Analysis of mountain and sub-mountain areas degradation using GIS technologies in Parkent district, Uzbekistan

Azamat Jumanov[1*], *Sharafatdin* Narbaev[1], *Shoxnazar* Boboqulov[1], *Sobir* Ruziboyev[1], *Yusuf* Usmanov[1], and *U.* Absoatov[2]

[1]Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, National Research University, Tashkent, Uzbekistan
[2]Tashkent State Pedagogical University, Tashkent, Uzbekistan

Abstract. In the modern era, it is crucial to analyze the soil of mountain and sub-mountain regions and study the degradation process with the help of remote sensing and geographic information system (GIS) data analysis. These methods are effective tools for planning purposes, including land cover analysis, forest, and water studies. The present study focuses on the changes in land cover and degradation processes in the mountain and sub-mountain regions of the Tashkent region, located in the western part of the eastern Tien-Shan mountains. Due to the climate, this area receives substantial precipitation. However, human encroachment has led to the improper use of pastures, resulting in land use and cover changes. The study area has seen vacant land and open forest converted into open land, leading to increased soil degradation due to rainfall. GIS technologies aid in monitoring such changes and developing effective solutions.

1 Introduction

Various researchers have studied the dynamics of land cover changes in mountain and sub-mountain regions of Uzbekistan [1]. These regions have been heavily impacted by inefficient land use pressures from human and animal activities and the ineffective use of pastures. To address this issue, GIS and remote sensing analysis can enhance machine learning capabilities and effectively monitor land use and land cover change[2, 3]. These technologies have also advanced new measurement and interactive approaches to mapping and analysis of recent changes in natural resources such as rangeland and forest in the mountain and sub-mountain regions[4,5]. In the Parkent area, the land cover has undergone significant changes over the past twenty years[6]. This allows studying these changes using data from space images such as Landsat 8OLI [7]. The land cover of the area is classified into separate classes based on the amount and type of surface vegetation, water, and soil cover, allowing for the identification of areas that are degraded or at risk of degradation[8]. The development of a map based on data from 2002 to 2022 can provide a basis for monitoring and evaluating vacant land and agricultural areas in the region and enhancing

* Corresponding author: jumanov.azamat81@gmail.com

the understanding and interpretation of land degradation impacts in remote sensing analysis[9,10]. Studying changes in land use is crucial for proper planning and management of land resources. The creation of monitoring maps using remote sensing data analysis and GIS technology can quickly and easily generate and store time and location data for large areas[11]. This technology is also predictive and provides managers with important data to analyze machine learning[12,13]. Thus, information on land use and monitoring of land resources is of great importance in making necessary decisions to reduce the intensity of land degradation[14].

2 Study area

The Parkent district is located on the Northern slopes of the Eastern Tien-Shan mountain range, forming the eastern region of Tashkent. This study involved preparing remotely sensed land cover images for ten years (2012-2022) to suggest possible measures for the area's improvement based on land cover change. The region extends from latitudes 41° 00' N to 41° 30' N and longitudes 69° 51' E to 71° 23' E, with the Ugam-Chotkal Biosphere Reserve covering a large part of the area. The reserve is a mountain range with well-defined zonation at an altitude of 550-3500m above sea level, occupying the steep slopes of the Chotkal ridge, cut by deep gorges[15]. The area has three types of firs: spruce, hemispherical, and kurman, forming mixed plantations. The understory vegetation comprises shrubs, including common hawthorn, Fedchenko's rose, Korolkov's annali, oblong zirk, many-flowered green, and Tien-Shan mountain ash. Over 700 species of vascular plants belonging to 70 families and 280 genera have been identified in the reserve, including 13 species listed in the red book of Uzbekistan and 48 species endemic to the western region of the Turkistan ridge. Additionally, 216 species of capped fungi were recorded and studied, along with more than 20 types of medicinal plants, such as aconite, colchicum, immortelle, valerian, ziziphora, and snake's head, and over 15 decorative species, including veronica, carnations, primrose, tulips, eremurus, crocuses, iris, delphinium, and others[16].

