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Use of remote sensing Landsat-EVI in the assessment of landscape degradation (On the example of the Aydar-Arnasay lake systems)

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Abstract. The Arnasay depression in Central Uzbekistan received large quantities of drainage water leading to the formation of the Aydarkul-Arnasay Lake System (AALS). The water level of the AALS drastically increased in 1969, when a flood in the nearby Syrdarya River basin could not be contained in the Chardarya reservoir, and today it occupies an area of 4000 km² of the Mirzachul and Kyzylkum desert. Increasing the lake's water level also affects the surrounding agricultural land, further enhancing the level of groundwater and soil salinization. But the irrigated farming areas also influence the lake system due to the pollution of the drainage water discharged into the lake. As a result, both the arable land and the lake system are in a process of degradation, leading to reduced productivity and a variety of ecological problems. Remote sensing was used to determine the degradation process in agroirrigation landscapes around the lake. Landsat EVI (Enhanced vegetation index) extremely resistant to various atmospheric resistances (aerosols). It monitors plants with very high sensitivity even in low biomass areas. Landsat EVI images were compared in March-April, May-June, June-July, July-August, and August-September to classify the degradation process in the agroirrigation landscapes around the lake. Landsat has 4,5,7,8 series programs. In the article used Landsat-5TM Collection 1 Tier 1 32-Day EVI and Landsat-8 ETM + Collection 1 Tier 32-Day EVI. In Landsat EVI, July-August was chosen as the optimal time to detect agroirrigation landscape degradation. Classifications of agroirrigation landscape degradation have been developed at Landsat EVI.

1 Introduction

Degradation is the deterioration of the fertility of soils, degeneracy of these plants, a decrease in the roductivity of irrigated lands. The problem of degradation can be found in countries all over the world. Degradation is high in arid climates [54, 55]. Degradation causes the degeneracy of agricultural land, causing food problems. Lately, growing demand for food and the planned economic development have led to the dramatic expansion of

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agricultural areas [8,29,7,53,13]. In arid regions, like the Central Asian lowlands, this agricultural expansion is intrinsically connected to large-scale irrigation projects [46, 4, 24, 47,]. Irrigation farming has been an essential element of the Central Asian land use for many centuries, but during the 20th century the area used for growing crops has increased manifold. During the second half of the 20th century this expansion of the irrigation schemes also included the virgin and new soil lands, which are not well suited for agricultural land use [18, 30, 11]. Large parts of the lowlands in the Aral Sea basin are characterized by aridity and soils rich in salts and the development of extensive irrigation schemes caused severe soil degradation [31, 37, 9, 19]. The continued population and economic growth in combination with the expected reduction of the available water resources due to climate change impacts makes the assessment and mitigation of soil degradation highly relevant in Central Asia [33, 17].

The virgin lands irrigation schemes form an anthropogenic landscape of more than 230,000 ha in the Jizzakh region of Uzbekistan, adjacent to the Aydarkul-Arnasay Lake System (AALS). It is the leading producer of cotton, grain, fruits, and vegetables in Uzbekistan and is characterized by hot and dry summers, with maximum air temperatures of up to 43-45°C and average annual precipitation of 388 mm [19]. Large-scale agriculture under these conditions requires intensive crop irrigation, especially for water demanding crops like cotton [27, 16, 5, 36]. The excessive irrigation with a low irrigation efficiency comes hand in hand with an insufficient drainage water system and an already high degree of mineralization of the irrigation water. This leads to water logging and salt accumulation [49, 48], while the leaching of the salts further increases the groundwater level and depletes the nutrient and humus contents in the soils. Countering this loss of productivity by increased fertilizer application and/or the continued expansion of the irrigation schemes into even less suitable areas leads to a vicious circle of soil degradation and desertification, which needs to be addressed. Problems of soil salinity, plant degradation occur in all arid regions of the world. The use of remote sensing techniques is important in overcoming these problems.

