# Monitoring of land cover using satellite images on the example of the Fergana Valley of Uzbekistan

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# Monitoring of land cover using satellite images on the example of the Fergana Valley of Uzbekistan

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**Abstract.** Sites for studying plants and forests of the Fergana Valley for 2000 and 2018 were analyzed using the remote sensing method. Archival images of Landsat satellite, cadastral map and city plan, satellite data of higher resolution Canopus and Rapid Eye were used for research. The data obtained indicate that over the past 18 years in the study area, there has been an increase in the fragmentation of urban forest areas and a significant reduction in the class of deciduous and mixed plantations from 28108.40 hectares to 27906.46 hectares. The accuracy of the data obtained is confirmed by modern criteria of geoinformation statistics. The proposed method of thematic mapping and assessment of urban forests using remote sensing methods for landscape indicators will reduce the cost of work compared to ground-based studies and increase their accuracy.

## INTRODUCTION

**The relevance of research.** Using satellite images, you can get high-quality and accurate information about the vegetation cover in different areas of the territory. Unfortunately, satellite imagery is not used in Uzbekistan to study vegetation cover. In this regard, it is necessary to carry out the temporal dynamics of the vegetation cover, draw the correct conclusions and analyze thematic maps. To do this, we must be based on concrete results of work. Satellite images give us evidence and accurate results for this.

**The purpose and objectives of the study.** The study aims to analyze the time series of the dynamics of the vegetation cover of the Fergana Valley of Uzbekistan using remote sensing of the Earth.

To achieve this goal, the following tasks have been completed:

1. Conducting field research.
2. Selection of satellite images for the study area.
3. Formation of thematic maps of vegetation cover.
4. Assessment of the accuracy of thematic maps.
5. Analysis of the dynamics of vegetation cover.

**The scientific novelty of work.** For the first time, the analysis of the time series of vegetation cover dynamics on the territory of the Fergana Valley of Uzbekistan was carried out using data from remote sensing of the Earth. The technique of vegetation cover dynamics in the study area based on satellite images of medium resolution Landsat is presented.

**Objects and subject of research.** The objects of the study were the areas of forest and non-forest lands on the territory of the Fergana Valley of Uzbekistan.

The author's contribution consists of collecting field material, selecting and laying test sites, processing it, classifying, analyzing, and summarizing the results obtained.

The reliability and validity of the research are based on the involved experimental material of the test areas, which is the object of research, complex and systematic approaches to the implementation of the tasks (using static methods for processing experimental data).

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**The practical significance of the results obtained.** The data obtained on vegetation cover dynamics, made based on satellite images at different times, are of great practical interest among forest tenants and forestry workers. Such information allows you to quickly track ongoing changes, plan forestry activities, and improve forecasts for the development of forest landscapes and territories.

In addition, tracking the dynamics of vegetation cover is necessary for their further assessment. Therefore, remote sensing techniques using satellite imagery data are of practical value to owners of such land.

**Basic research methods**. Technique for processing satellite images, the formation of classes of the generalized legend of vegetation cover, a technique for forming a thematic map are used.

**The main result of the work.** Thematic maps on the territory of the Fergana Valley of Uzbekistan. Since the 90s, international and national programs have been carried out to develop the capabilities of global satellite mapping of vegetation cover. The results of these projects are used to assess forest resources, ensure food security, assess impacts and predict climate change modeling.

However, despite the ongoing efforts, the methodological and technological aspects of satellite mapping of vegetation cover over large areas still require significant development. In the opinion of a group of scientists from the Space Research Institute of the Russian Academy of Sciences (Russian Academy of Sciences), this situation is explained by the conceptual complexity of the problem of mapping vegetation, if it is necessary to automate the processing of satellite data as much as possible using algorithms that ensure high accuracy of recognition of land cover objects in conditions of spatio-temporal variability, spectral and reflective characteristics [1-7].

The forest vegetation cover of the Volzhsky forestry of the Republic of Mari El is based on the analysis of multi-temporal multispectral satellite images of medium resolution Landsat using GIS technologies. As a result of the work, an overview of existing GIS projects on thematic mapping of forest vegetation cover based on the use of satellite imagery data was made. A method for monitoring disturbed forest lands was developed and applied to remote sensing data in a GIS environment [8-14].