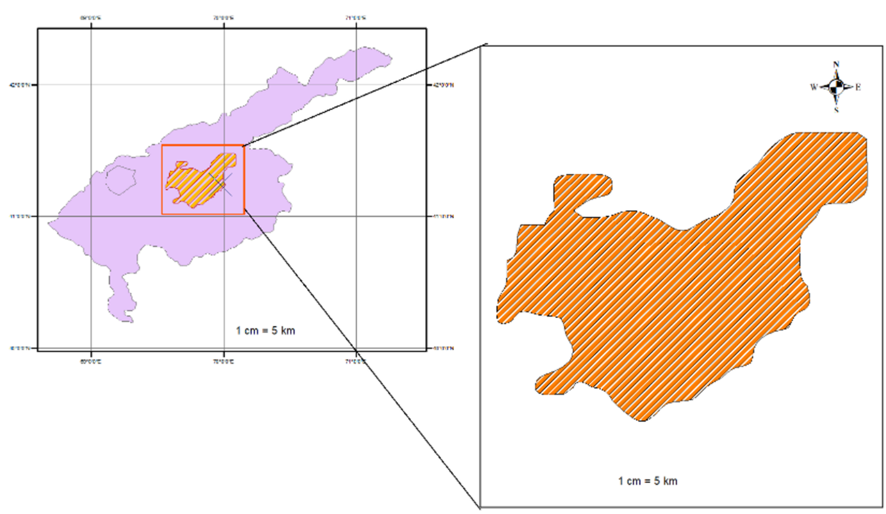

Fig. 1. Study area Parkent districts, Tashkent region

The presence of many rare plants in the study area and land degradation suggests that this ecosystem is undergoing significant transformation. Monitoring land cover change is a key criterion for assessing degradation[17,18]. This involves the correct application of remote sensing, which produces additional analysis by modeling remote sensing data indices specifically targeted to certain areas of interest[19,20]. This technology has facilitated the development of GIS, which in turn has led to the automation of land cover studies, the creation of measurement systems to collect information on land use, and the ability to understand changes in land cover[21]. Proper analysis of land cover change is essential for assessing and monitoring the consequences of future land use change[22].

3 Materials and methods

For the current research data periods of 2012 and 2022 (Landsat 5 TM thematic mapper and Landsat 8 OLI operational land imager) were provided by the USGS (United States Geological Survey) Earth Explorer database system. The spatial resolution of Landsat imageries is equal to 30 m. The classification of images used Google Earth Pro to analyze the study area is mountainous and ground data reference for visual interpretation. Processing classification steps were completed using the software packages and tools ArcGIS 10.6. The data reprocessing steps included the assignment of the borders, coordinate system, and sub-setting of the images based on the polygon of the research area. Supervised classification methods and the maximum likelihood algorithm of ArcGIS were used for Land classification. Fig.3. Land Cover Changes Index (LCCI) algorithms are the most used and well-known in assessing Landsat satellite imageries[23]. Land classification classes were identified in the study area: bare land cover, forest, waterbodies, agriculture areas, and built-up areas. For obtaining more accurate land cover classification maps, 20 training samples were selected from the study area for every land class. Fig. 2.