2 Materials and methods

2.1 Study Area

This study was conducted in the Jizzakh region of Uzbekistan (near the eastern shore of the Aydar-Arnasay lakes system). The study area included the Arnasay, Dustlik, Zarbdor, Zafarabad, Mirzachul, Pakhtakor, Sharof Rashidov districts (Figure 1), with a population of 0.67 million people (54,2% of Jizzakh region). These territories are geographically located in the Mirzachul oasis, which was transformed into an irrigation land during the 1960s.

The statistical data of the basin management of Syrdarya and Zarafshan irrigation systems in Jizzakh region in 1995-2017 years were used to coverage of the research work. Using these statistics, the dynamics of groundwater levels in agroirrigation landscapes connected to the Aydar-Arnasay lake system, indicators of changes in groundwater mineralization levels in the vicinity of the lake, the area of irrigated lands over the years changes were analyzed. Conditions were compared in irrigated lands between Zarbdor and Sharof Rashidov districts located far from the lake and Arnasay, Mirzachul, Zafarobod, Dustlik, Pakhtakor districts near the lake.

In field studies conducted in May and June 2018, samples were taken from groundwater in the lake area to detect chemical compounds (Figure 1). Nitrogen was detected from hazardous chemical compounds in water samples.

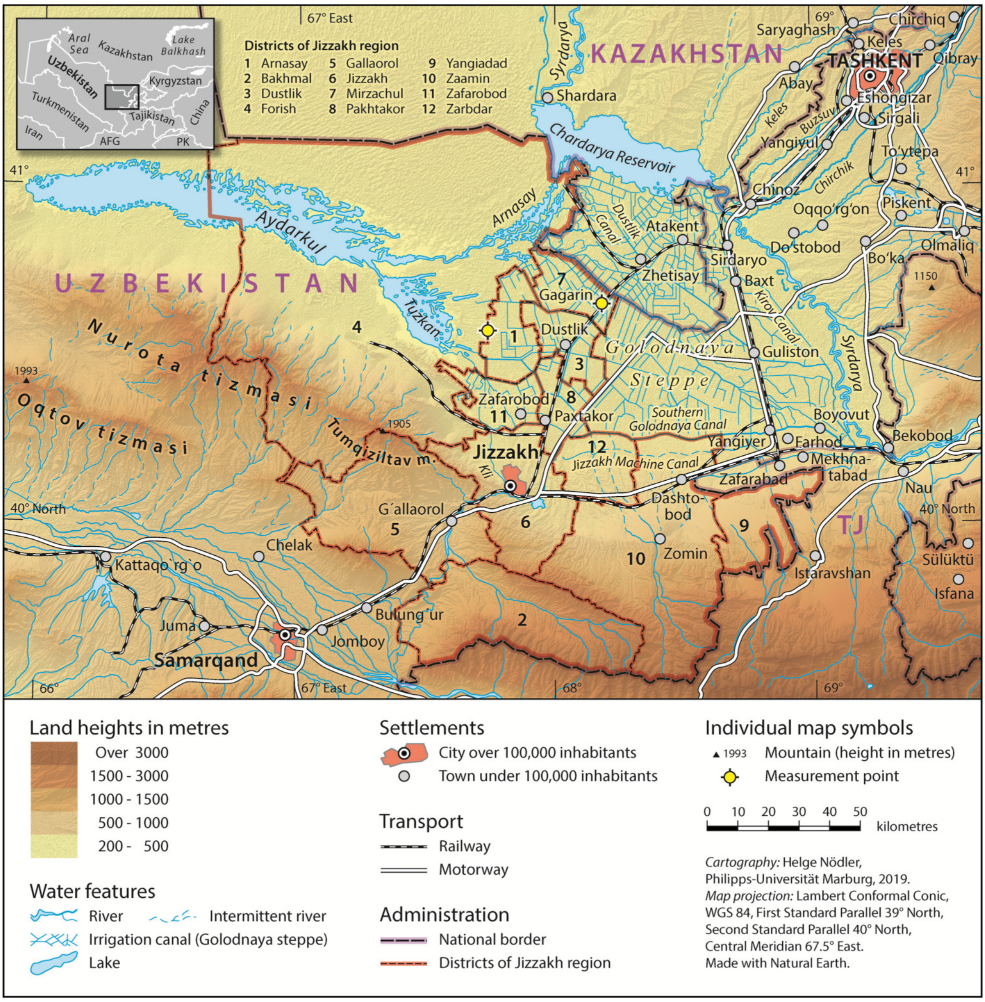

Fig.1. Study area: Aydar-Arnasay lakes system and agroirrigation landscapes.