The upper border of forests is highly dependent on the degree of humidity of the climate; in more humid conditions, on average, it goes higher, in arid conditions - lower, that is, the upper boundaries of the growth of trees and shrubs do not always coincide with the same isotherm. In the conditions of Central Asia, including the Southwestern Tien Shan, the lower boundaries of the forests are extremely diverse not only in height but also in the composition of the dominant species of woody plants, in the structure and environment-forming impact of forest communities that go beyond the lower limit. The lower limit of the forest is the degradation of forest flora, where continuous shrub formations of forest flora dominate, which are a transitional link between forest and steppe belts [15, 16].

Several types of pastures have been identified in the Fergana Valley: xerophilic-semi-shrub pastures on stony-gravelly soils, mountain and adyr steppe and meadow-steppe pastures, mountain-meadow and forest pastures. Further, knowing the coordinates of the location of certain lands on the MODIS map, these coordinates were marked in the Google Earth program. Thus, the areas of distribution of the main agricultural crops and territories prone to waterlogging or desertification were identified on satellite images. In other words, comparing the data of MODIS maps with space images of Google Earth and Landsat-7, it was revealed how different types of natural and anthropogenically modified complexes are displayed on the images [17-20].

**Research program.** Using satellite images, you can get high-quality and accurate information about the vegetation cover in different areas of the territory. Unfortunately, satellite images are not used to study vegetation cover in the Fergana Valley of Uzbekistan. In this regard, it is necessary to carry out the temporal dynamics of the vegetation cover, draw conclusions and analyze thematic maps. To do this, we must be based on concrete results of work. Satellite images give us evidence and accurate results for this.

Purpose of the study– to analyze the time series of the dynamics of the vegetation cover of the Fergana Valley of Uzbekistan using remote sensing of the Earth. To achieve this goal, the following research tasks were solved:

1. Conducting field research.
2. Selection of satellite images for the study area.
3. Formation of thematic maps of vegetation cover.
4. Assessment of the accuracy of thematic maps.
5. Analysis of the dynamics of vegetation cover.

**Research objects.** The objects of the study were the areas of vegetation on the territory of the Fergana Valley of Uzbekistan.

## RESEARCH METHODOLOGY

The method of work includes two stages: field and office research.

Field studies. Field studies were conducted from June to September 2018.

When choosing plots for laying test plots, a detailed analysis of inventory descriptions of forestries and plans for afforestation, cadastral data on the agricultural redistribution fund, as well as satellite imagery materials of a medium and high resolution was carried out. The main criteria were:

1) select the most represented areas of forest and non-forest lands (Figure 1-2) for the purpose of their subsequent recognition on satellite images;

2) lay the maximum number of test sites for the subsequent validation of the generated thematic maps of the vegetation cover.

**FIGURE 1.** Test plot (TU No. 1) of the vegetation cover, covered with deciduous plantations

**FIGURE 2.** Geographical location of the test site (TU No. 1) of the vegetation cover

The coordinates of each test site were recorded using a GARMIN eTrex GPS receiver to identify them on satellite images.

**FIGURE 3.** Test plot (TU No. 2) of vegetation cover covered with mixed plantings


**FIGURE 4.** Geographical location of the test site (TU No. 2) of the vegetation cover

### Description of software and satellite "Landsat"

All work with satellite images was carried out in the software packages "ENVI 5.2" and "ArcGIS 10.3".

Description of the capabilities of the software package "ENVI 5.2" for processing satellite images.

## Cameral research

The vegetation monitoring procedure included a number of the following stages of work carried out in the ENVI 4.8 and ArcGIS 10 software packages:

1. Selection of satellite images for the formation of thematic maps for the study area.
2. Radiometric and geometric processing of 1G level images.
3. Geolocation of Landsat images in ArcGIS 10.3.
4. Creation of thematic maps for 2000 and 2018. by the method of unsupervised classification by the "IsoData" method in the PC ENVI 5.2.
5. Assessment of the accuracy of the generated thematic maps in PC ENVI 5.2.
6. Assessment of the dynamics of vegetation cover.

