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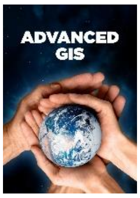

Geochemical heat maps in complex geological structures via using QGIS: Maden (Elazığ) district

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ABSTRACT

Geochemical analysis results are one of the most significant indicators that reveal the characteristics of the geological structures in a region. In particular, the differences in the composition of complex geological structures can be evident in field and Geographic Information Systems (GIS) studies. Turkey includes a character consisting of quite complex features with its geological structure. The Maden (Elazığ) complex has also attracted the attention of many researchers with its complex structure. The Maden Complex also contains basalts, basaltic andesite, andesite, dacite, diabase, and pyroclastic rocks, which are intercalated and lateral-vertical transitive with all these sedimentary successions. Mapping and lithological differentiation of the Maden Complex, which has a very complex structure, is difficult. The geochemical analysis of the samples taken from the field was transferred to the GIS environment with their coordinates. Thematic maps are created to make the geological interpretations in this region cleaner and the field data more predictable. These maps also allow the correlation of major oxides and trace elements. In this study, the geochemical data obtained in the Maden Complex were analyzed in the QGIS program. The geochemistry of the region has been made more understandable and interpreted with heat maps. The diversification of thematic maps, which gives a new perspective to geochemical data, will provide more support to geological studies.

1. Introduction

The Southeast Anatolian Orogenic Belt (SAOB) constitutes the eastern part of the Taurus Orogenic Belt, which is one of the most critical tectonic belts in Turkey, located between the Arabian platform and Anatolian micro-plate (Şengör & Yılmaz 1981; Ural et al., 2015; Ertürk et al., 2017, 2018, 2022; Sar et al., 2019; Yılmaz et al., 2022) This belt is a complicated part of the Alpine–Himalayan Mountain range with numerous distinct characteristics. This region has a complex geodynamic history, with northward subduction and closure of the Tethyan Ocean branch and the collision of various continental blocks. The Southeast Anatolian Orogenic Belt has been studied by many researchers in three belts from south to north (Yılmaz, 1993; Yılmaz, 2019).

(1) During the period from Precambrian to Early Miocene, the "Arabian Platform" consists of a thick autochthonous sedimentary sequence accumulated in the marine environment and the base volcanic rocks.

(2) The "Zone of Imbrication" occurs in the north of the Arabian Platform, forming a reverse fault zone developed in the Late Cretaceous-Early Miocene interval, about 5-10 km in width.

(3) The uppermost central tectonic unit, which includes the Middle Eocene Maden Complex, is the "Nap Zone". These zones are separated from each other by thrust faults. The study area is located north of the Bitlis–Zagros suture zone. It covers the most widespread and the best-observed regions of the Maden Complex, which have an important place in understanding the geodynamic evolution of the region.

Geochemical inputs are applied to clarify many geological problems. One of the powerful practices of these data is statistical and spatial approaches. As it is recognized, many geological studies have been supported by remote sensing and geographic information systems in recent years. These studies are conducted with advanced programs in a computer environment with technology development. Now, many GIS programs are used, and an open-source-coded QGIS program was used in this study.

With scientific advances in spatial analysis techniques, linearity, ore exploration and morphological

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investigations have developed into approximately practical. Geographic Information Systems (GIS) have also been used in many mineral exploration studies and mine probability maps (Porwal et al., 2001; Joly et al., 2012; Lindsay et al., 2014).

The Maden Complex is an extraordinarily significant structure for the geology of Turkey. Major oxide and trace element analyzes were carried out of the samples compiled from the field in this region, which has many complex geological characteristics. The geochemical distribution of this complex region and the relationship between the elements can become more visible with thematic maps in the GIS environment. Heat maps of some of the analysis results of the sample points were created, and discussions on the geological structure were prepared. The spatial geochemical changes of the Maden Complex, which has a very complex structure, will be an important finding for the enlightenment of the geology of the region.

The purpose of this study is the spatial interpretation of geochemical data.

2. Method

Data analysis in geochemical studies requires consideration of both geographic locations and attributes. With the development of computer hardware and software along with technology, an increasing number of spatial analysis and statistical techniques have been integrated into GIS, which makes a great contribution to geochemical analysis studies (Fotheringham & Rogerson, 2013).

At the same time, with the development and application of spatial analysis techniques, problems related to geochemical mapping, mineral exploration, and many geological problems can be solved (Overpeck et al., 2011; Reichman et al., 2011).

The samples collected from the field study are detected via XRF and ICP-MS methods. The major elements were measured by X-ray fluorescence techniques on fused glass beads. Trace elements were measured by inductively coupled plasma-mass spectrometry (ICP-MS). The major oxides and trace element analysis detected by Ertürk et al. (2018) was digitized in the GIS environment, and sample points were located. Afterward, heat maps dwelling on major oxide and trace elements were made.

3. Geological Background

The Maden Complex is situated in the Bitlis-Zagros Suture Zone, including the Zone of Imbricate and Nappe Zone. In the study are the Upper Cretaceous Guleman Ophiolite and the Maastrichtian Lower Eocene Hazar Group thrust over the Middle Eocene Maden Complex. The Guleman Ophiolite crops widely in the east and southeast of Hazar Lake and presents its most typical outcrops around the Alacakaya-Maden districts. Regarding the formation of the Guleman ophiolites, many researchers have stated that the Guleman Ophiolites are products of the Neotethys oceanic crust that began to open from the Upper Triassic between the Pütürge Metamorphites and the Keban-Malatya massifs (Michard et al., 1984; Yazgan & Chessex, 1991). The Guleman ophiolites emplaced on the continental crust towards the south with the closure of the Neo-Tethys Ocean in the Late Cretaceous.

Rizeli et al. (2016) accept that the Guleman Ophiolite was formed in the fore-arc basin at the beginning of the northward subduction of the southern branch of Neo-Tethys.

According to Kaya (2004), the Hazar group consists of a red-brown basal conglomerate at the bottom, and grey, green and light brown coloured sandstone, siltstone, mudstone, shale, marl and limestone towards the top.

For the formation of the unit, researchers such as Özkan (1982), Perinçek & Özkaya (1981), and Aktaş & Robertson (1984) stated that the environment initially presented terrestrial conditions. The units at the base of the Hazar group represent this terrestrial environment and are laterally associated with the Simaki Formation. They stated that the deposition basin gradually deepened with block faults, and the formation was deposited under marine conditions. In contrast, the uppermost Gehroz Formation was pelagic limestones deposited in the shelf environment.

The Maden Complex cropped out over vast regions in Eastern Taurus (Figure 1). The representative field photographs are given in Figure 2.

The Maden Complex also contains basalts, basaltic andesite, andesite, dacite, diabase and pyroclastic rocks, which are intercalated and lateral-vertical transitive with all these sedimentary successions. The brecciation is widespread due to tectonism. Also, the region observes intensive alterations depending on the thrusts and imbrications. The magma constituting the Middle Eocene Maden Complex was derived from a source like E-MORB and N-MORB enriched by previous subduction components.

In addition, this situation shows that crustal contamination processes play an active role in addition to the fractional crystallization of the mechanism that is effective in the development of rocks (Ertürk et al., 2018).

After the Late Cretaceous collision in the region, ophiolites were thrust on the Arabian Plate, and the Pütürge-Bitlis Metamorphic Massifs overlaid the ophiolites, and a significant crustal thickening occurred. The bottom part of the Late Cretaceous subduction zone and Bitlis-Pütürge Metamorphics and the gap formed due to the drifting of the lower ophiolites into the asthenosphere were filled by the asthenosphere. The magma formed by partially melting the adiabatically rising asthenosphere with the effect of the volatiles released from the collapsed part rose and formed the Maden Complex on the Guleman ophiolites (Ertürk et al., 2018).

Perinçek (1978) stated that the Maden Complex was deposited in the deep sea, was complicated by intense tectonics, and gained its present position by moving south as drift covers.

Yazgan et al. (1987) stated that the Maden Complex is volcanism due to intraplate continental subduction, which is formed by partially melting the upper mantle due to post-collisional compressional tectonics.

Ertürk et al. (2018) reported that the middle Eocene Maden magmatism developed in a post-collisional environment by asthenospheric upwelling owing to convective removal of the lithosphere during an extensional collapse.

Yalçın et al. (2020) stated that Cu anomalies in Maden Complex are around Hasenekevleri (Maden-Elazığ) and said that Cu mineralization is in vein type within diabases.

Ertürk & Yalçın (2022) evaluated geochemical analyses in the Maden complex, which has significant geological structures, via the QGIS program. They stated that the major oxides and trace elements show the distribution of the geochemical signatures of the study area.

The spatial geochemistry data in this study will be helpful in interpreting the elemental distributions of the rock groups in the region.

3.1. Petrography

The Maden Complex comprises basalts, basaltic andesite, dacite, diabase, and pyroclastic rocks (Ertürk et al., 2018). Basalts largely crop out in the study area. The volcanic rocks are dominated by plagioclase and pyroxene phenocryst assemblage. They display aphanitic, microlitic, ophitic, subophitic, and intersertal textures (Fig. 3). Basalts are generally greenish, brownish, bearded in colour, and massive, ellipsoidal-shaped pillow lavas and broken pillow basalts.

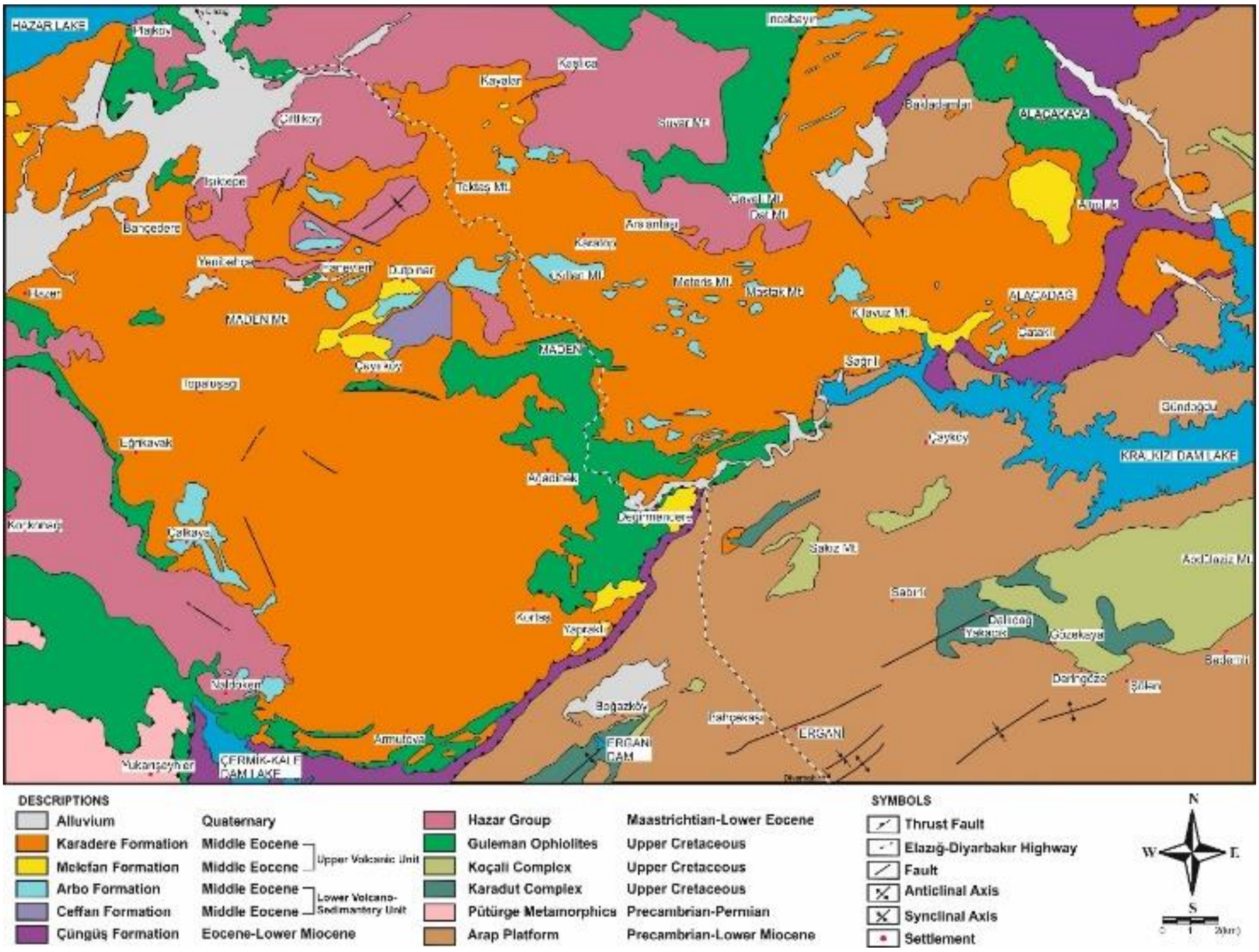

Figure 1. Geological map of the study area (modified from MTA, 2011)

Basalts are intercalated mainly with red cherts and mudstones. Basaltic andesites and andesites are in grey colours compared to basalts, and it is challenging to distinguish macroscopically from basalts. However, it is possible to make this distinction according to petrographical and geochemical features.

The dacites are macroscopically lighter, grey, whitish, and darker than the mafic volcanics and are fine-grained volcanic rocks.

The diabases often cut the basalts. The diabases greenish coloured is medium-grained and varies in thickness.

The study area represents pyroclastic rocks represented by agglomerate, lapillistone, and tuff. The agglomerates are composed of bombs with a grain size of more than 64 mm, and a cement material welds the volcanic parts. The lapillistones have a basic and andesitic composition. The tuffs are fine grain.