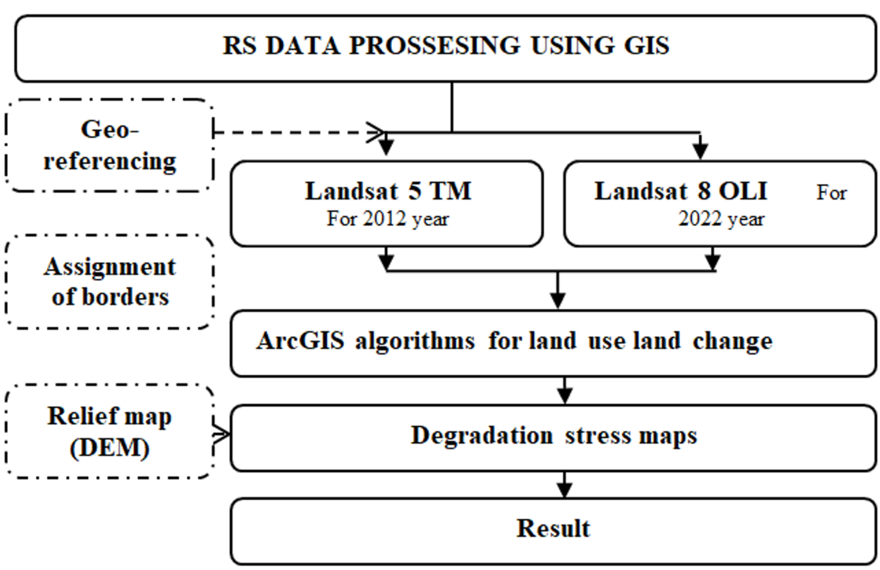

Fig. 2. Flow chart for adopted using ArcGIS methods

4 Results

A land use land cover index study used remote sensing data to map foothill areas and open lands. The index was able to differentiate between foothill areas and open land using ArcGIS software, and the classification performance was effective due to the significant spectral responses of both land types in all Landsat 5 TM+ bands and Landsat8 OLI. The land cover change map for 2012-2022 revealed a mixture of forest and bare land change classes. While significant land cover changes occurred in some areas during this period, extensive forest and wasteland were not converted to other land uses. Some apparent land cover changes were due to agricultural activities. Deforested areas were included in the land cover change map to show the anthropogenic factors driving land cover change in the region over the observed 10-year period (Fig. 4). The relief map of the study area was generated from a DEM file obtained from earthdata.nasa.gov. Elevation zones were identified to determine changes in the surface classification based on elevation. Analysis showed that forests in the study area mainly decreased and turned into open lands between 1000 m to 2500 m elevation during 2012-2022 (Fig. 3).

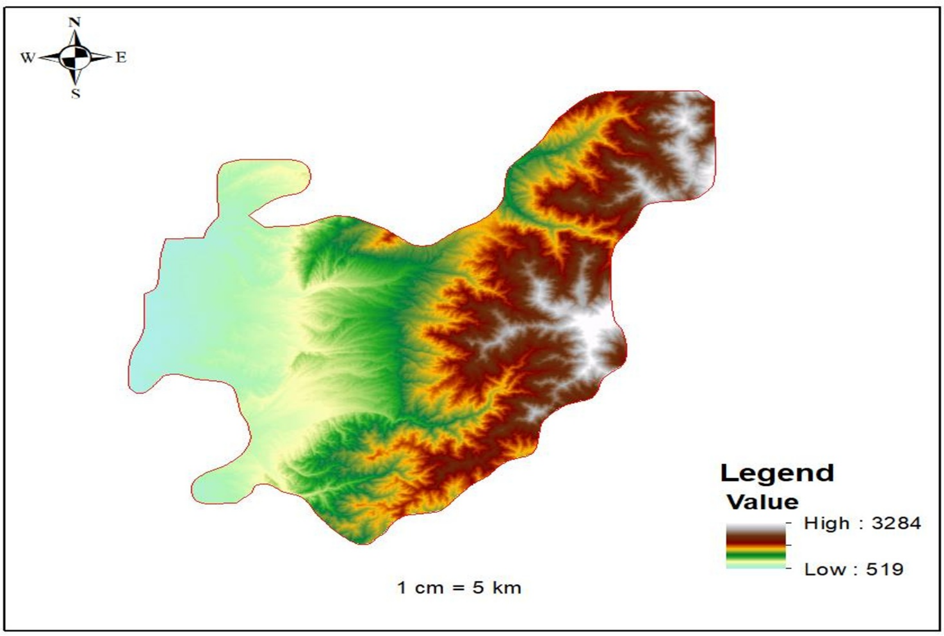

Fig. 3. Relief map research area using DEM file. (Source: earthdata.nasa.gov)