### Selection of satellite images for the formation of thematic maps for the study area.

The next stage of the work was the selection of satellite images for the formation of thematic maps for the study area to further track the vegetation cover dynamics.

The choice was made among the multi-temporal multispectral satellite images of Landsat TM and ETM + for the study area, which were used in work. All images, in turn, underwent radiometric and geometric correction procedures.

As a result of a detailed analysis, the images of 2000 and 2018 were selected for work, which are the most consistent with the goals and objectives of our study.

### Radiometric and geometric processing of 1G level images.

Previously, Landsat images have undergone radiometric and geometric correction.

Radiometric correction - eliminates the variation in pixel brightness values that occurs due to improper operation of detectors, the influence of terrain and atmosphere.

Geometric correction includes correction of such image distortions as banding, line dropping, and geocoding - image binding in such a way that each point of the image is assigned the coordinate of the corresponding point on the terrain. Mathematically, georeferencing is usually done using power polynomials. The snapping accuracy increases in the presence of control points, then the image is, as it were, "planted" along with them. After geocoding, the brightness characteristics of the already transformed image are determined by various methods: nearest neighbor, bilinear interpolation, bicubic convolution.

Atmospheric correction was carried out using special functions (FLAASH) in PC ENVI 5.2.

Atmospheric correction - correction for the influence of the atmosphere, which determines the location of the shooting ranges due to transparency windows.

### Geolocation of Landsat images in ArcGIS 10.3.

To analyze and display the location of satellite images in exact geographic correspondence with other data, raster data requires binding to the existing coordinate system.

The work on referencing to the geodetic coordinate system was carried out in the ArcGIS 10.3 PC in the Pulkovo 1942 coordinate system generally accepted in Russia (WGS 84). Creation of thematic maps 2000/2018 by the method of unsupervised classification by the "IsoData" method in the PC ENVI 5.2.

Classification is understood as the process of assigning raster image objects to one of the predefined thematic classes (Sukhikh, 2005). The basis for this is a certain set of criteria for the proximity of the values of their characteristic features, that is, differences in the values of spectral brightness. When classifying an image, the minimum elements of this image — pixels — are used as the minimum objects. There are two classification methods: unmanaged and managed.

Unmanaged classification is classified as automatic because it is less dependent on user control. Only some parameters are determined (the number of allocated clusters, iterations, etc.), which are then used by the system to identify distinguishable groups of objects based on data analysis (spectral, texture and other characteristics of objects). The result of this classification is a set of automatically generated classes.

Guided classification is based on the use of dividing the feature space into classes of characteristics of recognizable classes, obtained using a training sample.

The thematic map of the vegetation cover for the investigated territory was formed by the method of uncontrolled classification using the IsoData method (Iterative Self-Organizing Data Analysis Technique - an iterative self-organizing method of data analysis), which is based on the assessment of criteria for the proximity of points in the feature space.

Before forming a thematic land cover map, a legend was created, which highlighted the main classes of land cover.

We used two Landsat images from 2000 and 2018.

The classification was carried out in several stages.

At the first stage, the primary classification of the original image into 25 classes (25 iterations) was carried out, after which two classes were identified - settlements and water bodies. The "settlements" class, in turn, underwent an additional classification with its subsequent division into classes (settlements, vegetation cover of settlements and areas devoid of vegetation).

At the second stage, the classes "settlements" and "water bodies" in the form of masks were removed from the original image.

With the resulting image, a secondary classification was carried out (Figure 5) into 25 classes (25 iterations), as a result of which 2 classes were identified - forest and non-forest lands.