As explained above, many rock groups with different characteristics are observed together in the Maden complex. Because of this structure, the geochemical contents of the rocks in this region should be interpreted by overlapping with the spatial data. In this way, the complex structure of the region will be illuminated.

4. Results

4.1. GIS application

GIS and statistical methods have been widely used to analyze the formation, origins and processes of geochemical characters in rocks.

Geochemical data in a region can qualify as typical spatial data when associated with geographic coordinates in any program geographic information system (GIS).

Therefore, data analysis in geochemical studies requires consideration of both geographic locations and attributes. With the development of computer hardware, software, and technology, many spatial analysis and statistical techniques have been integrated into GIS, which greatly contributes to geochemical analysis studies (Fotheringham & Rogerson, 2013).

At the same time, with the development and application of spatial analysis techniques, problems related to geochemical mapping, mineral exploration, and many geological problems can be solved (Overpeck et al., 2011; Reichman et al., 2011).

Many samples were taken from the field in the petrographic and petrological study by Ertürk et al. (2018). Geochemical analyzes of these samples were carried out and used in many clarifications. In this study, a heat map was prepared in the QGIS program to compare and review the attribute information of the sample points.

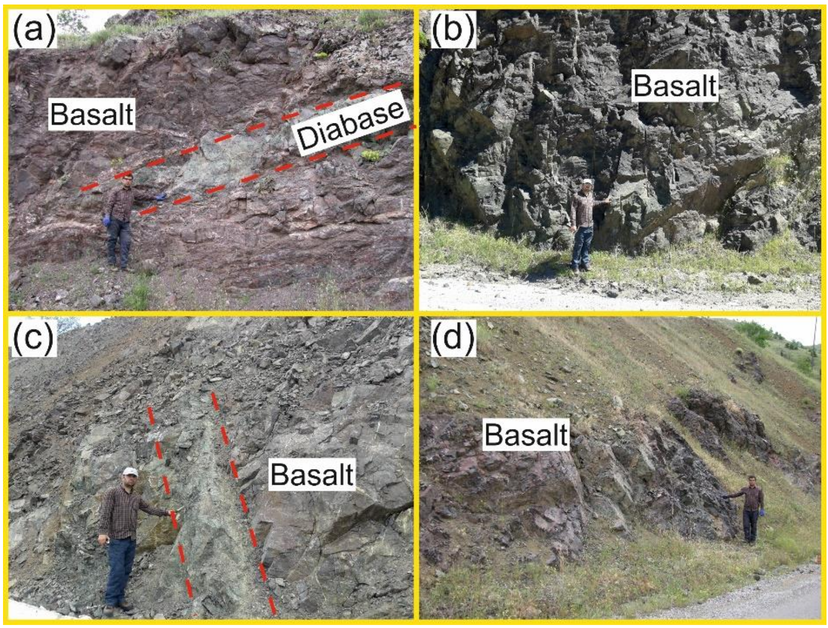

Figure 2. Representative field photographs of the volcanics

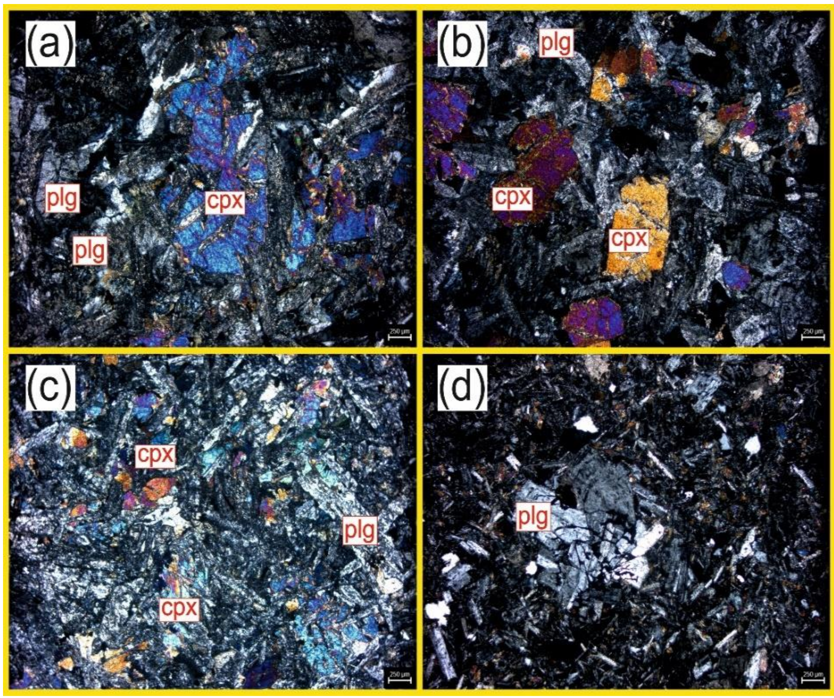

Figure 3. Microscopic views from the volcanic rocks (plg = plagioclase, cpx = clinopyroxene)

In Figure 4, it is seen that the major oxide values commonly show a similar distribution in many samples. SiO_2 is an essential component of minerals that make up many rocks. Other oxides (Figure 4) take place in the structure of silicate minerals together with SiO_2.

The SiO_2 distribution also summarizes whether the rocks are acidic or basic. Higher values represent acidic rocks, while lower values represent basic and ultrabasic rocks. Except for the northeast of the study area, most basic and near-basic rock groups are observed (Fig 4).

Al_2O_3, Fe_2O_3 and Na_2O values from other major oxides show approximately similar distributions and positive correlations with each other (Figure 4).

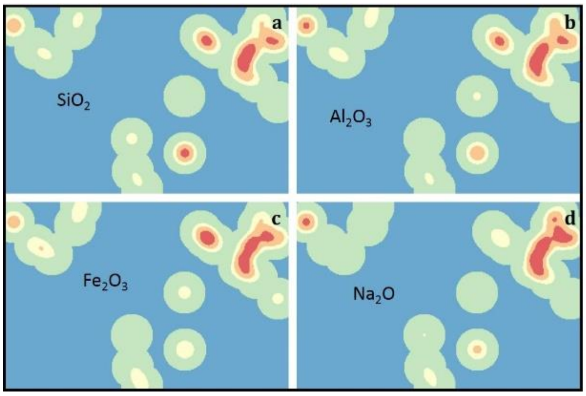

Figure 4. Heat map of the study area via major oxide contents (On each thematic map, the red areas represent the densest regions)

To further elucidate the geochemical data in the region, CaO, K_2O, MgO and P_2O_5 values from other major oxides were also analyzed. CaO values show concentration in more areas than MgO values, while MgO values show concentration in northeastern areas. (Figure 5).

Although K_2O and P_2O_5 values show a similar distribution, P2O5 values also present high anomalies, as in MgO in northeastern areas (Figure 5).

As explained above, the distribution and correlation relationships in the major oxide values indicate that rocks of different origin and characteristics exist in the region. These differences are due to mineralogical change and geochemical character.

The distribution of some trace elements is given in Figure 6. While Cr, Ga and V have a roughly similar distribution, Cu, W and Rb have different patterns. These differences are due to lithology, mineralogy and geochemical differences.

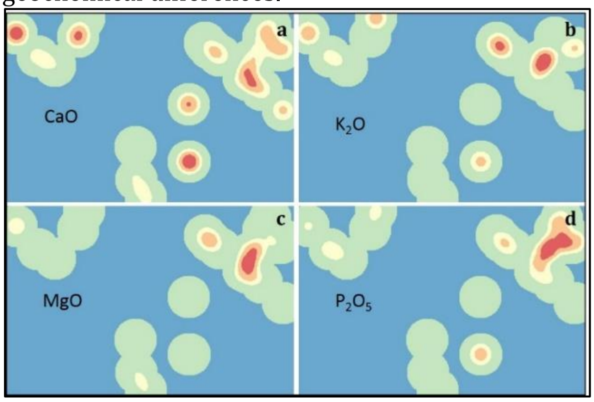

Figure 5. Heat map of the study area via major oxide contents

There are significant Mn mineralizations within the Maden Complex. For this reason, Mn values from trace elements are evaluated and shown in Figure 7a.

The Y values used in many petrogenetic interpretations were also analyzed (Figure 7b). These two elements, which present a similar distribution, offer variation in the central and southern areas.

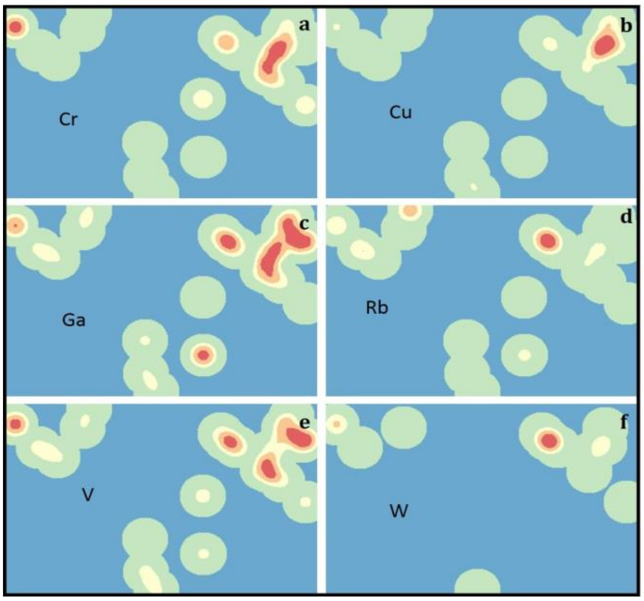

Figure 6. Heat map of the study area via trace element contents

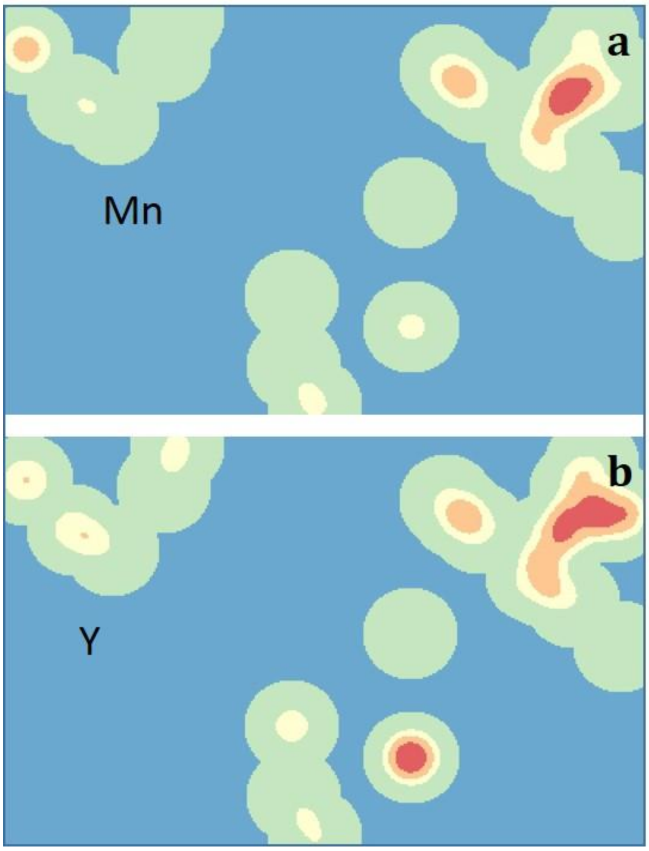

Figure 7. Heat map of the study area via trace element Mn-Y contents

In this study, the regional geochemistry character was digitized in the QGIS program. This digitization was created by evaluating the coordinates and elemental contents of the samples taken with GPS in the field. As it is known, QGIS enables GIS analysis. Thanks to this program, an approach to the character of the study area with a complex geological structure has been provided.

With these studies, the existence of structures with different characteristics should be correlated with field data. Therefore, the information that will be a guide will lead to more meaningful interpretations. Moreover, it is exceedingly challenging to make lithological discrimination in the Maden Complex, where rocks of many different characters are observed closely. For this reason, it is significant to evaluate the data obtained in the field in the GIS environment.

5. Discussion and Conclusion

GIS-based modelling has been proposed in addition to geology-geochemistry studies (Brown et al. 2003; Partington, 2008). This modelling provides a geostatistical approach to the geological structures.

For example, Atakoğlu & Yalçın (2021) explained the statistical properties of Sutlegen (Antalya) bauxite according to their geochemical content and set up thematic maps with the Krigging interpolation method.

Yalçın et al. (2021) created thematic maps in the Geographical Information Systems (GIS) environment by using Adobe Illustrator 2020 program to reveal the spatial geochemical changes of Cu enrichment in the Kuzuluk (Sakarya, Turkey) region. These maps interpreted that the Cu concentration increased as the fault zone was approached and changed into altered zones as it moved away from the fault zones.

In another similar study, U-Th anomalies in the vicinity of Arıklı (Çanakkale) were revealed in the QGIS program (Yalçın et al., 2022). Although the applications described above are mainly mineralization, GIS applications can be successfully applied in petrogenetic interpretations or mapping studies in complex geological structures.

Mapping minerals, elements or oxides based on multi-source geoscience data (geology, geochemistry, and remote sensing) and computer technology is an effective technique that merges information and data-driven production (Bonham-Carter 1994; Zhao, 2002; Wang et al., 2016). For this reason, the data of the study conducted by Ertürk et al. (2018) in the Maden (Elazığ) district were re-evaluated in the QGIS environment. In the evaluations prepared, GIS-based thematic maps correctly exhibit the relationship of the geochemical contents of the study area correctly.

The thematic maps obtained in this study show that geochemical data can be interpreted with the help of GIS in complex geological environments. These and similar studies, which are important for the interpretation of regional geology, can be preferred especially in mineral exploration. For this reason, it will be important to evaluate the data obtained from geological studies in the GIS environment.

Author Contributions

The contributions of the authors of this article is equal.