The Land Cover Change Index (LCCI) provides insight into the current state of land use and land cover. LCCI algorithms analyze land at different points during the growing season, including at summer's beginning, middle, and end. By examining changes in LCCI during the growing season, it is possible to better understand how plants and trees have changed over time (Fig. 4).

 https://doi.org/10.1051/e3sconf/202340102011

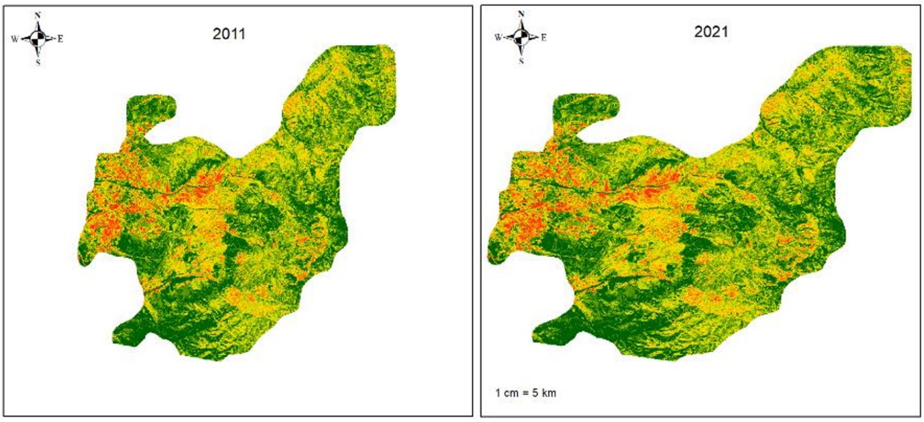

Fig. 4. Land cover changing map.

However, it is important to note that high Land Cover Changes Index (LCCI) algorithms require confirmation of land cover classes using Google Earth Pro in the studied area. The land cover categories confirmed variations in the univariate statistical values of radiation heat flux parameters, as shown in Fig. 3. The spatial parameters exhibited a gradual change in the values of each parameter, as depicted in Fig. 2. The maps in Fig. 2 illustrate the range of each parameter under study, with their average and standard deviation values yielding the best results in terms of land cover classification accuracy. Fig. 4 compares classes and accuracy for each land cover class for classifications. The land cover categories highlighted a relative increase in accuracies for all forest and bare land cover categories, which showed an increase and decrease in classification accuracy, respectively.

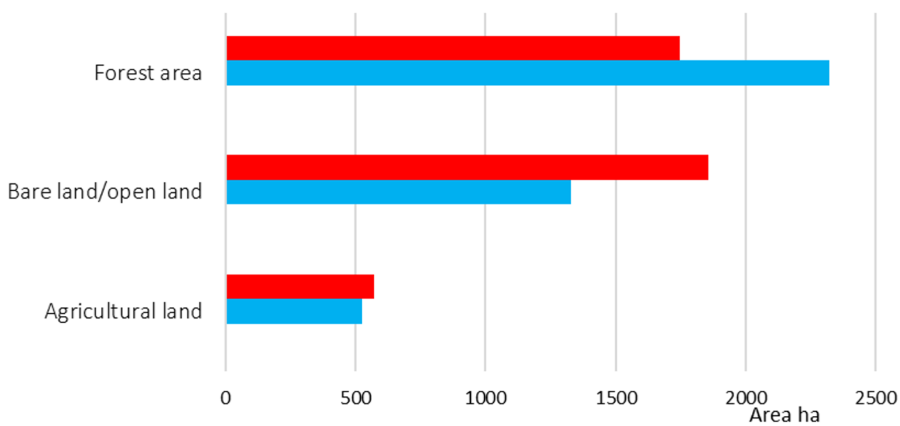

Fig. 5. Land cover changing of ten-years data (2012 blue, 2022 red).