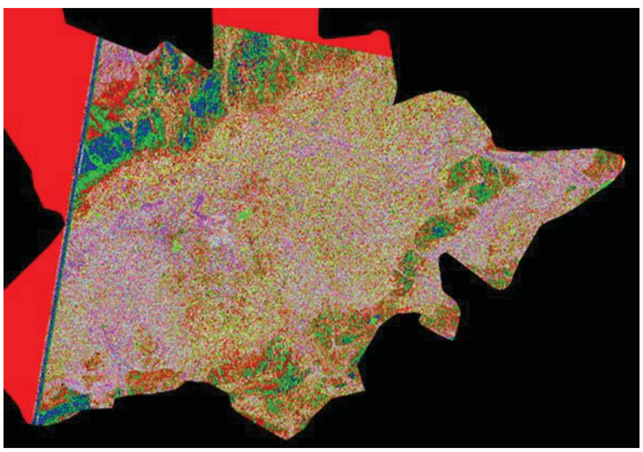

**FIGURE 5.** Primary classification of the 2000 image into 25 classes

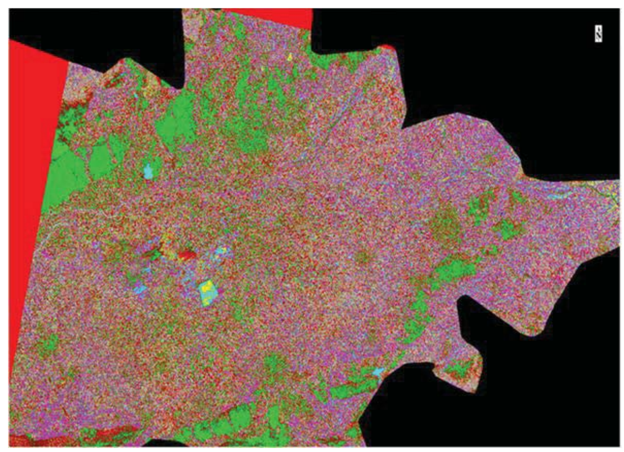

**FIGURE 6.** Classification of satellite imagery in 2018 by the IsoData method in the PC ENVI into 20 classes

**Further work continued with each class separately.**

For example, the "forest land" class identified in the form of a mask was classified into 14 classes, followed by the identification of smaller vegetation cover classes (coniferous, deciduous, mixed stands).

All the thematic map layers went through a similar secondary classification procedure until the final classes were selected.

### Assessment of the accuracy of the generated thematic maps in PC ENVI 5.2

The next stage of the study was the assessment of the generated thematic maps of vegetation cover for accuracy.

Initially, a compilation of available taxation data and field research was carried out in the form of a training sample of a combination of vector objects.

Further, using the functions of the PC ENVI, the results of the accuracy assessment were obtained for the following indicators:

1) a matrix of differences,
2) Kappa coefficient,
3) coefficient of overall accuracy.

Functions of the PC ENVI include post-classification image processing, which allows determining the correctness of the selected classes of pixels of the obtained thematic map to field data using the Confusion Matrix

(matrix of differences).

This module covers a wide range of methods used to identify, describe and determine the percentage of differences between the resulting thematic maps and field data (Figure 7).

| | A | B | C | D | E | F | Σ |
|---|---|---|---|---|---|---|---|
| A | $n_{AA}$ | | | | | | $n_{A\cdot}$ |
| B | | $n_{BA}$ | | | | | $n_{B\cdot}$ |
| C | | | $n_{DC}$ | | | | $n_{C\cdot}$ |
| D | | | | $n_{DD}$ | | | $n_{D\cdot}$ |
| E | | | | | $n_{EE}$ | | $n_{E\cdot}$ |
| F | | | | | | $n_{FF}$ | $n_{F\cdot}$ |
| Σ | $n_{A\cdot}$ | $n_{B\cdot}$ | $n_{C\cdot}$ | $n_{D\cdot}$ | $n_{E\cdot}$ | $n_{F\cdot}$ | N |

**FIGURE 7.** Confusion Matrix (Verbula, 2000)

The first vertical column of the matrix is the actual (reference) field data, and the upper horizontal row includes the estimated classes.

The values on the diagonal of the matrix (in gray) represent the number of matched pixels of the calculated classes and real (reference) data. The diagonal sum shows the total number of correctly classified pixels, and the ratio of this number to the total number of pixels in the matrix is called the overall classification accuracy, expressed as a percentage:

$$\text{Overall accuracy} = \frac{Naa+Nbb+Ncc+Ndd+Nee}{N} \quad (1)$$

In addition, the matrix of differences includes the calculation of the Kappa coefficient, which shows the assessment of the reliability of the correspondence of the classification carried out to field studies:

$$k=\frac{P-Pc}{P} \quad (2)$$

where P is the overall classification accuracy,

Pc is the possible classification accuracy, which is the expected accuracy of the random values of the classes assigned to each pixel (produced automatically in the ENVI 5.2 program).