Statement of Conflicts of Interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

Research and publication ethics were complied with in the study.

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Heat maps of U-Th enrichments in open source coded geographical information systems (GIS); Arıklı (Çanakkale, Turkey) district

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ABSTRACT

Uranium (U) and Thorium (Th) are both strategically important elements in the world. For this reason, it is exceedingly significant to explore for these elements, which are enriched in many geological environments. U-Th enrichments in Turkey were usually discovered in the Western Anatolian geography. U-Th anomalies were still observed in the Arıklı region in the south of Çanakkale. Remote sensing (RS) and geographic information systems (GIS) are platforms for the map-based evaluation of geological structures. In this study, RS and GIS were utilized in the QGIS program to carry out the geochemical data obtained in the field more understandable. GIS and remote sensing methods have been widely used to analyse the formation, origins, and processes of geochemical characters in ore deposits. U-Th values, which show high values in the fault zones in the Arıklı region, are immediately related to the CaO values. As in many geological studies, remote sensing and GIS studies suggest the opportunity to check out field data with a significant quality in the exploration of ore deposits.

1. Introduction

Uranium and Thorium are significant and strategic radioactive elements. For this reason, applications are carried out to explore for these elements, which are enriched in many geological environments.

Granite and volcanic rocks are essential sources for Uranium enrichment (Zhang & Zhang 1991; Qin & Liu 1998). U deposits are divided into four groups corresponding to the host rock lithology (Li et al., 2002). These are granite-rock type (G-type), sandstone type, volcanic-rock type (V-type), and carbonaceous-silica-pelitic-rock type (CSP-type) respectively. It has been described that the important uranium enrichments in Turkey are situated in western Anatolia (Şaşmaz, 2008).

Uranium exploration activities in Turkey were started by MTA in 1953 and after that, exploration studies continued (Contencin, 1960; Günaydın, 2017). In the Ayvacık-Küçükkuyu field near Çanakkale province, the U_3O_8 value was 0.08% in Miocene carbonate rocks (MTA, 2009; MTA 2010). There are phosphate nodules and natural radiation sources in the volcanic tuffs between Küçükkuyu and Ayvacık (Atabey, 2006). On the Geyikli coast close to the region, there are minerals (taurite and uraninite) consisting of heavy metals, uranium and thorium in the sands (Andaç, 1971). The origin of these radioactive minerals is the granitic rocks outcropping around Geyikli (Andaç, 1971).

Günaydın (2017) explained that there is a U enrichment in the composition of bayleite and ningyoite in and around Arıklı. High natural radiation values were also reached in the fault zones around Örencik and Feyzullah Tepe, northwest of Arıklı (Atabey, 2006). Magnesite breccias located in the northwest of Arıklı are formed by the effect of hydrothermal waters and there are U up to 700 ppm and Th greater than 1000 ppm in this fault zone (Günaydın, 2017).

Öztürk et al. (2021) examined microthermometric measurements from magnesite observed in these fault zones and determined that (Th, ^{o}C) was between 282-348 ^{o}C and % NaCl salinity equivalents were between 4.2-8.0. They also set forth that the solution system of liquid inclusions is in the form of H_2O-$MgCl_2$-$CaCl_2$ and the density of liquids is between 0.58-0.74 g/cm^3.

Yalçın et al. (2022) evaluated the U-Th anomalies by using the remote sensing and GIS applications respectively. They stated that the geochemical components of the ore zone is changed with the effects of fault systems.

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In recent years, high resolution digital applications have been widely used in geological studies. Remote sensing (RS) and geographic information systems (GIS) are principles for map-based interpretation of many geological structures.

With scientific advances in spatial analysis techniques, linearity, ore exploration and morphological investigations have developed into approximately practical. Geographic Information Systems (GIS) have also been used in many mineral exploration studies and mine probability maps (Porwal et al., 2001; Joly et al. 2012; Lindsay et al., 2014).

Many GIS-based applications have been carried out in uranium exploration studies. On the principle of these, GIS-based modeling has been proposed in addition to geology-geochemistry studies (Brown et al., 2003; Partington, 2008).

Atakoğlu & Yalçın (2021) explained the statistical properties of Sutlegen (Antalya) bauxite according to their geochemical content and set up thematic maps with the Krigging interpolation method.

Yalçın et al. (2021) created thematic maps in the Geographical Information Systems (GIS) environment by using Adobe Illustrator 2020 program in order to reveal the spatial geochemical changes of Cu enrichment in the Kuzuluk (Sakarya, Turkey) region. From these maps, they interpreted that the Cu concentration increased as the fault zone was approached, and changed into altered zones as it moved away from the fault zones.

In another study, Ertürk & Yalçın (2022) were revealed petrogenetic interpretations or mapping studies in complex geological structures by the way of GIS applications.

In this study, the results of the analysis obtained in the study by Öztürk et al. (2021) were evaluated. Samples collected in the field, geological maps, satellite images and thematic maps were evaluated together. This study is based on Öztürk et al. (2021)'s spatial evaluation of geochemical analysis data. Because the results of these analyses were not evaluated in a GIS environment, no spatial geochemistry interpretations were made. This study presents an innovative approach to revaluating previously obtained geochemical modeling studies using satellite images.

2. Method

Geochemical data in a region can qualify as typical spatial data when associated with geographic coordinates in any program geographic information system (GIS).

Therefore, data analysis in geochemical studies requires consideration of both geographic locations and attributes. With the development of computer hardware and software along with technology, an increasing number of spatial analysis and statistical techniques have been integrated into GIS, which makes a great contribution to geochemical analysis studies (Fotheringham & Rogerson, 2013).

At the same time, with the development and application of spatial analysis techniques, problems related to geochemical mapping, mineral exploration and many geological problems can be solved (Overpeck et al., 2011; Reichman et al., 2011).

Remote sensing techniques are applied with multispectral (Landsat-8, ASTER, Sentinel-2, etc.) and hyperspectral (EO-1 Hyperion, AVIRIS, AVIRIS-) methods in mapping, morphological features, lithological separation, mineral exploration, mineralogy or hydrogeology in geological studies (Waldhoff et al., 2008; Rani et al., 2018; Chattoraj et al. 2020; Jain et al. 2021; Guha et al., 2021; Pandey & Purohit, 2022).

The DEM image of this geologically significant region has been downloaded from the United States Geological Survey (USGS) website. Aspect, 3D map and slope map of the region were created by evaluating the downloaded images in the QGIS environment.

In boost, the geological map prepared by Öztürk et al. (2021) was digitized in the GIS environment and sample points were located. Afterwards, heat maps dwelling of major oxide and trace elements were made.

2.1. Geological framework

The application area is in the south of the Biga peninsula in Western Anatolia. The application area situated in the Ayvacık district of Çanakkale is tectonically located in the Sakarya Zone (Figure1). Okay et al. (1990) described the units in Çanakkale region as pre-Tertiary and post-Tertiary units respectively. In their following studies, it was divided into three pre-Tertiary tectonic zones observed in NE-SW direction (Okay et al. 2001; Okay & Altıner, 2004). These zones are Ezine Zone, Ayvacık-Karabiga Zone and Sakarya Zone respectively.

There are many metamorphic facies along with magmatic, ophiolite, sedimentary and volcanic rock groups established in the north of Gulf of Edremit (Figure 1) (Okay & Satır 2000; Şengün et al., 2011). In the vicinity of Arıklı, the Miocene Pliocene aged continental sediments and Cretaceous aged Çetmi melange are outcrop (Figure 1).

The Cretaceous Aged Çetmi Ophiolitic Melange, Küçükkuyu Formation and Quaternary aged alluvial deposits are located in the study area. In the Küçükkuyu formation, shale-sandstone member, and Arıklı tuff member were separated and diabases that cut these units were mapped on the Örencik Tepe (Fig 2).

Öztürk et al. (2021) stated that there are U and Th anomalies in the NE-SW and NW-SE trending dip-slip fault zones (Fig 3) observed in the northwest of Arıklı. The highest U and Th values are found in the area of magnesite breccia (Fig 4) in the northwest of Arıklı. In the light of these data, it has been understood that the U and Th mineralizations in the region are related to the fault zones developed in the Arıklı ignimbrites, therefore the fault lineaments in this region are important.

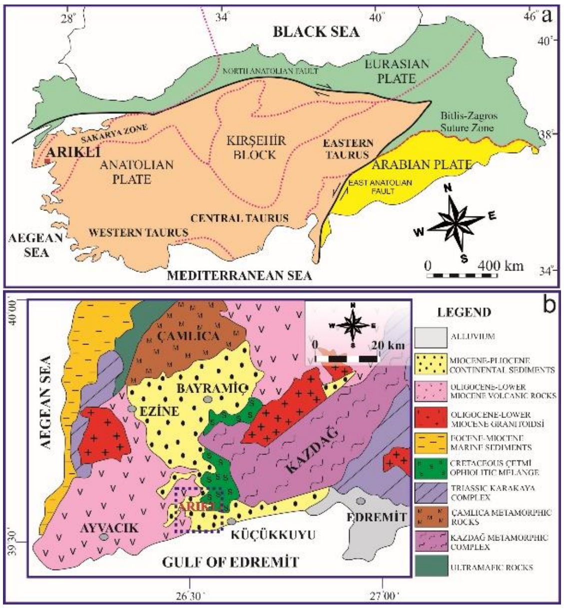

Figure 1. (a) Tectonic location of the study area (modified from Işık, 2016), (b) Generalized geology map of the Biga region and location of the study area (modified from Okay & Satır 2000; Şengün et al., 2011)

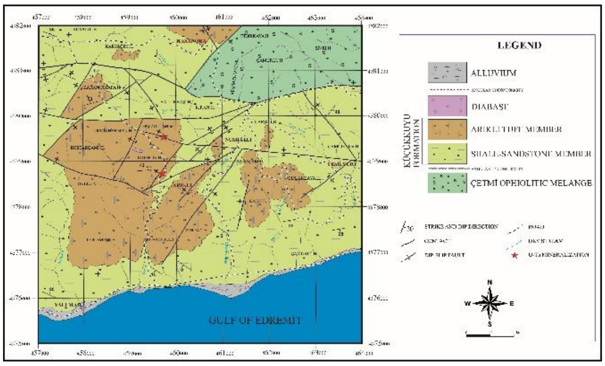

Figure 2. Geological map of the study area

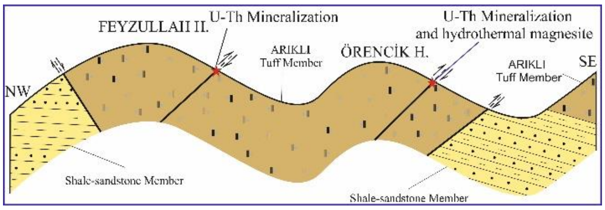

Figure 3. Geological cross-section of the study area

Figure 4. General view of hydrothermal magnesite in northwest of Arıklı

3. Results

3.1. Ore geochemistry

Öztürk et al. (2021) collected 48 samples in the field. These collected samples were analyzed by XRF and ICP-MS method in Istanbul Technical University Geochemistry Research Laboratory (ITU-JAL). Corresponding to the results of the analysis, U and Th anomalies are observed in the dip-slip fault zones. In these fault zones, U is between 64-1640 ppm and Th is between 302-11813 ppm respectively. As a result of these data, U and Th mineralizations in the region are related to fault zones observing in Arıklı ignimbrites.

3.2. Remote sensing

DEM data enables numerous geomorphic and morphometric analyses in geological studies, as well as timely and cost-effective production of consistent results (Grohmann et al., 2007).

Topographical approaches were obtained with the DEM image of Arıklı and its vicinity. The downloaded DEM images were evaluated in the QGIS environment, an open-source Geographical Information System.

The images of the region generally obtained by remote sensing were evaluated in the QGIS environment. DEM data was classified and coloured in the QGIS environment with a single band pseudocolour application. Then 3D map of the region was created to obtain a more understandable image (Figure 5).

3.3. GIS application

Sample points of major oxide and trace elements are yielded Figure 6. Heat maps were established corresponding to spatially major oxide and trace element values appropriately. CaO and U-Th enrichments are observed strongly in similar areas, and a direct ore-fault-and lithology relationship is observed. There are U-Th enrichments exclusively in CaO rich and faulted areas. This relationship still shows pretty useful in the GIS environment.

In order to obtain more detailed data, Sr, Na_2O and SO_3 values were also analyzed. While Sr gives anomalies in limited areas (Fig 7a), it reaches high values in Na_2O (Fig 7b) and SO3 (Fig 7c) fault zones.

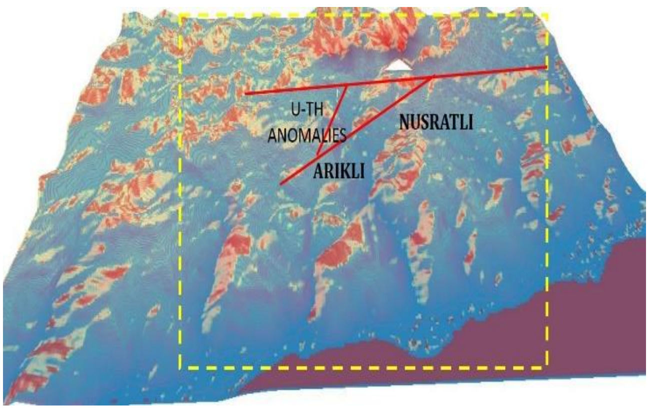

Figure 5. 3D-map of the study area and surroundings

4. Discussion and Conclusion

Mapping minerals, elements or oxides based on multi-source geoscience data (geology, geochemistry, and remote sensing) and computer technology is an effective technique that merges information and data-driven production (Bonham-Carter, 1994; Zhao 2002; Cheng et al., 2007; Asadi et al., 2016; Ford et al., 2016; Wang et al., 2016). For this reason, the data of the study conducted by Öztürk et al. (2021) in the Arıklı region were re-evaluated in the QGIS environment. Field data, remote sensing and GIS data were correlated. In the evaluations prepared, field and spatial data are consistent with each other and supported by thematic maps.