2.2 Use of Landsat EVI in detection in landscape degradation

We have also used remote sensing methods in our research. Landsat EVI (Enhanced vegetation index) extremely resistant to various atmospheric resistances (aerosols). It monitors plants with very high sensitivity even in low biomass areas. Landsat has 4,5,7,8 series programs. Herein, we used Landsat-5 TM Collection 1 Tier 1 32-Day EVI and Landsat-8 ETM+ Collection 1 Tier 1 32-Day EVI [21]. Landsat-5, from 1 January 1984- to May 8, 2012 and Landsat 7, from 1 January 1999 to the present day data is stored [34, 14]. But we have analyzed Landsat EVI data from 1990 until 2017. Because in the history of Aydar-Arnasay lakes system, twice the high rise of water has occurred. These are the years 1969 and 1994 . We studied the situation after 1990.

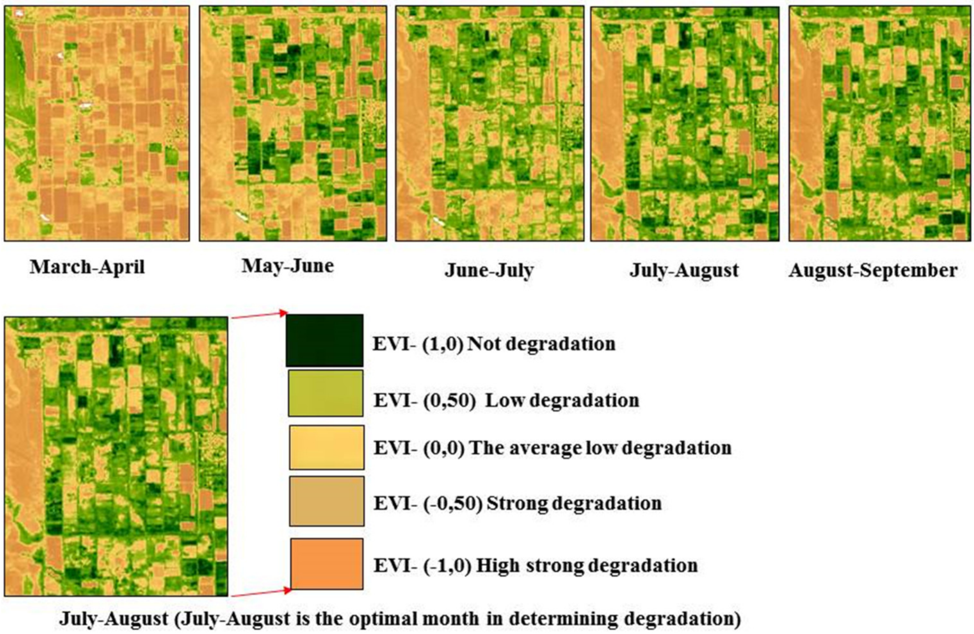

Fig.2. Vegetation areas in the Arnasay district agroirrigation landscapes. 2018 Landsat 8 EVI (Enhanced Vegetation Index) image

To classify the degradation process in agroirrigation landscapes around the lake, we compared Landsat EVI images from March-April, May-June, June-July, July-August, August-September. We selected July-August as the optimal month to determine the perennial degradation process (Figure 2).

The occurrence of salinization in agroirrigation landscapes leads to degradation of fertile lands. We classified the degradation process using Landsat EVI images as not degradation, low degradation, average low degradation, strong degradation, high strong degradation (Table 1). It is accepted that the total ground beef of Landsat EVI is equal to 1,0 to -1,0. The dark green color indicates areas without degradation. In dark green areas, plant density is higher.

Table 1. Classification of the degradation process in EVI- Enhanced Vegetation Index.