The estimation of the Kappa coefficients is carried out using the values of the pre-formed error matrix.

The kappa coefficient can range from -1 to +1. If k = 1, then the consistency between the studied data is absolute; k = 0 - lack of consistency. It is usually considered that with a value of k> 0.75, we can talk about significant and high reliability of data consistency and a lack of reliability - with k <0.40 (Table 1).

**TABLE 1.** Criteria for the consistency of classification data by the Kappa coefficient

| Kappa coefficient | Consistency |
|---|---|
| < 0 | no consistency |
| 0.0 — 0.20 | Insignificant |
| 0.21 — 0.40 | Weak |
| 0.41 — 0.60 | Moderate |
| 0.61 — 0.80 | Significant |
| 0.81 — 1.00 | High |

## RESULTS OF THE STUDY

### Field studies

As a result of field studies, 90 test sites were established in the Fergana Valley of Uzbekistan. The coordinates of the location of each test site were recorded using a GARMIN eTrex GPS receiver. All data were recorded in the accounting records (table 2).

**TABLE 2.** Characteristics of test sites in the Fergana Valley of Uzbekistan

| Test section № | District | Planting composition | Average height | Average diameter |
|---|---|---|---|---|
| 1 | Fergana Valley, Andijan region, Balikchi district | Poplar | 15 m | 12 m |
| | | Maple silver | 28 cm | 15 cm |
| 2 | Fergana Valley Bogishamol | Plane maple / Platan leaved maple | 24 m | 50 cm |
| | | Alder gray | 16 m | 35 cm |
| | | Norway spruce | 30 m | 25 cm |

**Cameral research**

**Use of Landsat satellite imagery.**

The work used satellite images of 2000 and 2018 at different times.

Because the images were taken in different periods of the phenological state of the vegetation cover (May-September), each of them underwent the procedure of an empirical linear transformation of the coordinates of the space of spectral features in the PC ENVI 5.2.

For further work, we used two images for 2000 and 2018, synthesized in three spectral channels (Figure 2), to obtain a single RGB image.

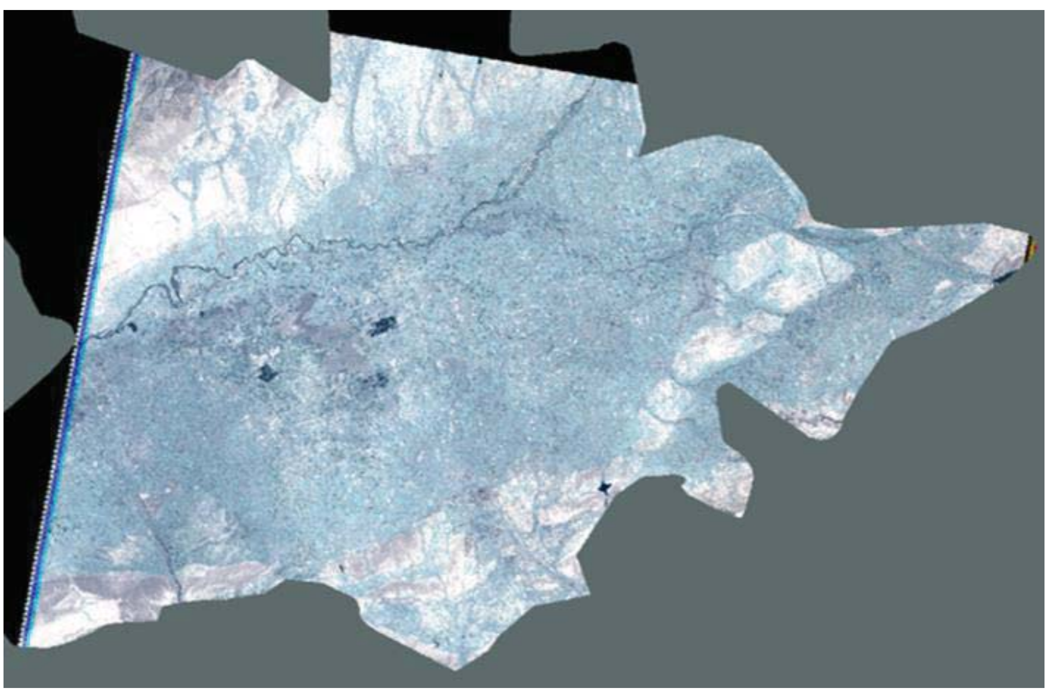

**FIGURE 8.** Multispectral satellite image Landsat for 2000 on the investigated territory of the Fergana Valley of Uzbekistan