More detailed information can be obtained by making oxygen or carbon isotopes from barite and magnesite in the ore zone in the Arıklı region, which has the potential to be an important area. By making similar isotopes from host rocks, isotopic data from different locations can be evaluated in GIS environment. Thus, the original researches will be able to be interpreted in more detail. In addition, fault systems can be compared in the GIS environment by aging the fault zones. In summary, every detail information obtained in the field can be successfully evaluated in the GIS environment with spatial data.

In this study, DEM data, which is also used in many geological problems, and geological information were merged to perform spatial analysis in an area where geochemical prospecting had previously occurred. When the field, laboratory, and satellite images are analyzed together, it is clear that the U-Th enrichment in the field is enriched in the fault zones and has a characteristic distribution that is appropriate for its formation system. This method is particularly useful in geochemical prospecting and mineral exploration studies. Because fieldwork and subsequent studies can be more clearly analyzed in a GIS environment.

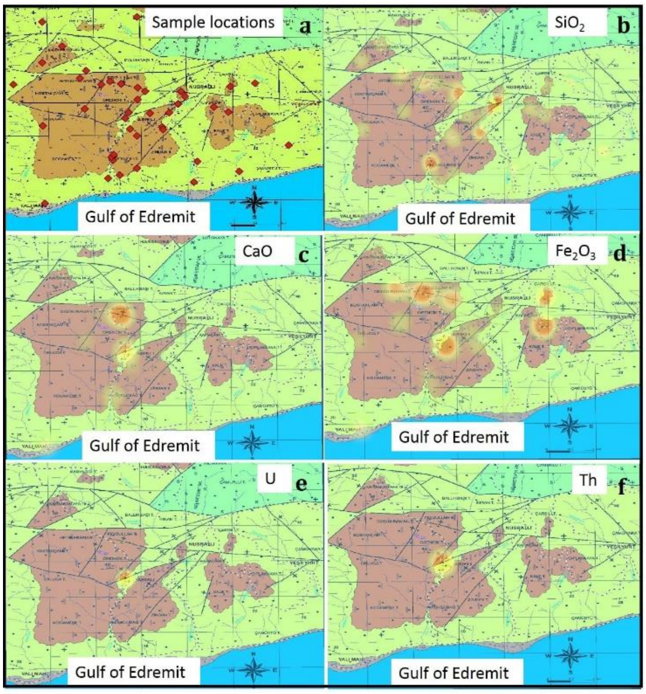

Figure 6. GIS applications of the study area

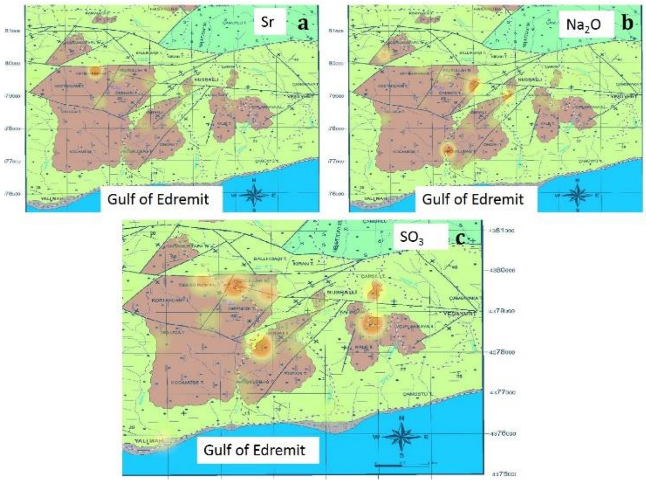

Figure 7. GIS applications of the study area

Author Contributions

The contributions of the authors of this article is equal.

Statement of Conflicts of Interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

Research and publication ethics were complied with in the study.

The study is an expanded version of the study presented at the 4th Intercontinental Geoinformation Days (IGD), "Evaluation of U-Th enrichments in QGIS platform Example of Arıklı (Çanakkale, Turkey) district".

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Spatio-temporal analysis and trend prediction of land cover changes using markov chain model in Islamabad, Pakistan

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ABSTRACT

Rapid urbanization is changing the landscapes of urban areas and affecting the quality of life and environment. One of the most dynamic components of urban environment is land cover, which have been changing remarkably since after the industrial revolution at various scales and population growth. Frequent monitoring and land cover change detection provides a better understanding of functions and health of urban environment. Remote sensing and Geographical Information System (GIS) are advanced techniques to visualize these dynamics in the digital map. Therefore, this study aims to analyze the existing spatial extent of different land cover classes and predict the future trend in Islamabad; Capital city of Pakistan, by applying Cellular Automata (CA)-Markov model. For this aim, three consecutive-year Landsat imagery (i.e. 200, 2010, 2020) were classified using the Maximum Likelihood Classifier. From the classification, three LULC maps with four class (Barren Land, Vegetation, Water Body, built up were generated, and then change-detection analysis was executed. Using remote sensing data, we simulated Spatio-temporal dynamics of land use and land cover changes Simulation results reveal that the landscape of Islamabad city has changed considerably during the study period and the change trend is predicted to continue into 2030. The study observed a significant increase in built-up area from 2000 (9.53%) to 2020 (28.2%), followed by an increase in the cover of bare ground. On the contrary, vegetation cover declined drastically 2000 (28.61%) to 2020 (25.08%). Rapid population growth triggered by rural urban migration coupled with hasty socio-economic development post democracy are the main drivers of these changes. Under the business as usual scenario, prediction analysis for the year 2025 and 2030 show that built up area will consume almost all of the city area (47.04%) to (57.25%) with vegetation significantly reduced to patches making up only about (17.23%) to (14.4%) of the city. These findings demand for an urgent and effective planning strategies to protect the existing vegetation covers, agricultural land, and limit the growth of built-up land. The study has also potential in planning sustainable cities.

1. Introduction

Globally, the structure and function of ecosystem have been altered by different human land uses (Mishra et al., 2022). In terms of geography and economics, the main human uses of land are crop cultivation, building construction, infrastructure development, protecting natural areas, and logging (Shah et al., 2022). The spatial pattern of changes in land cover provides an insight into the factors leading to these changes (Shafiq & Mahmood, 2022). Land cover changes are mostly caused by urban expansion, particularly in emerging nations (Mohammad 2021). The primary driver of urban growth and the conversion of green space and undeveloped land into built-up land is urban population growth (Zhang et al., 2022). The The increased global urbanization is one of the biggest concerns facing the entire planet because around 55% of the world's population is urban and by 2050, this percentage is anticipated to increase to 68% (UN, 2018). Additionally, this will result in growth in the urban population, urban communities and frequency of disasters (Marando et al., 2022). There are several issues plaguing major cities as a result of the rapid urbanization of developing nations, including urban flooding, air and noise pollution, socioeconomic inequality, and political instability (Cheng et al., 2022). Rapid urban growth also jeopardises the local government's ability to give residents access to facilities like clean water, infrastructure, housing, and sewage systems (Magidi & Ahmed, 2019).

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The development of human settlements has also altered the ecosystem's composition and functionality. Additionally, the natural cover of the ground has been affected (Stalker, 2000). Cities put a pressure on resources and surrounding lands because of their fast growth (Leao et al., 2004). The use of Geographic Information System (GIS) and Remote Sensing (RS) in modeling land use land cover (LULC) is a suitable approach to understand the future pattern. Different Land cover are freely available particularly probabilistic models and multi regression approaches which includes the Cellular Automata (CA) Markov Synergy Models use to find out that how different scenarios can affect landscape changes, forecast changes and their consequences (Karimi et al., 2018). Land use change models, on the other hand, analyze the dynamics of land use in order to understand the outcomes and causes of land use changes. These models help with land use planning and policy making (Harish et al., 2017). High-quality understanding of the urban growth factors, past trends and previous studies is vital. As a typical model, the CA Automata Markov chain can determine the ratio of conversion of diverse land uses and anticipate their future development. The study of LULC changes is important in providing critical input for decision makers to manage future ecological and environmental changes (Kennedy et al. 2009).

In Pakistan urbanization tendencies have experienced rapid expansion over the past few decades, with a current rate of 3% that is the highest in South Asia. Compared to 36.4% in the 2017 census, the country's urbanization is predicted to reach 50% by 2025 (PBS, 2017).

The rapid urbanization with significant challenges particularly pressure on land, services and infrastructure (Zaman, 2012). Islamabad as Pakistan's capital attracts people from all over the country in search of job, education and better way of life. As a result, the city's population has increased dramatically in recent years and caused urban sprawl (Hassan et al., 2016). This urban sprawl has led to many urban issues like traffic congestions, land demand, water supply and sanitation, deforestation, loss of barren lands, increased street crimes etc. High levels of urbanization have been caused by the country's industrial boom, increasing economic activity, and inflow of foreign remittances from Pakistanis living abroad. Therefore, urban sustainability study is required for better urban planning, policy development for eradicating poverty, infrastructure planning, disaster management & prevention, environmental sustainability. The purpose of this study is to assess the spatio-temporal land use/land cover change detection and prediction in Islamabad, Pakistan by using CA-Markov Chain Modal.

2. Materials and Methods

2.1. The study area

Islamabad is the capital of the Islamic Republic of Pakistan, which was developed in the early 1960s when it was decided to shift the capital of the country from Karachi to Islamabad, by Field Marshal Muhammad Ayub Khan; president at that time. Islamabad is regarded as one the example of modern planning (Sohail et al., 2019). According to the 2017 census, its population was about 1.7million and it has spread over an area of 906km2 with population density is 1876 persons/km2. The topography of the study areas is Potohar Plateau ranges, with elevation range from 457 to 610 m above mean sea level (Shah et al., 2022). The Specified Green Area covers an additional 3626 km2, with the Margalla Hills to the north and northeast. According to the United Nations World Urbanization Prospects (2018), the population was 1.095million in 2018 and projected population 1.67million by 2030. The Capital Territory comprises of urban and rural areas. The rural consists of 23 union councils (UC: smallest electoral unit), 133 villages while urban has 27 UCs (Figure 1). The city is characterized by a grid pattern which divides the city into eight basic zones viz., administrative, diplomatic enclave, residential areas, educational sectors, industrial sectors, commercial areas, rural and green areas, along with protected green belts (Ali et al., 2014).

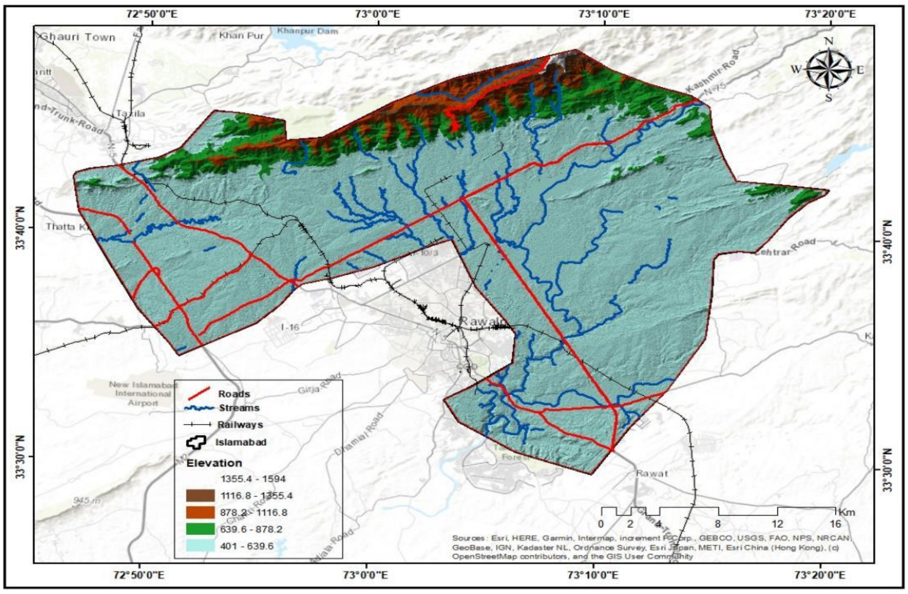

Figure 1. Location of the study area

2.2. Research methodology

The study is based on secondary data. Landsat satellite images for the years 2000, 2010 and 2020, and ASTER Global Digital elevation model (GDEM) bothhaving 30m spatial resolution were downloaded from United States Geological Survey (USGS) open source geo-database (Figure 2).

