынған нәтижелерді Жоңғар-Алатау және Іле-Алатау МҰТП қоршаған ортаны басқаруды ұтымды басқару үшін пайдалануға болады.

Негізгі сөздер: NDVI, Сиверс алма ағашы, көп спектрлі қайта құрулар, Жоңғар-Алатау мемлекеттік табиғи қорығы, Іле-Алатау мемлекеттік табиғи қорығы.

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ОЦЕНКА НОРМАЛИЗОВАННОГО РАЗНОСТНОГО ВЕГЕТАЦИОННОГО ИНДЕКСА В ПОПУЛЯЦИЯХ ДИКОЙ ЯБЛОНИ, ПРОИЗРАСТАЮЩИХ В ГОРНЫХ РАЙОНАХ ЮГО-ВОСТОЧНОГО КАЗАХСТАНА

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АБСТРАКТ

NDVI – один из наиболее распространенных индексов растительности для решения различных задач оценки состояния растительного покрова и его динамики. Целью исследования была оценка состояния диких яблонь Сиверса на территории Фенологической площадки, Генетического резервата, Таутургень и резерват яблони Сиверса (Жонгар-Алатауский и Иле-Алатауский ГНПП) с использованием индекса NDVI. Период исследования – осень 2022 и весна 2023 годов. Созданные интерактивные карты исследуемой территории с мультиспектральными реконструкциями в формате NDVI позволили установить состояние яблони Сиверса. Которое базировалось на основе анализа отклонения NDVI каждого дерева на исследуемой территории от среднего значения индекса для растительности всего типа территории. Это позволило идентифицировать территориальные особенности состояния яблони Сиверса и выявить болезненные деревья. Полученные результаты могут быть использованы для рационального управления природопользованием Жонгар-Алатауского и Иле-Алатауского ГНПП.

Ключевые слова: NDVI, яблоня Сиверса, мультиспектральные реконструкции, Жонгар-Алатауский ГНПП, Иле-Алатауский ГНПП.