EVI (Enhanced vegetation index)	Degradation classifications
EVI- (1,0)	Not degradation
EVI- (0,50)	Low degradation
EVI-0,00	The average low degradation
EVI-(-0,50)	Strong degradation
EVI-(-1,0)	High strong degradation

3 Results and discussion

3.1 Soil salinity condition in agroirrigation landscapes

It should be noted that the agroirrigation landscapes are comprised the loess sand and sandy soils in the ancient flood-lands of the Syrdarya, and the alluvial and proluvial deposits of the seasonal flowing water from the mountains in the south. In the past, by several times of the sea floods the rock layers of salty carbonate, gypsum and clay have been formed. Particularly, deposits related to sand-clay, carbonate sulphate formation were washed away from the surrounding mountains of Mirzachul's oasis and accumulated in the area [22, 39, 35, 36, 37, 52]. As can be seen from this information, nature of the soil of the agro irrigation landscapes adjacent to lake is saline. However, due to the irrigation system disruption in these geocomplexes, the disproportionate of water-salt balance has been intensified by the process of secondary salinization in irrigated lands and it is rapidly developing, despite the increasing use of countermeasures [50]. The secondary salinization process is occurring as a result of the accumulation of additional salts into irrigation layers, excessive irrigation measures, elevation of mineralized groundwater levels and their evaporation [51, 43]. So far the irrigated land that adjacent to the lake has been subjected to various, weak, moderate and very strong secondary salinization [6, 44, 45]. In areas near the lake, salinity increases. Salinization is especially high in Arnasay, Dustlik, Mirzachul regions. The main reason for this is that the slope and closed river-bed basins are located in the central part of the oasis, and they head towards the lake. Such conditions effect for the accumulation of salts in the slope and AALS, as well as, increase mineralization of lake water [23,25,26]. With the rising of lake water level, the groundwater level in the surrounding landscapes and secondary salinization in the soil will also increase [56,57,26].

3.2 Increasing groundwater levels in agroirrigation landscapes

The rising level of groundwater in irrigated lands also leads to degradation of agricultural lands [57]. Today, the excessive irrigation systems in the agro-irrigated landscape are much higher than norms (norms, total irrigation lands – 1746,6 thousand m^3, used irrigation lands – 1765,9 thousand m^3, and 19,3 thousand m^3 more than norms) and due to the proximity of these landscapes to the lake, the surface water level is quite high.

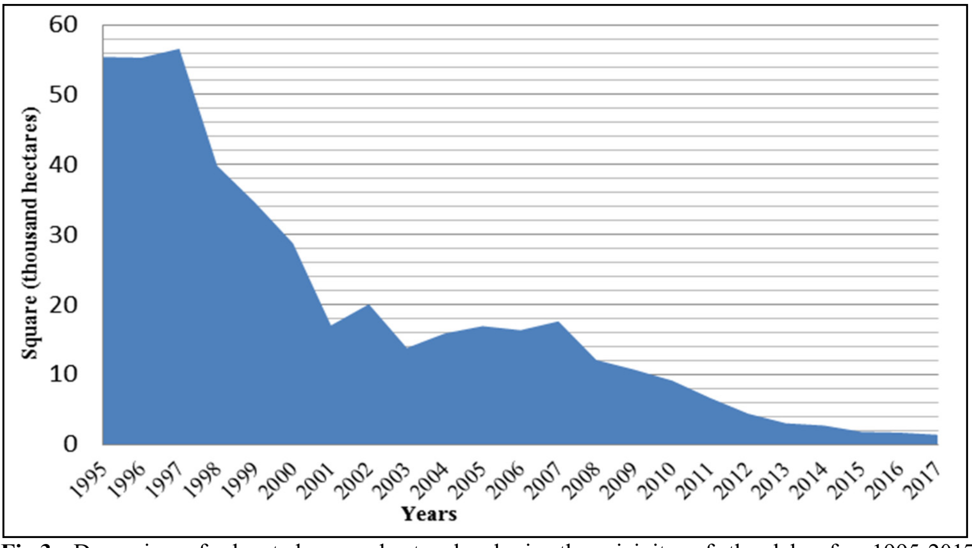

Fig.3. Dynamics of elevated groundwater levels in the vicinity of the lake for 1995-2017. (Groundwater levels range from 0 to 2 meters)