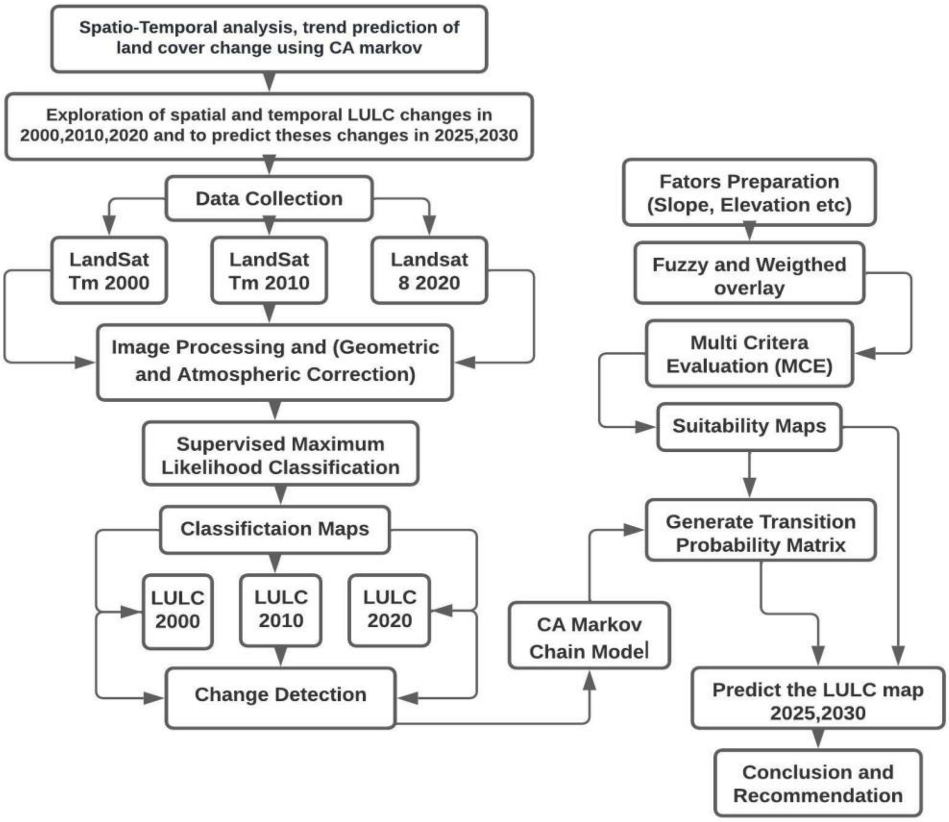

Figure 2. Research process

2.3. Data acquisition and pre processing

Pre-processing is a crucial step in determining a direct link between the collected data and biophysical phenomena. The remotely sensed data is subject to brightness, geometric, and atmospheric aberrations. When optical sensor data is processed then one of the main functions of pre-processing is removal of aberrations. Atmospheric correction involves removal of haze primarily originating from water vapor, fog, dust, smoke, or other particles in the atmosphere. The satellite images were then imported into ArcGIS environment to classify image

2.4. Supervised image classification

Satellite images were classified using the Maximum Likelihood Classifier (MLC) technique. The MLC classifier was employed since it is a reliable and widely used algorithm for LULC mapping. The probability density distribution functions for each particular land use class are prepared using a parametric statistical technique in the MLC procedure. MLC is considered to be more accurate than other methods because it calculates the total amount of variance and the correlation of the spectral values of different bands according to the specimen and uses this property for the association of pixels classified into one of the groups based on the pixels' most similarity. LULC maps were identified on the basis of four classes in Table 1.

Table 1. LULC Classes

No	LULC Class	Description
1	Built-Up Area	Residential, commercial, industrial, transportation, roads
2	Green Cover	Mixed forest lands, Crop fields and fallow lands
3	Barren Land	Land use exposed to soil
4	Water Body	River, open water, lakes, ponds, and reservoirs

2.5. Land cover trend prediction

For simulating and forecasting LULC, CA-Markov is a robust model that has outperformed previous techniques. As a result, the CA-Markov model was chosen for simulating and forecasting. This approach entailed Markovian chain analysis in order to construct transition area matrices and producing LULC transitional area maps. Each LULC class's transition appropriateness maps were created utilizing four input parameters namely elevation, slope, distance from streams and distance from roads. GDEM with 30m spatial resolution was used to extract elevation, slope and drainage input spatial layers. The distances from roads and streams are significant. The Euclidean Distance Technique was used to compute the distances from roadways and drainage.

The road network (2000-2020) was geo-visualized using heads-up digitizing from time-series Landsat imagery (Figure 10).

2.6. Markov chain analysis

The possibility of the proper positions (pixels) of the four factors having an effect on the LULC classes was evaluated using a fuzzy set function. Visual analysis was used to analyze the effect of each element by overlaying the urban cover and each factor separately, and once satisfied, the values of each factor were changed based on the present condition of urban expansion. The MCE technique was used on the factors that were chosen. MCE combines a number of criteria (factors) to determine the most appropriate locations (pixels) for each land cover type. The four parameters (elevation, slope, distance from roads, and distance from streams) were examined to construct the suitability map for the urban class. In order to anticipate future change, the Markov model simulated changes in LULC from one time to the next. The Markov chain model analyses and summarizes changes in land use over time by transitioning areas from one status to another using a set of probabilities. Furthermore, the probabilities transition areas may be utilized to anticipate and uncover possible future scenarios of land use change and urban growth patterns. The prediction of future land use changes can be calculated based on conditional probability formula by using Eq.1

$$S(t+1) = P_{ij} * S(t) \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (1)$$

Where $S(t)$ is the state of the system at time $t, S(t+1)$ is the state of the system at time$(t+1)$; P_{ij} is the matrix of transition probability in a state Low transition will have a probability near (0) and high transition probability near. The 2000 LULC image of the Islamabad city was used as the base (t1) image while 2020 LULC map as the later (t2) image in this model to obtain the transition matrix between 2000 and 2020. In this study, ArcGIS was used to generate transitional area matrices by multiplying each column in the transition probability matrix by the number of pixels of corresponding class in the later image.

2.7. Accuracy Assessment

Classification accuracy assessment is critical to obtain reliable results and its impacts. Hence, a total of 929 systematic points is generated at a fixed distance of 1 × 1 km throughout the study area, as given in Figure 1. Among them, approximately 10 10 points were checked in the image Vegetation, build-up, water bodies, barren land etc. using the global positioning system (Stonex S-7), while the remote locations are validated from high-resolution satellite images. User accuracy and producer accuracy are calculated for each land-cover class; the overall accuracy of classification exceeds (i.e., those for 2000, 2010 are 93.19% and 94.87% and 2020 are 92.17% with Kappa coefficients of 0.89 and 0.91 and 0.87 respectively), which meet the requirement of the study (Table 2).

Table 2. Accuracy assessment

LULC Class	2000%	2010%	2020%
Barren Land	87.3	88.5	88.9
Green Cover	89.3	90.2	88.3
Built-Up Area	92.3	93.1	90.1
Water Body	95.8	97.1	98.2
Overall accuracy (%)	93.19	94.87	92.17
Kappa coefficient	0.89	0.91	0.87

3. Results and Discussion

3.1. Land Cover (2000)

A classified image of Islamabad taken in the year 2000 figure 3. It depicts that Barrens cover a large region. Barren Land covers 519.8 land area, which is the most among the other groups. Vegetation covers 241.9 sq. km, built-up area is 80.5 sq. km, and water bodies cover only 2.94 sq. km of the land area figure 6.

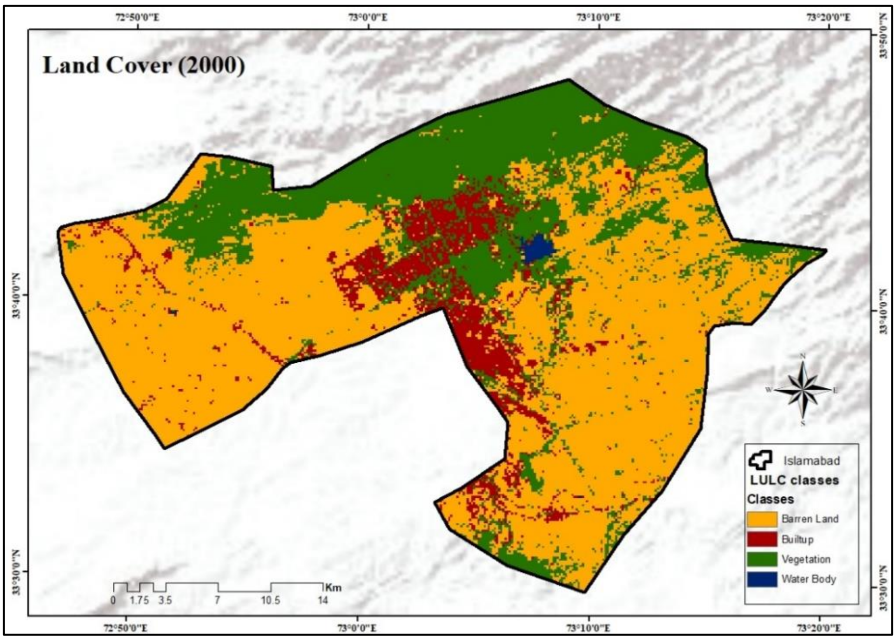

Figure 3. Land Cover 2000

3.2. Land Cover (2010)

The categorized map of Islamabad for the year 2010 is shown in Figure 4. The graph depicts a massive increase in built-up area. The year 2010 can be remembered as a year in which the urban city's growth caught up with the rest of the world. According to the image classification results, the area covered by barren land was 478.1 sq. km, the largest among the other classes, such as green cover, which covered about 202.5 sq. km of area. The built-up area was 19% covered an area 162.29 sq. km, while the water body covered the bare requirement of 0.58% and area of about 2.38 sq. km. The data in the pie chart Figure 6 provides a visual representation of the area of LULC in each class in 2010.

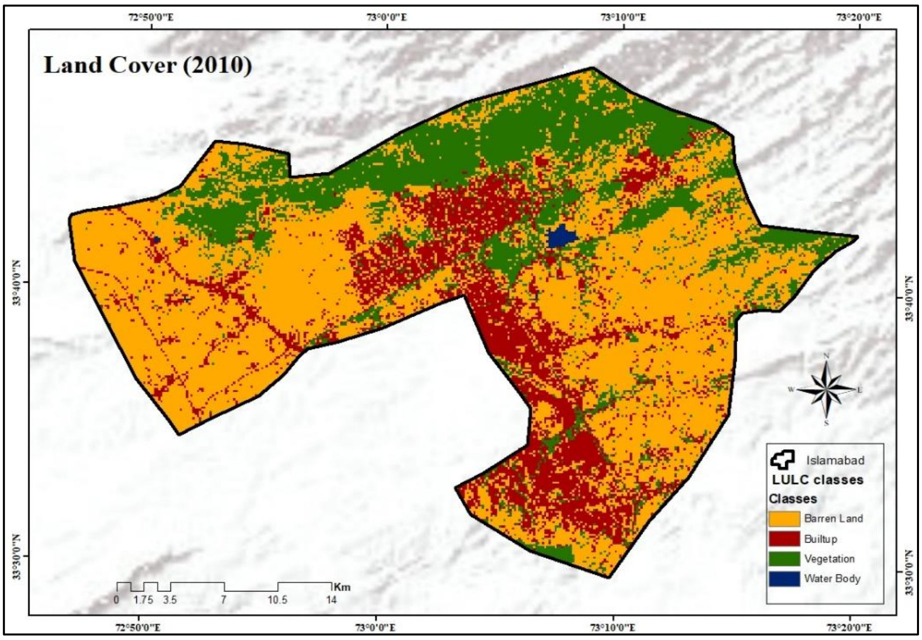

Figure 4. Land Cover 2010

3.3. Land Cover (2020)

The result depicts a classified map of Islamabad in the year 2020 figure 5, clearly demonstrating the largest change in the built-up area. The results of image classification show that the area covered by built up is 238.4 sq. km, which is the greatest among the other classes, such as green covered at 212.02 sq. km, barren land area 389.1 sq. km, and water body covered 5.82 sq. km of area figure 5.

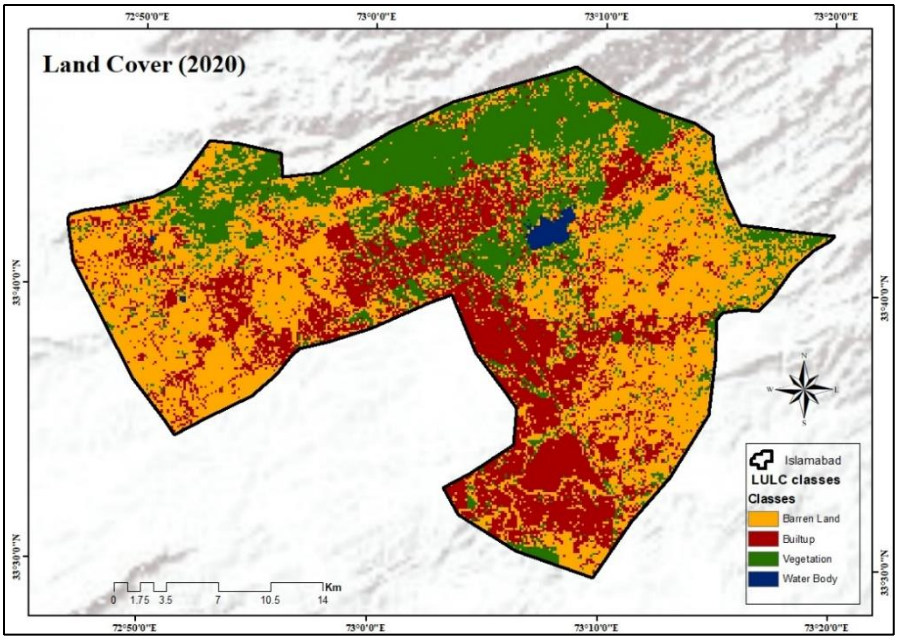

Figure 5. Land Cover 2020

Comparative Analysis (Change Detection)

The LC in Islamabad was compared using a change detection map, which consisted of categorized photos of the city and was used to extract information about dynamic changes in the city from 2000 to 2010 and from 2010 to 2020, as shown in Figure 6. A comparison of three years (2000, 2010 and 2020) (figure 6) revealed dramatic changes in built-up area, which expanded due to newly constructed housing.