These Landsat satellite images with a spatial resolution of 30 m were transformed by 15 m.

The obtained pictures differ by 10 years. Our main goal is to identify areas of natural origin. The task is to determine their breed composition and assess the results found in our study.

The color characteristic of these images corresponds to an arrangement of colors from red to blue, according to the reduction of the emission wavelength. The resulting image is informative for forestry purposes, especially when monitoring vegetation cover (turf areas are displayed in shades of light pink, and trees and shrubs - blue, green). Thus, the RGB image allows you to distinguish cultivated land from trees and shrubs.

**Thematic land cover maps for 2000 and 2018 to the territory of the Fergana Valley of Uzbekistan**

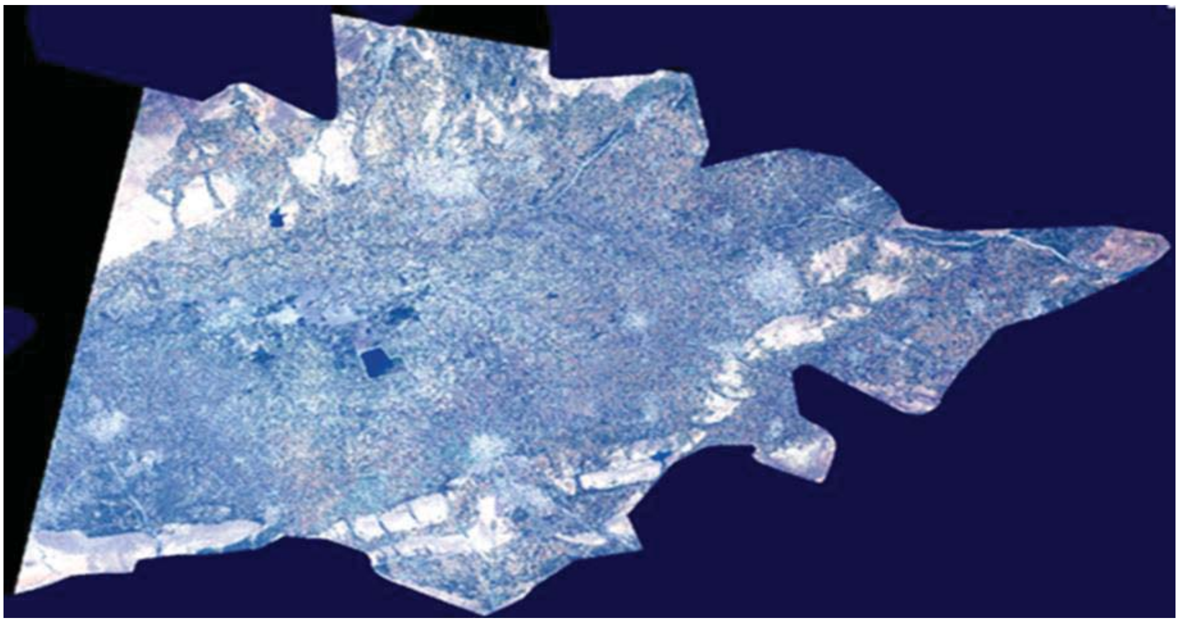

**FIGURE 9.** Landsat multispectral satellite image for 2018 of the study area.

When forming a thematic map, additional information from field research data was used - transects, test sites.

The result of the classification of the 2000 and 2018 images are thematic maps of the distribution of vegetation cover in the study area (Figures 10, 11).