Ten years from 2012 to 2022 was considered to analyze the land cover change pattern. In 2012, forest area covered approximately 61% of the total study area, while bare land and open land constituted nearly 28%, and agricultural land covered approximately 12% of the area. Between 2012 and 2022, there was a significant increase in bare land and open land, which accounted for up to 45% of the total area. In contrast, forest cover decreased from 61% in 2012 to 42% in 2022, indicating a decline of 19% in the last 10 years. Fallow land showed the greatest change in the pattern. It is worth noting that during the initial year, i.e., 2012, nearly 32% of the total area was covered by bare land and open land, which increased by approximately 7% during the 10-year period. These changes in land cover were substantial, highlighting the need to monitor and manage land use effectively to maintain ecological balance and sustain natural resources.

5 Conclusions

In conclusion, this study demonstrates significant land cover changes in the study area over the past decade. Using remote sensing techniques and accurate Landsat data proves valuable in monitoring these changes and assessing their impacts. The results show that remote sensing data and monitoring results can help evaluate the changing behavior of land cover. The 10-year study of the Mountains and Highlands shows a considerable decrease in forests and an increase in open land areas, which raises the risk of degradation in the study area. The complex terrain in mountainous and sub-mountainous regions accelerates this process. Inefficient use of open lands may lead to the degradation of these lands, causing the burning of the fertile layer of the soil. This indicates that land changes may lead to future soil erosion, flooding, and landslides, which may become a recurring hazard permanently.

Therefore, the land cover change maps obtained in this study can be used in subsequent landslide susceptibility mapping of this area. The deforested areas in the land cover change map indicate the impact of dynamic anthropogenic factors on land cover change in the region over the 10-year period. These maps can assist public authorities and stakeholders in natural hazard warning and land use planning for the local government. Furthermore, the maps can aid in landslide susceptibility mapping and help government agencies and stakeholders plan land use to prevent natural hazard losses. Overall, the results of this study demonstrate the importance of remote sensing methods and accurate Landsat data in assessing and monitoring land cover changes and their impacts, especially in mountainous and sub-mountainous regions where land cover changes may cause significant hazards.

References

1. Musaev I, Bokiev A and Botirova M 2021 The Value of the Cards in Water Basins with the Installation of Solar Power Plants in Yangiyul District of Tashkent Province of Uzbekistan ed L Foldvary and I Abdurahmanov E3S Web Conf. 227 05004
2. Oymatov R K, Mamatkulov Z J, Reimov M P, Makhsudov R I and Jaksibaev R N 2021 Methodology development for creating agricultural interactive maps IOP Conf. Ser. Earth Environ. Sci. 868
3. Inamov A, Avilova N, Norbaeva D, Mukhammadayubova S, Idirova M and Vakhobov J 2021 Application of GIS technologies in quality management of land accounting in Uzbekistan ed V Kankhva E3S Web Conf. 258 03014
4. Jansen V S, Kolden C A, Schmalz H J, Karl J W and Taylor R V. 2021 Using Satellite-Based Vegetation Data for Short-Term Grazing Monitoring to Inform Adaptive Management Rangel. Ecol. Manag. 76 30–42
5. Michez A, Lejeune P, Bauwens S, Lalaina Herinaina A A, Blaise Y, Muñoz E C, Lebeau F and Bindelle J 2019 Mapping and monitoring of biomass and grazing in pasture with an unmanned aerial system Remote Sens. 11
6. Théau J, Lauzier-Hudon É, Aubé L and Devillers N 2021 Estimation of forage biomass and vegetation cover in grasslands using UAV imagery PLoS One 16 1–18