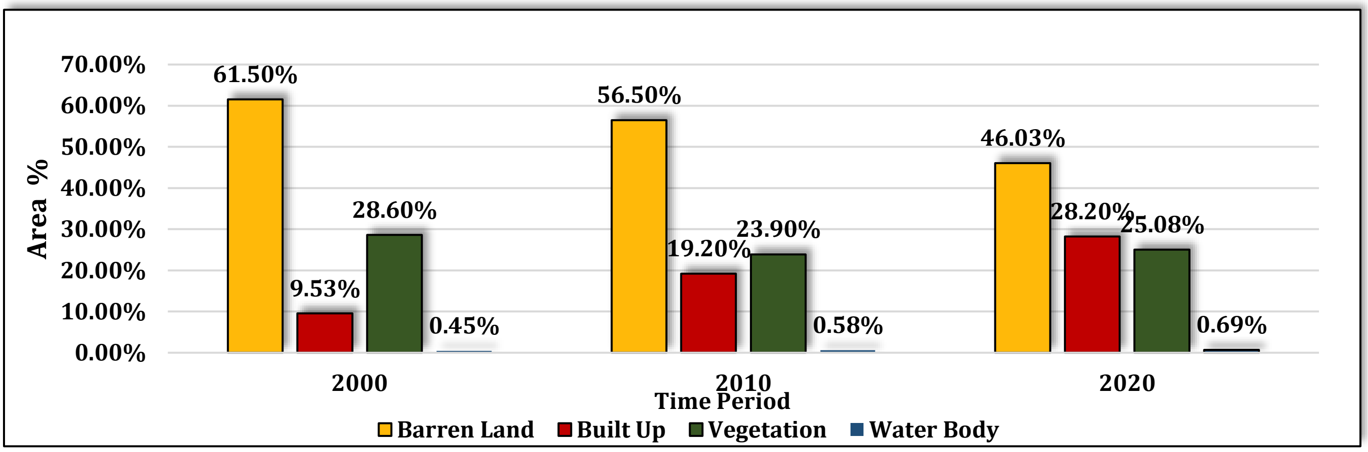

Figure 6. LULC Change detection (2000-2020)

Due to enhanced chances and facilities, as well as increased population density, infrastructure is being created in the center and western parts of Islamabad. Barren land has declined by around 36% in 10 years, primarily from 2010 to 2020, with the most significant shift being the transition of most barren ground into built-up regions, which has continued to increase. Vegetation cover was reduced in this study, it has decreased by 25% in the last 10 years, from 2000 to 2020, according to this study (Table 3).

Table 3. Analysis of LULC change

No	Classes	Year 2000		Year 2010		Year 2020	
		Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)
1	Barren Land	519.8	61.5%	478.11	56.5%	389.1	46.03%
2	Green Cover	80.59	9.53%	162.29	19.2%	238.4	28.2%
3	Built-Up Area	241.9	28.6%	202.55	23.9%	212.02	25.08%
4	Water Body	2.94	0.45%	2.38	0.58%	5.82	0.69%

3.4. Transition Suitability Maps (Factor Maps)

Each LC class's transition appropriateness maps were created utilizing four variables or parameters. Elevation, slope, distance from streams, distance from roadways was all considered Below Figure 7 (a, b, c, d) showing the factor maps.

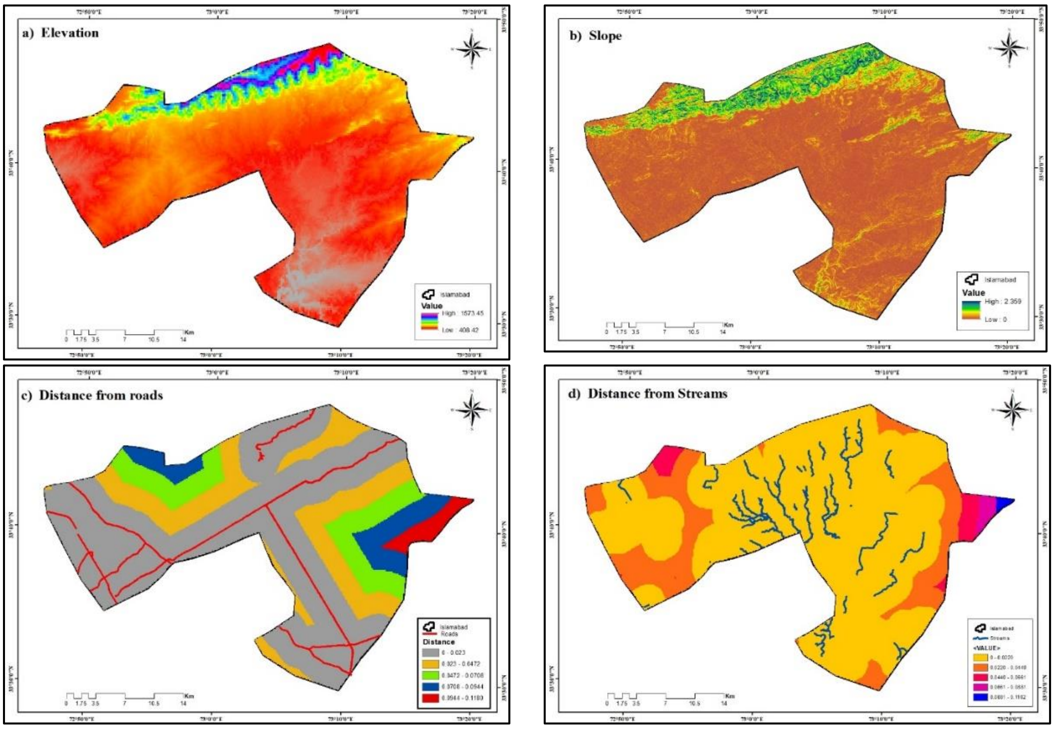

Figure 7. Suitability Maps

3.5. Prediction of land cover change (2025 and 2030)

Results of LC prediction using CA-Markov analysis are shown in Table 4 and comparison between the base years (2000, 2010, and 2020) and predicted years has been shown in Figure 8.

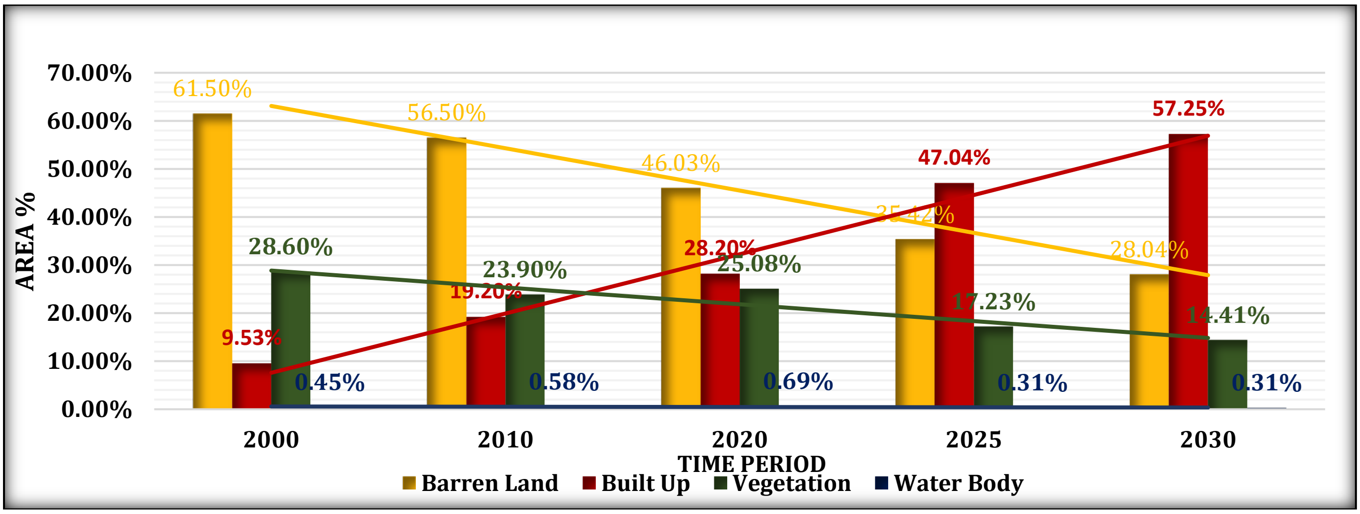

Figure 8. Predicted analysis comparisons

Figure 9 predicted figure for 2025 and 2030 is showing further decrease in the vegetation cover (17.23%) and (14.41%) water body (0.31%) land use types which compared to 2000, 2010, 2020 figures represent a loss of vegetation respectively (Table 4). These losses are gained by built-up area 2025 of (47.04%) and of 2030 (57.25%) bare ground (35.42%) and (28.04%) taking their total coverage to (298.48) and (236.59) area sq km respectively.

Table 4. Land Cover Prediction

No	Classes	Year 2025		Year 2030	
		Area (km^2)	Area (%)	Area (km^2)	Area (%)
1	Barren Land	298.48	35.42%	236.59	28.04%
2	Green Cover	396.38	47.04%	483.06	57.25%
3	Built-Up Area	145.22	17.23%	121.55	14.41%
4	Water Body	2.61	0.31%	2.6	0.31%

Figure 9 shows the predicted spatial destruction of LC in 2025 and 2030. Overall, Vegetation cover is fragmented with smaller patches remaining mainly in the north of the city along the Margalla hills. Small and narrow patches of forests are also seen scattered across the city figure 9 also reconfirm the findings that most of what is covered by forest in 2000, 2010, 2020 will transition into built-up and bare ground. The presence of bare ground indicates soil excavations probably. These findings are reflective of the current urbanization trend and government policy. If Islamabad city is to avoid irreversible problems that are plaguing many global cities, the city must shift form present business model to urgently adopt ecosystem based approach to urban development.

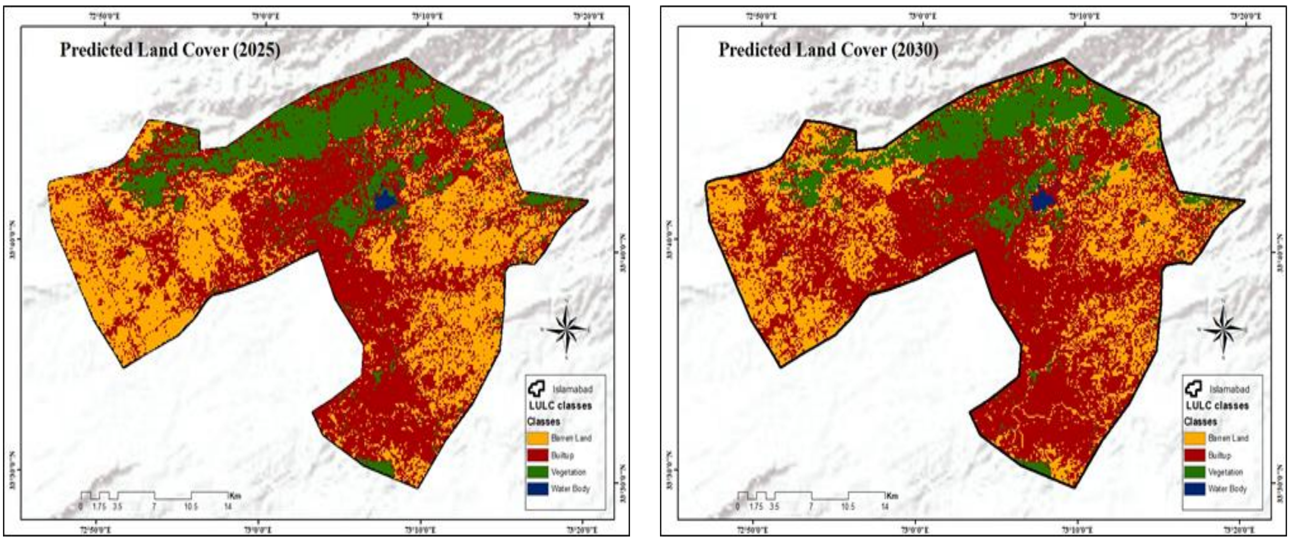

Figure 9. Predicted Land Cover 2025 and 2030

4. Discussion

The increase in population growth further augment the rate LULC changes especially in the metropolitan cities of the world that are threatening the sustainability of these cities. Islamabad is planned as a linear metropolis with straight sections and crossing roadways, according to the master plan. Each residential sector is characterized by an alphabet letter and a number and spans an area of around 906.50 km. It indicates that the city is designed for the present while also considering the future development.