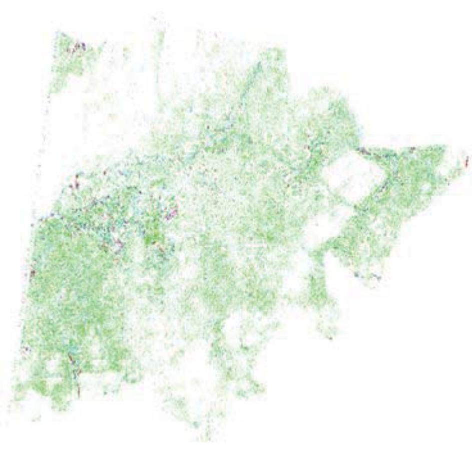

**FIGURE 10.** Thematic land cover map 2000

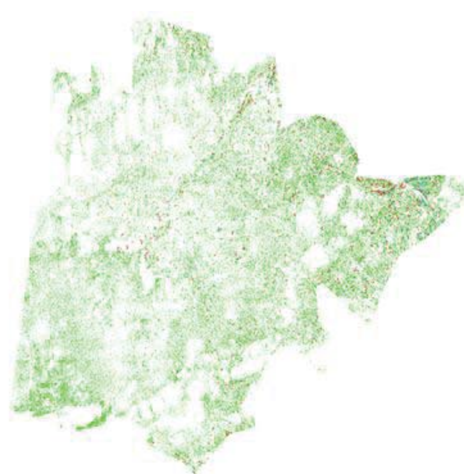

**FIGURE 11.** Thematic land cover map 2018

The resulting thematic land cover maps reflect the distribution of land cover classes on the Fergana Valley of Uzbekistan territory.

**Assessment of the accuracy of a thematic land cover map**

To determine the accuracy of the classification and assessment of the generated thematic map, post-classification processing of the obtained thematic vegetation map was carried out. This algorithm allows you to determine the reliability of the pixels of the thematic map classes by independent data using the Confusion Matrix (matrix of differences).

The average overall accuracy of the generated thematic land cover maps for 1985 and 2010. to the territory of the Mari Trans-Volga region was 71%.

In addition, the Kappa coefficient was calculated to assess the accuracy of thematic maps, which was 0.64.

As a result, the overall accuracy and the Kappa coefficient indicate significant reliability of the generated thematic maps by independent data (field research data, map plans).

**Monitoring of vegetation cover in the Fergana Valley of Uzbekistan**

According to the thematic map for 2000, the area of arboreal and shrubby vegetation amounted to 4733.82 thousand hectares, deciduous plantations - 28108.40 thousand hectares, shrubs - 16762.52 thousand hectares, herbaceous vegetation - 150313.32 thousand hectares ( Table 3).

**TABLE 3.** Areas of land cover classes for 2000

| Class | Area, thousand hectares |
|---|---|
| Arboreal and shrubby vegetation (Rosemary willow, Narrow-leaved willow) | 4733.82 |
| Deciduous plantations (willow) | 28108.40 |
| Shrubs | 16762.52 |
| Herbaceous vegetation (cattail, reed, sedge) | 150313.32 |

According to the thematic map for 2018, the area of arboreal and shrubby vegetation amounted to 5297.54 thousand hectares, deciduous plantations - 27906.46 thousand hectares, mixed - 6039.61 thousand hectares, herbaceous vegetation - 168751.40 thousand hectares ( Table 3.3).

**TABLE 4.** Areas of land cover classes for 2018

| Class | Area, thousand hectares |
|---|---|
| Arboreal and shrubby vegetation (Rosemary willow, Narrow-leaved willow) | 5297.54 |
| Deciduous plantations (willow) | 27906.46 |
| Mixed plantings (Norway spruce, Walnut) | 6039.61 |
| Herbaceous vegetation (cattail, reed, sedge) | 168751.40 |

Forest areas in the study area of the Fergana Valley for 2000 and 2018 are different and have an uneven distribution pattern. Areas of tree and shrub vegetation decreased over the studied period, but other types of forest plantations were preserved. At the same time, forest plantations are being created in these territories. The reasons for such changes are the influence of natural factors, for example, a sharp increase in temperature and anthropogenic activity.