7. Nguy-Robertson A, Gitelson A, Peng Y, Viña A, Arkebauer T and Rundquist D 2012 Green leaf area index estimation in maize and soybean: Combining vegetation indices to achieve maximal sensitivity Agron. J. 104 1336–47
8. Aslanov I, Khasanov S, Khudaybergenov Y, Groll M, Opp Ch C, Li F and Del-Valle E R 2021 Land cover-adjusted index for the former Aral Sea using Landsat images ed L Foldvary and I Abdurahmanov E3S Web Conf. 227 02005
9. Khasanov S, Kulmatov R, Li F, van Amstel A, Bartholomeus H, Aslanov I, Sultonov K, Kholov N, Liu H and Chen G 2023 Impact assessment of soil salinity on crop production in Uzbekistan and its global significance Agric. Ecosyst. Environ. 342 108262
10. Aslanov I, Jumaniyazov I and Embergenov N 2023 Remote Sensing for Land Use Monitoring in the Suburban Areas of Tashkent, Uzbekistan ed A Beskopylny, M Shamtsyan and V Artiukh Springer Int. Publ. 575 1899–907
11. Fadhillah M F, Hakim W L, Panahi M, Rezaie F, Lee C W and Lee S 2022 Mapping of landslide potential in Pyeongchang-gun, South Korea, using machine learning meta-based optimization algorithms Egypt. J. Remote Sens. Sp. Sci. 25 463–72
12. Ngandam Mfondoum A H, Hakdaoui S and Batcha R 2022 Landsat 8Bands' 1 to 7 spectral vectors plus machine learning to improve land use/cover classification using Google Earth Engine Ann. GIS 00 1–24
13. Mohammad P, Goswami A, Chauhan S and Nayak S 2022 Machine learning algorithm based prediction of land use land cover and land surface temperature changes to characterize the surface urban heat island phenomena over Ahmedabad city , India Urban Clim. 42 101116
14. Farmanov N, Amankulova K, Szatmari J, Sharifi A, Abbasi-Moghadam D, Mirhossein-Nejad M and Mucsi L 2023 Crop Type Classification by DESIS Hyperspectral Imagery and Machine Learning Algorithms IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens. 16 1–17
15. Babajanov A R and Inamov B N 2020 Issues of involvement in circulation of unused agricultural lands in Uzbekistan IOP Conf. Ser. Earth Environ. Sci. 614 012131
16. Nilufarbegim K, Kizi N, Mukhriddin K, Ugli K and Temirkulovich U J 2020 Ecotourism-an important factor in sustainable development and environmental protection: the experience of Uzbekistan Int. J. Adv. Sci. Technol. 29 1845–51
17. Zhang X, Lei J, Wu S, Li S, Liu L, Wang Z, Huang S, Guo Y, Wang Y, Tang X and Zhou J 2023 Spatiotemporal evolution of aeolian dust in China: An insight into the synoptic records of 1984–2020 and nationwide practices to combat desertification L. Degrad. Dev. 1–19
18. Yang Y and United Nations Convention to Combat Desertification (Secretariat) 2011 Combating desertification and land degradation : proven practices from Asia and the Pacific (Korea Forest Service)
19. Aslanov I 2022 Preface IOP Conf. Ser. Earth Environ. Sci. 1068 9–11
20. Kholdorov S, Jabbarov Z, Aslanov I, Jobborov B and Rakhmatov Z 2021 Analysing effect of cement manufacturing industry on soils and agricultural plants ed A Zheltenkov and A Mottaeva E3S Web Conf. 284 02005
21. B U M, Aslanov I and Lapasov J 2023 Creating Fertilizer Application Map via Precision Agriculture Using Sentinel-2 Data in Uzbekistan Uzbekkhon ed A Beskopylny, M Shamtsyan and V Artiukh Springer Int. Publ. 575 1915–21

22. Ullah W, Ahmad K, Ullah S, Tahir A A, Javed M F, Nazir A, Abbasi A M, Aziz M and Mohamed A 2023 Analysis of the relationship among land surface temperature (LST), land use land cover (LULC), and normalized difference vegetation index (NDVI) with topographic elements in the lower Himalayan region Heliyon 9 e13322
23. Gautam V K, Gaurav P K, Murugan P and Annadurai M 2015 Assessment of Surface Water Dynamicsin Bangalore Using WRI, NDWI, MNDWI, Supervised Classification and K-T Transformation Aquat. Procedia 4 739–46