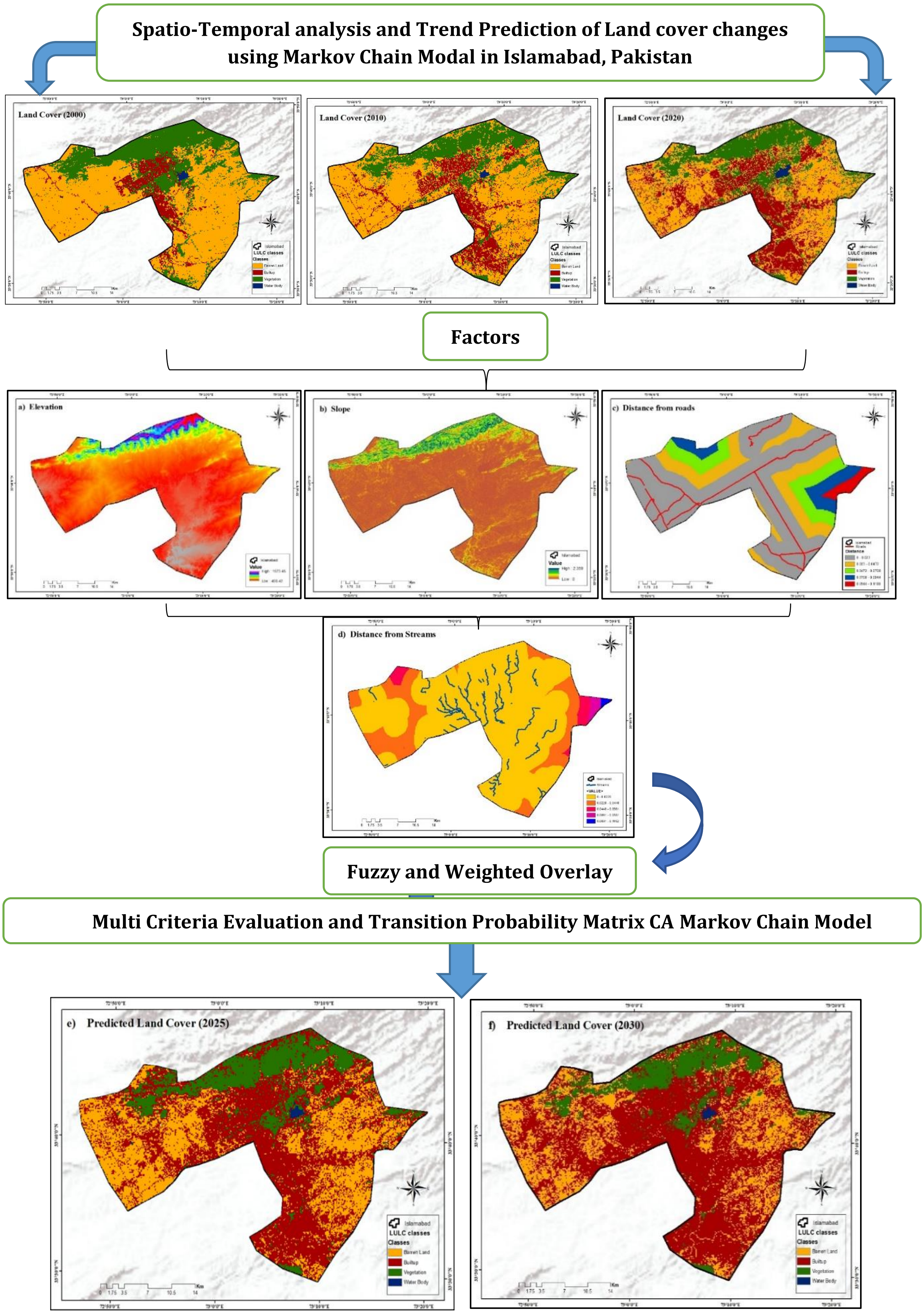

Figure 10. The method used in trend prediction of land cover changes

However, above results of LU analysis, the city landscape has altered with LULC changes, affecting the city thermal climate from 2000 to 2020. The study emphasizes on the Land cover change and its future behavior by showing the increase in built up areas by 9.53% to 51.8% annually, the expansion of built up mainly occurred in central part of the city, whereas the vegetation decreased by 28.6% to 25.08% from the years 2000-2020. Based on results derived from the LULC change map, the vegetation cover is replaced by grass land, Such LULC changes bring differences in surface energy impervious surfaces has increased the surface temperature due to the transformation of high to low evaporative surfaces.

Comparing the above mentioned graphical results it is evidenced that the agricultural land is converting into barren land and residential land in the city. This barren land is transforming into commercial or industrial land. The technology is being used. Remote Sensing and Geographic Information System are playing their vital roles in the detection and assessment of the land use land cover changes. In the previous studies Chim (2021) applied the Multi-layer perceptron neural Network-Markov chain (MLPNN-MC) to assess the land use and climate change on hydrology of the upper Siem Reap River. Kundu et al. (2017) assessed the LU change impact on sub-watersheds prioritization by analytical hierarchy process (AHP). Logistic regression model (LRM) has been applied by Muhammad Salem in 2020 to assess the Land use/land cover change detection and urban sprawl in the peri-urban area of greater Cairo since the Egyptian revolution of 2011. This study has predicted Land cover changes in 2025 and 2030 showing the shrink in vegetation 17.23% to 14.41% and water areas by 0.31% which is devastating for the environmental behavior of the city. The built up showed is increasing about 47.04% to 57.25%. It is observed that urban growth is very fast and eating up not only barren lands but also very fertile agricultural lands. In addition these land cover maps and predicted results which are produced by remote sensing techniques and CA Markov model of class definition, meet the growing need of legend standardization.

The output of this study is invaluable for Government, environmental scientists, conservation biologists, nature-related NGOs, decision-makers, and urban planners to protect the existing vegetation covers, agricultural land, and limit the growth of built-up land. The prediction has potential to assist the local management authorities and planners to control the urban expansion in built up environment because the question arises, Are the residents and authorities prepared to face the consequences of urban growth? The predicted space of urban growth is precisely engulfing the natural vegetation that is posing risk on natural environment. These future analysis studies can help to use more detailed socio-environmental variables to improve the understanding of the causes, locations, and trends of land cover changes in such regions. Understanding how the changes in the landscape and climate change might influence the distribution of the important species will help guide conservation planning in the area. The study can serve as guidelines for other studies attempt to project LC change in arid lands areas experiencing similar land use changes. Urbanization in Pakistan is increasing at 3% annually, the highest in South Asia. 50% of the population is expected to urbanize by 2025. The capital city of Pakistan, Islamabad has experienced phenomenal increase in the urban population and extent in the last four decades (Shah et al., 2022).

5. Conclusion

Existing land cover trend and predicting future trend is very important for sustainable land use planning and management. In the last two decades significant change in LULC has been occurred. The built-up land is continuously increasing by engulfing the green cover. The results shown of the 2025 and 2030 estimate vegetation cove will further decreased by 17.23% in 2025 and 14.4% in 2030. The loss of forest cover will weaken essential ecological functions and make the city more vulnerable to gulley erosion, drying water supplies, increase in temperature, exacerbated air pollution, and loss of biodiversity.

It is highly recommended to bane construction on agriculture land and forest cover. Second vertical development must be encouraged and horizontal expansion should be discouraged.

Author Contributions

The contributions of the Authors of this article is equal.

Statement of Conflicts of Interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

Research and publication ethics were complied with in the study.

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Spatial assessment of forest cover change in Azad Kashmir, Pakistan

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ABSTRACT

In this study spatial assessment of forest cover in Azad Kashmir was carried out. The study is based on secondary data. Satellite imageries of the past 20 years having temporal extent of five years were utilized for assessment of changes in vegetation covers. Supervised image classification and Normalized Difference Vegetation Index (NDVI) techniques were used to achieve objective of the study. The results indicated that forest cover is declining leading to different environmental problems. Increase in population acted as booster for the factors such as deforestation, conversion of forest land into agriculture and built-up land. These anthropogenic activities put pressure on the forest of the study region. After 2005 disastrous earthquake, rapid development of built-up environment was the leading factor behind clearing of forest. It was found from the analysis that forest cover has significantly declined in the last two decades and affected ecosystem services. Location specific management strategies are highly recommended to reduce the rapid decline in forest cover. Strategy must also consider the population growth and traditional forest conservation strategies. Alongside, keeping in view the agricultural activities and infrastructural development in the dense forest cover areas are also recommended.

1. Introduction

Globally, forest cover has been undergoing extensive and unprecedented changes as a result of various anthropogenic activities (Maus et al., 2020; Mishra et al., 2022). Forests offer numerous ecological, economic and societal benefits like conservation of biological and genetic diversity, contributions to nutrient cycling, soil erosion risk reduction, air filtration, climate regulation, and provision of food, fiber, and fuel (Mohamed, 2021a, b). However, deforestation: centuries back human activity leading to depletion of forests and significant environmental, social and economic consequences. It is estimated that from 1990 to 2020, global forest cover decreased by 3.2%. This significant loss of forest cover, estimated at alarming rate of 10 million hectares per annum. Therefore, international conventions have been developed to monitor forests cover on spatial and temporal scales and appraise sustainable forest management strategies (Mohamed et al., 2020). Gou et al. (2022) also suggested that these strategies needs to take into account the particularities of regional socio-ecological contexts at multiple spatial and temporal scales to identify when, where, how and why deforestation is taking place. Forests and forest cover is very significant for the sustainable environment and for survival of life on earth. Increase in population is leading to increase in demands of food and land for living units. Similarly, construction of roads and infrastructure is also responsible for declining of forest cover (Ahmad et al., 2022).

In Pakistan forest cover decreases very rapidly because of anthropogenic activities. Pakistan is losing forest cover at very alarming rate due to rapid population growth, urban expansion and agriculture development. According to UN only 2.2 % of total area of Pakistan is covered with forest and according to state institutes 4.8 % means 4.2 million hectares of land is covered with forests and it is very low area which remains under forest cover (Ullah et al., 2016). The forest size of Pakistan is shrinking continuously. The forest cover in Khyber Pakhtunkhwa is 17.3 % of total forest area of the country. Sindh province has second largest forest area in the country with 923,000 hectares and Punjab province has third largest forest area with 687,000 hectares (Hamilton & Casey, 2016). Due to lack of facilities, most of the people particularly in mountainous areas are highly dependent on the forest and forest products. The universal standard of forest cover is 25% of the total area but Pakistan only has 4 % which is very little (Akbar, 2017. Decreasing forest cover is accelerating glacier-melting leading to floods (Sebald et al., 2019). Forest cover is very significant natural resource which should be protected and conserve properly. There are several techniques that are used to study and analyses forest cover changes around the globe.

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In Azad Kashmir, deforestation is rapid and about 46% of land area is covered with forest. In the past two decades about 400 hectares of forest cover has been lost. The decrease in forest cover may reduce amount of precipitation and change the spatial pattern of rainfall. This may lead to desertification and water shortage (Amjad & Arshad, 2014). Forest act as shield and protect us from different hazards like hinder soil erosion and land sliding (Ahmad et al., 2012).

Therefore, aim of this study is to spatially assess forest cover change and geo-visualize forest cover at various temporal scales in Azad Kashmir. As this is preliminary research of whole area of Azad Kashmir. So, it will be beneficial to identify problems and find solution to the problem. This study will help in making policies about countering the issue of deforestation and decrease in forest cover. And, will be effective by spreading awareness to the people through this research about the significance of forest cover and motivate them for plantation drives and protection of forests.

Geographically, Azad Kashmir shares borders with Gilgit Baltistan on the north, in south and west it shares its borders with Punjab and Khyber Pakhtunkhwa provinces and on eastern side Azad Kashmir is separated from the Indian illegally occupied Kashmir by line of control (Figure 1). The border between Azad Kashmir and occupied Kashmir is known as Line of Control (LOC). Azad Kashmir's total area is 13,297 Kilometers square. The Total population of Azad Kashmir according to 2017 census is 4.045 million and has population density of 300 per km square. The Capital of the state is Muzzafrabad. The temperature in Azad Kashmir varies from south to north. In south due to lower elevation temperature is hot in summer but in central and north mild. Winter is dominated by snowfall in months of December and January. The region gets rainfall in both summer and winter season. The main rivers are Jhelum, Neelum and Poonch. The mountains are covered with forests. Most of the area is covered with thick forests.

2. Study Area

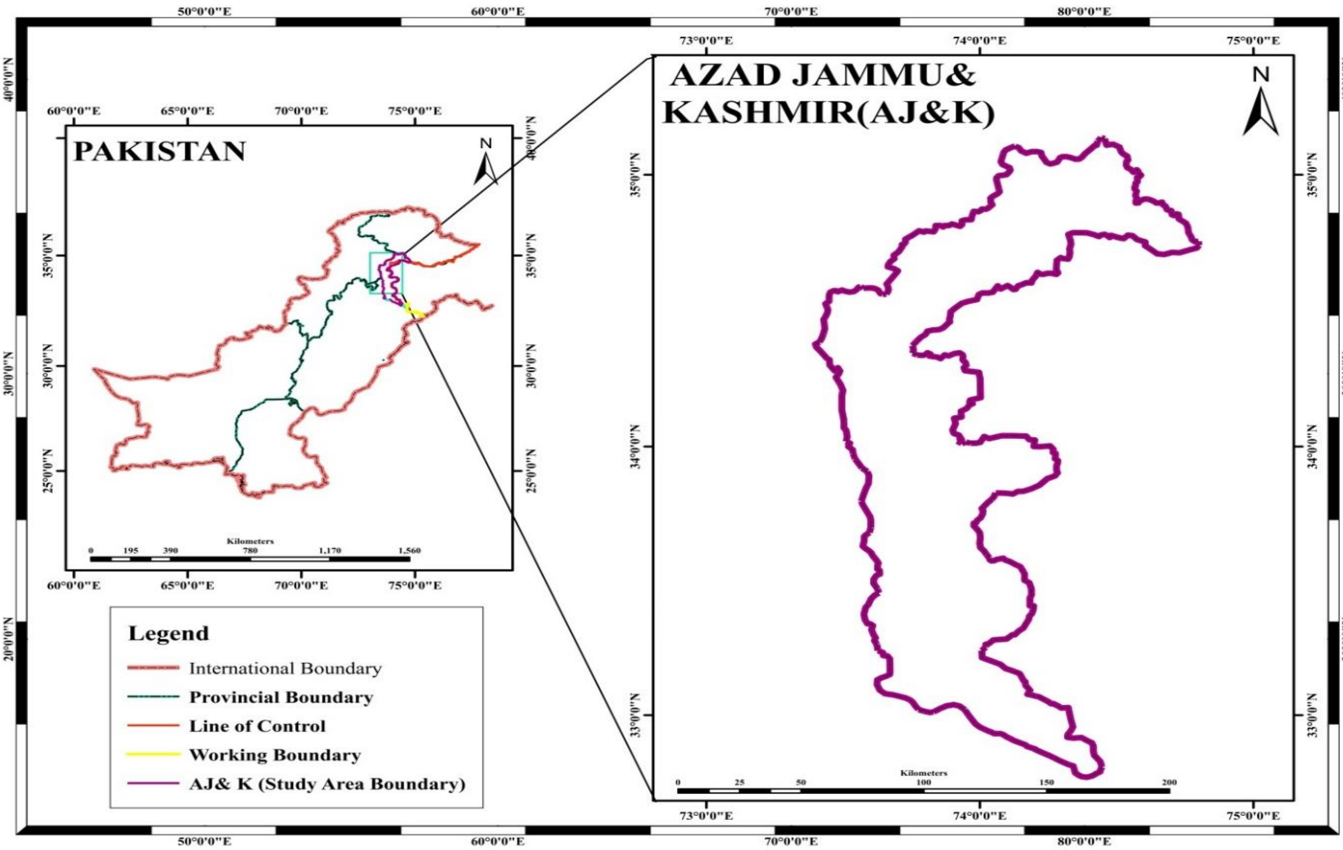

Figure 1. Study area map

3. Research Methodology

The detail and stepwise methodology of the study is given in the following section (Figure 2).