According to the data of July 1, 2017, the level of groundwater is 1-2 meters in the area of 104,3 thousand hectares of irrigated lands. In the agro irrigation landscapes adjacent to the eastern part of the lake, the level of groundwater is 0-1 meters, and the irrigated land has formed hydromorphic landscapes, which are more susceptible to swamping and excessive irrigation. The level of groundwater is 2-3 meters in the area of 163 thousand hectares or 87,3% of the irrigated lands**.** Especially these indicators are high in Arnasay, Dustlik, Mirzachul, Zafarobod districts which adjacent to the lake and there are also a lot of territories which total subsoil water consist of 0 to 3 meters. After 1994, the lake level rose. This also affects the agroirrigation landscapes. During these years, groundwater levels have risen dramatically (Figure 3). This is particularly evident in areas near the lake (Figure 4). This situation requires a high level of land reclamation over many years.

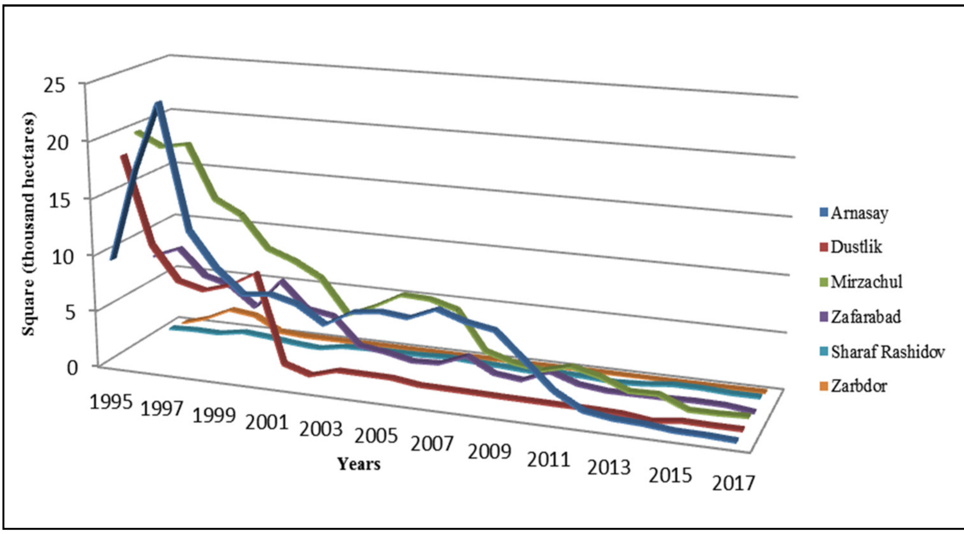

Fig.4. Increasing groundwater levels in the lake adjacent regions (1995-2017 years) (Groundwater levels range from 0 to 2 meters)

3.3 Impact of chemicals on soil fertility and changes in water quality indicators of Aydar-Arnasay lake system

Soil salinization also occurs under the influence of human farming. This situation requires further development of ameliorative measures in agroirrigation landscapes and strict adherence to the irrigation system. Various toxic chemical compounds and preparations used to increase productivity in soils have a negative impact on soil quality and fertility. We can say, that the first (1960-1985 years) use of chemical compounds, mineral fertilizers, herbicides and pesticides in the developing new lands were more than the highest standard. In particular, an average of 284.4 kg (438 kg for cotton) fertilizers per hectare and up to 19.5 kg of toxic chemicals (sometimes 50 kg for cotton) were used [22]. The use of excessive chemicals in soils will result in loss of productivity and natural condition. Of course, we can say that the soil is a renewable natural resource, but it would take 2000 to 7000 years to restore its 18 cm layer of productivity by naturally [12]. Moreover, the chemical compounds that are used excessively will lead to the degree of pollution not only to the soil cover of agro irrigation landscapes, but also the open water reservoirs, rivers, canals, lakes, groundwater and even drinking water [1,2,3,41,42].