In the city of Andijan in the Republic of Uzbekistan, tree and shrub vegetation such as chestnuts and walnuts are being planted. Almonds, pistachio trees, persimmons, jida, unabi, pomegranates, wine trees (yellow and black figs), laurel and various fruit trees for the garden grow in the urban areas. In recent years, many lemonarias and kiwis have appeared in the city of Andijan and its suburbs. The suburbs of Andijan, especially the foothills, are rich in fir and juniper forests, sea buckthorn groves, in the east of the region - walnut forests.

**FIGURE 12.** Pine felling in Andijan (October 16, 2018) in the Fergana Valley of Uzbekistan

**FIGURE 13.** Damage to trees by pests and diseases

The decrease in the areas of mixed and deciduous stands is because by the end of 2018, there was massive deforestation in the Fergana Valley (Figure 3, 5).

As a result of the expansion of roads, protective green spaces have recently been cleared. This is also reflected in the change in areas on the 2018 thematic map compared to the 2000 map.

Everyone knows that excess moisture negatively affects most plants. The main reason for this is lack of air, as a result of which crops die from pollution, tree roots rot. In this regard, pathological changes impact the state of forest plantations (Figure 3.6). In the study area, forests, which are dominated by willow plantations (poplars), are negatively affected.

## CONCLUSIONS AND RECOMMENDATIONS

The work carried out a systematic analysis of domestic and foreign literary sources, considered the existing methods, problems and solutions in the field of remote sensing in forestry. In addition, the ways of improving their quality based on the methods of foreign researchers are analyzed.

The existing data on the natural and economic conditions of the location of the Fergana Valley of Uzbekistan allowed us to carry out a qualitative and quantitative analysis of their impact on the forest fund and economic activity of the study area.

The number of forests in Uzbekistan has decreased significantly over the past decades. Today, the forests of the desert zone occupy 2.4 million hectares or 87% of the total forest area. Currently, great importance is attached to the monitoring of forest decline. The Fergana Valley consists of three regions, each of which carries out forestry work.

In the course of the study, work was carried out to refine the methods:

- ✓ selection and processing of satellite images,
- ✓ formation of classes of the generalized legend of vegetation cover,
- ✓ creating a thematic land cover map and
- ✓ assessment of vegetation cover.

Field and office studies were carried out based on the Center for Sustainable Management and Remote Sensing of Forests of the Federal State Budgetary Educational Institution of Higher Professional Education PSTU.

In the study, field studies were carried out, where 90 test sites were laid.

Using satellite images on the territory of the Fergana Valley of the green territory of Uzbekistan, new thematic data were obtained, necessary for monitoring the vegetation cover of the study area.

The paper also presents theoretical provisions on forming thematic maps of the vegetation cover in the Fergana Valley of Uzbekistan.

When comparing the images, an analysis was made of changes in forest areas and green zones. Among them are the districts adjacent to the Syrdarya river: Mingbulak district, Namangan region, Pap district, Namangan region, Dangara district, Fergana region, Ulugnor district, Andijan region and others.

The transformation and degradation of vegetation cover taking place on the territory of the Fergana Valley of Uzbekistan require immediate analysis and measures to eliminate them. The use of remote sensing means obtaining reliable materials with the help of which it is possible to carry out a qualitative assessment and monitoring of the vegetation cover of the Fergana Valley.

The transformation and degradation of vegetation cover taking place on the territory of the Fergana Valley of Uzbekistan require immediate analysis and measures to eliminate them.

The results of using remote sensing tools made it possible to obtain reliable materials that are needed for the subsequent assessment and monitoring of the vegetation cover of the Fergana Valley.

The practical and scientific significance of the work lies in the fact that for the first time, the vegetation cover was monitored for an 18-year period (2000-2018), and the areas of forest-growing thematic classes in the Fergana Valley of Uzbekistan were determined using satellite images of medium resolution.

In addition, a methodology for mapping the vegetation cover in the studied territories using satellite images of medium resolution Landsat is presented. The information obtained makes it possible to promptly track ongoing changes, plan forestry activities for the maintenance of forest plantations, and improve forecasts of the development of forest landscapes and territories.

The methodology developed in the master's thesis will improve the efficiency of research and development work and the activities of well-known forestry enterprises, improve the quality of development results.

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