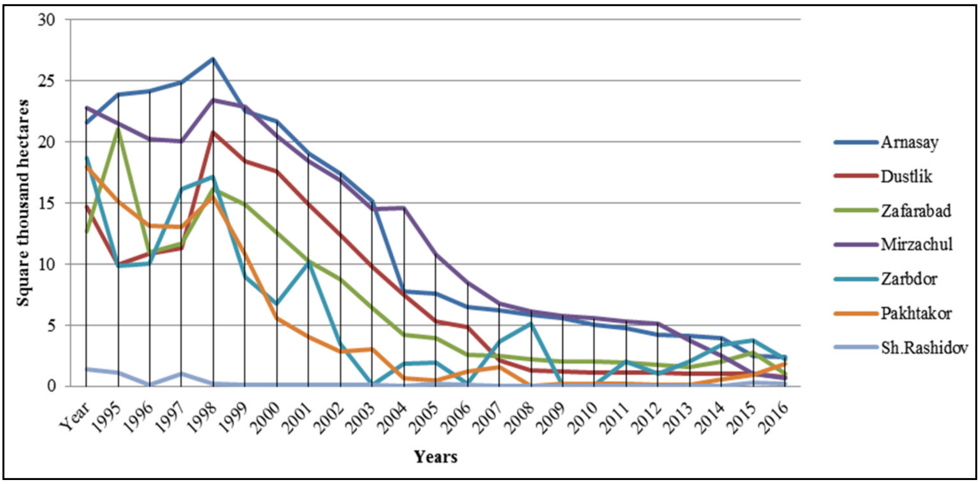

Fig.5. The dynamics areas of groundwater levels of 10 g / l and above in the lake adjacent regions.

It should be noted that in the months of May and June, during study of lakes and landscapes around the lake in the field expedition, we received water sampling for analysis from the 8 meters and 12 meters artesian wells adjacent to the lake in Gagarin city of Mirzachul district and center of Arnasay district (Figure 1). The results of the analysis revealed that nitrite content in the groundwater of these zones (0.08 mg/dm^3 in Mirzachul district and 0.02 mg/dm^3 in Arnasay district). It is known that nitrite is a highly poisonous compound that is caused using various chemical compounds against pests, weeds and wild plants diseases in the agriculture, it is also dangerous to have a 0.001 mg/dm^3 in nature [20, 32]. Unfortunately, today these waters are unfit for drinking, but it is used for irrigation of plants and livestock. In addition, similar hazardous compounds are also influenced to water quality indicators by the ditch-drainage water of the AALS, which has the potential to increase the mineralization of the lake water and to increase the number of dangerous compounds in the water.

According to the analysis, the lake water mineralization is average 4.0-4.5 g/l between 1972-1983 years in the Tuskan lake, average 2.5-2.0 g/l in the western part of this lake and average 9-10 g/l in the Aydarkul part. The impact on the quality indicators of the lake water is also influenced by wastewater, collector, ditch-drainage water of agro irrigation landscapes. Mainly Central-Mirzachul, Akbulak, Kli, ARK and boundary collector-drainage waters are poured to the lake. The highest mineralization of drainage waters consists of 5.4 g/l in ARK collector, then boundary water 4.9 g/l, Central Mirzachul 4.4 g/l, Akbulok 4.1 g/l, Kli 3.6 g/l. However, being poured of drainage waters during long years leaded with improvement of mineralization of lake water [19]. Today, the lake water mineralization is average 14-15 g/l [15]. Such changes in the quality influence on the groundwater mineralization.

Soil salinization also depends not only on the depth of the ground waters, but also on the level of mineralization. The level of the groundwater mineralization in the irrigated lands is average 5-7 g/l, even in areas close to the lake makes up to 10 g/l. Among them there are high levels of mineralization in underground waters in Arnasay, Dustlik, Mirzachul, Zafarobod regions. The level of mineralization of groundwater on the landscapes of Agroirrigation increased from 1995 to 2000.

The reason for this is that the water level of Aydar-Arnasay lakes sestem was increased in 1994. Due to the increased collector systems, the level of mineralization of the groundwater in the regions decreases after 2000 (Figure 5). As we mentioned above, with increasing of the mineralized water levels of the lake the level of groundwater also rises in the agro irrigation landscapes around them. Such processes lead to deterioration of soil quality, increase of strong saline lands field and degradation of agricultural lands [41, 42, 45].

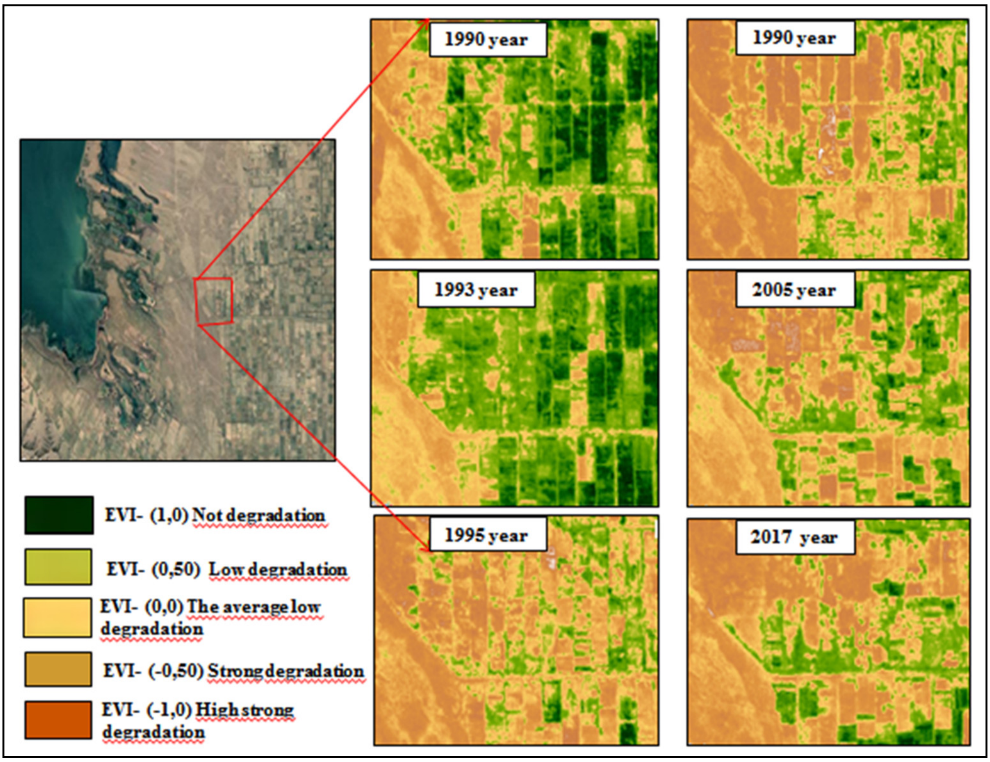

Fig.6. Degradation processes of irrigated lands. From 1990 to 2017. Landsat-5 TM Collection 1 Tier 1 32-Day EVI and Landsat-7 ETM+ Collection 1 Tier 1 32-Day EVI (in July-August) dates.

We have analyzed the degradation of the lake adjacent regions in the Landsat 5 Collection 1 Tier 1 32-Day EVI and Landsat 8 Collection 1 Tier 1 32-Day EVI. To analyze, we chose the EVIs long-term, July-August. Agroirrigation landscapes are the most water-consuming agricultural periods in July-August. In addition, elevated lake water levels lead to an increase in groundwater level and mineralization. As a result, the degradation process in the lake adjacent areas will be intensified (Figure 6).

In general, if we analyze the data of the management of the Syrdarya and Zarafshan Irrigation Systems from 1995 to 2017 on irrigated lands of areas located around of the lake. 6,34 thousand hectares of total agroirrigation landscapes have left from the agricultural use as a result of various problems that have been analyzed above.

We can observe the highest index between them in Dustlik (2,65 thousand hectares), Zafarabad (2,49 thousand hectares), regions. The fact that the irrigated lands in these areas is out of the agricultural use are very close to the lake and can be explained by the poor compliance with the agrotechnical regulations. However, it can be seen in Arnasay (0,22 thousand hectares), Mirzachul (0,03 thousand hectares) regions (Figure 7).

Although the Arnasay, Mirzachul regions is very close to the lake, the largest drainage network passes through these regions. The area of irrigated lands in these areas has been improved due to drainage systems. Basic drainage waters pass through these areas and flow into the lake. Anthropogenic load is high in these regions.

The soils of areas we are studying contain a large amount of the sulfate and chloride salts, these salts have the feature as fast solubility. Such soils in the soil cause serious damage to agricultural crops and lead to a sharp decline in their yield. Saline washing is carried out on purpose of increasing the productivity of agricultural crops in autumn and winter every year. Because underground water levels in these seasons are low. However, saline washing works for agro-irrigation landscapes adjacent with the Aydar-Arnasay lakes system are carried out without observance specified technologies can lead to negative consequences. Because from the Chardara reservoir is usually flooded to the Aydar-Arnasay lakes system in February, March, and September. During this period, the lake's water level will increase and it will affect to increasing of the groundwater level.

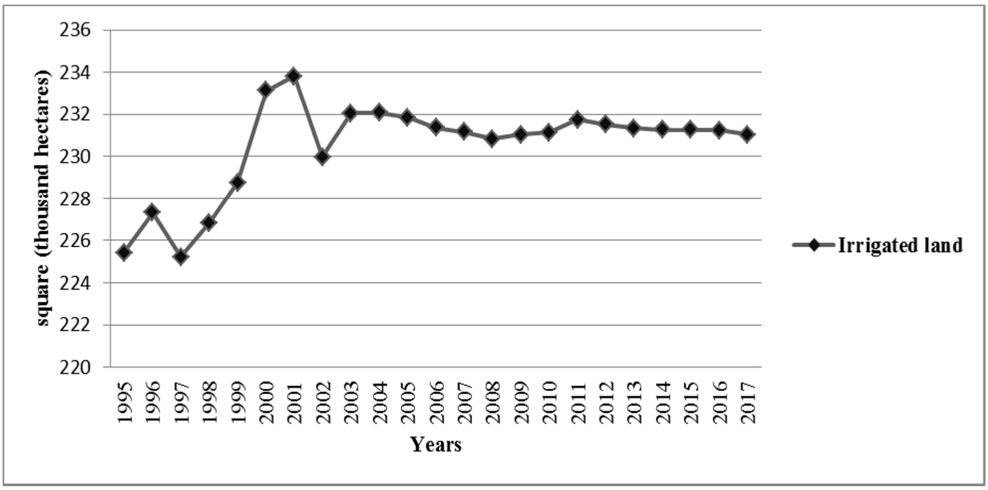

Fig. 7. Dynamic change in agroirrigation landscapes adjacent to Aydar-Arnasay lakes system (during the years 1995-2017).

Also, various chemicals or fertilizers cannot be used to increase the yield of saline soils. Such activities can further enhance salinization. Such a quality change is affecting the mineralization of subsoil waters of the agro-irrigation landscapes. Productivity indicators reduce according to the level of salinity. In particular, weak salined soils reduce productivity to 10-20%, and strong saline soils - up to 50%.

4 Conclusions

In summary, agro irrigation landscapes are developing paragenetically with the lake system. Because the AALS is included of the irrigation lakes. The water of ditch-drainage branches that are being built to improve the soil-reclamation state of the irrigated lands are poured directly into the lake. As the agro irrigation landscapes affect to the lake, the lake also has a high impact on irrigated lands, and such a connection significantly increases the soil degradation problem. In general, today, to avoid soil degradation issues, it is desirable, first of all, to adjust the irrigation system and to work out scientific-practical research and optimally relevant issues. It is also necessary to reduce the discharge of collector-drainage water from irrigated lands into the lake. Control of excessive irrigation of lake agroirrigation landscapes. Improving agricultural specialization, introducing less water-intensive crops. It is advisable to maintain a stable flow of 2 km^3-2.5 km^3 from the Chordara reservoir. Remote sensing of agroirrigation landscapes Monitoring by Landsat EVI will ensure accurate and intensive use of irrigated lands in the future.

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