3.1. Data collection

MODIS satellite images for the year 2000, 2005, 2010, 2015 and 2020 were downloaded from United States Geological Survey (USGS) open source geo-database. Survey of Pakistan map was used as base map.

3.2. Data processing and analysis

Pakistan's political map was digitized in GIS environment and study area boundary was extracted by using extract by mask operation. Satellite images with different bands were stacked into one raster file by using ArcGIS 10.5 software.

3.3. Image classification

Supervised classification is used is transform image into different land cover classes including Built-up land, water body, barren land, forest cover and snow cover. The images were classified by using spectral signature obtained from training sample.

3.4. Normalized difference vegetation index (NDVI)

Normalized Difference Vegetation Index (NDVI) is commonly and mostly used for the analysis of vegetation cover. The NDVI is obtained by using Equality.1.

$$NDVI = (NIR - RED)/(NIR + RED) \quad (1)$$

In ArcGIS 10.5, bands of NIR and RED were added. Then, Raster Calculator was used and the query $(Band2 - Band1)/(Band2 + Band1)$ were applied. The NDVI was applied and as resultant classified image with maximum and minimum value is obtained.

3.5. Accuracy assessment

The classified images were vectorized and then converted into Keyhole Mark-up Language (KML). The KML layer was open in Google Earth Pro to check accuracy of different land cover classes. All classes were correct.

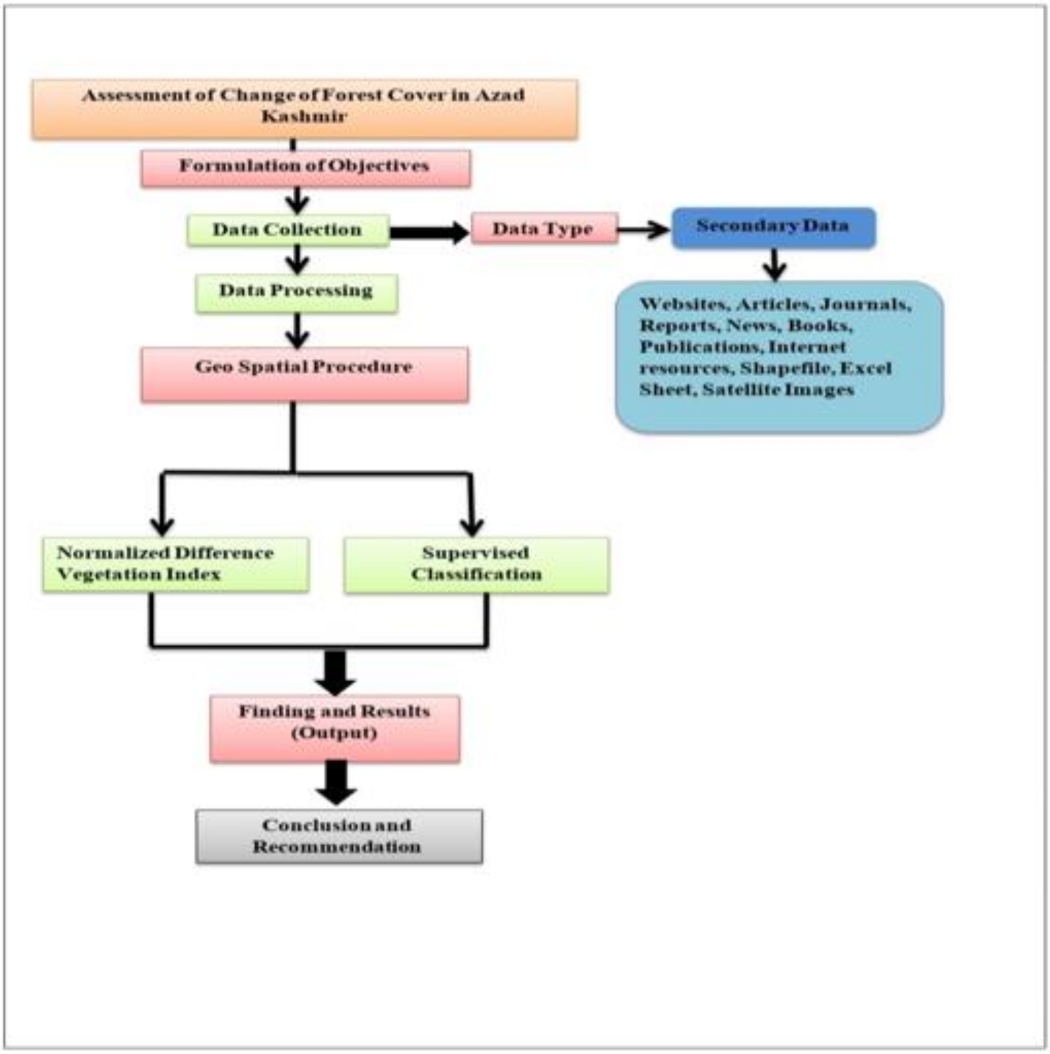

Figure 2. Research methodology

4. Results and Discussion

The Normalized difference vegetation index (NDVI) and Supervised Classification were used to calculate changes in forest cover across the Azad Kashmir from 2000 to 2020. Supervised classification is used to investigate the changes in land cover classes. Which include built up areas, water bodies, forest cover and some other. By using NDVI, the change is calculated and analyzed about vegetation cover across Azad Kashmir.

4.1. NDVI and forest cover trend in AJK

Figure 3 is the normalized difference vegetation index maps of 20 years of Azad Kashmir from 2000 to 2020. In these maps, NDVI is applied on satellite image of Azad Kashmir. In these maps high and low intensity of vegetation cover is represented and from 2000 to 2020. Map of year 2000 represents that the highest value or the green or dark green area represent that most reflection of vegetation and these green areas shows that more forests and in green colored areas there is more forest cover and the lesser value which shows less reflectance of vegetation are in yellow or dark red and these areas show less vegetation or no vegetation at all. The image of year 2005 of Azad Kashmir shows that the highest value of vegetation decreases, and it is less than the value of year 2000 and this indicates that vegetation cover decreases. Therefore, this means that forest cover decreases in five years from 2000 to 2005. In year 2010, that high value decreases and which is clear that vegetation decreases. This is post-earthquake time and new wave of construction for rehabilitation of people. Therefore, this development is main cause of decrease of forest cover in area. So, this shows that forest cover also decreases in these five years as well from 2005 to 2010. The satellite image of year 2015 of Azad Kashmir represents that the high value get after the NDVI is less than previous image so that represents vegetation cover is tend to decrease. This means that forest cover area of region is decreasing in 5 years from 2010 to 2015. And, we can observe that in year 2020 image clearly represents the decrease in high value of vegetation. This means that vegetation cover decreases during the time of five years from 2015 to 2020. This is the clear indicator that forest cover in the region is decreasing by passing of time. This is due to the increase in population and anthropogenic activities. In 2020 image there is a clear decrease in vegetation cover from image of 2000.

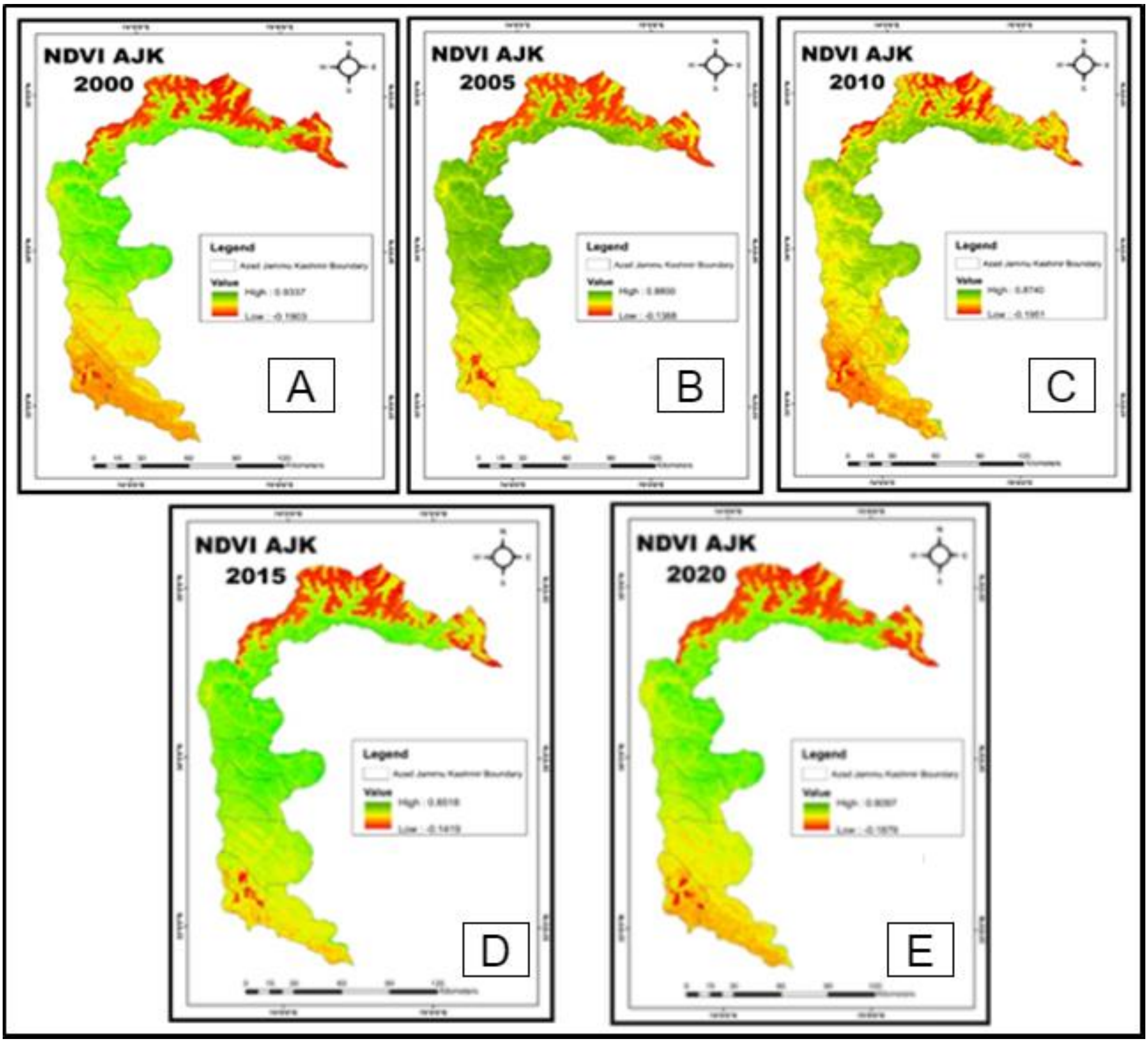

Figure 3. Trend of vegetation cover over these 20 years from 2000 to 2020.

The figure 4 represents the trend of vegetation cover over these 20 years from 2000 to 2020. In this, it is represented that vegetation cover decreases gradually with passing of time. As it is clearly represented that in 2000 the forest area is high and after 5 years, in 2005 it decreases and again after 5 years more forest cover decreases until 2020 where forest cover is lower ever.

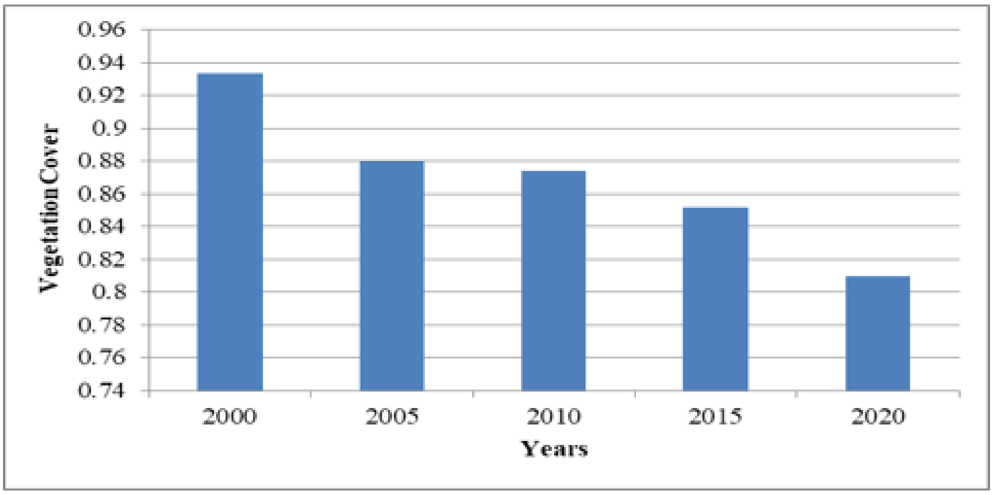

Figure 4. Graph of NDVI and forest cover trend land cover variation in AJK from year 2000 to year 2020

The figure 5 represents the supervised classification maps of 20 years of Azad Kashmir. Through supervised classification land cover classes are separately identified and analyse the increase or decrease in certain class.

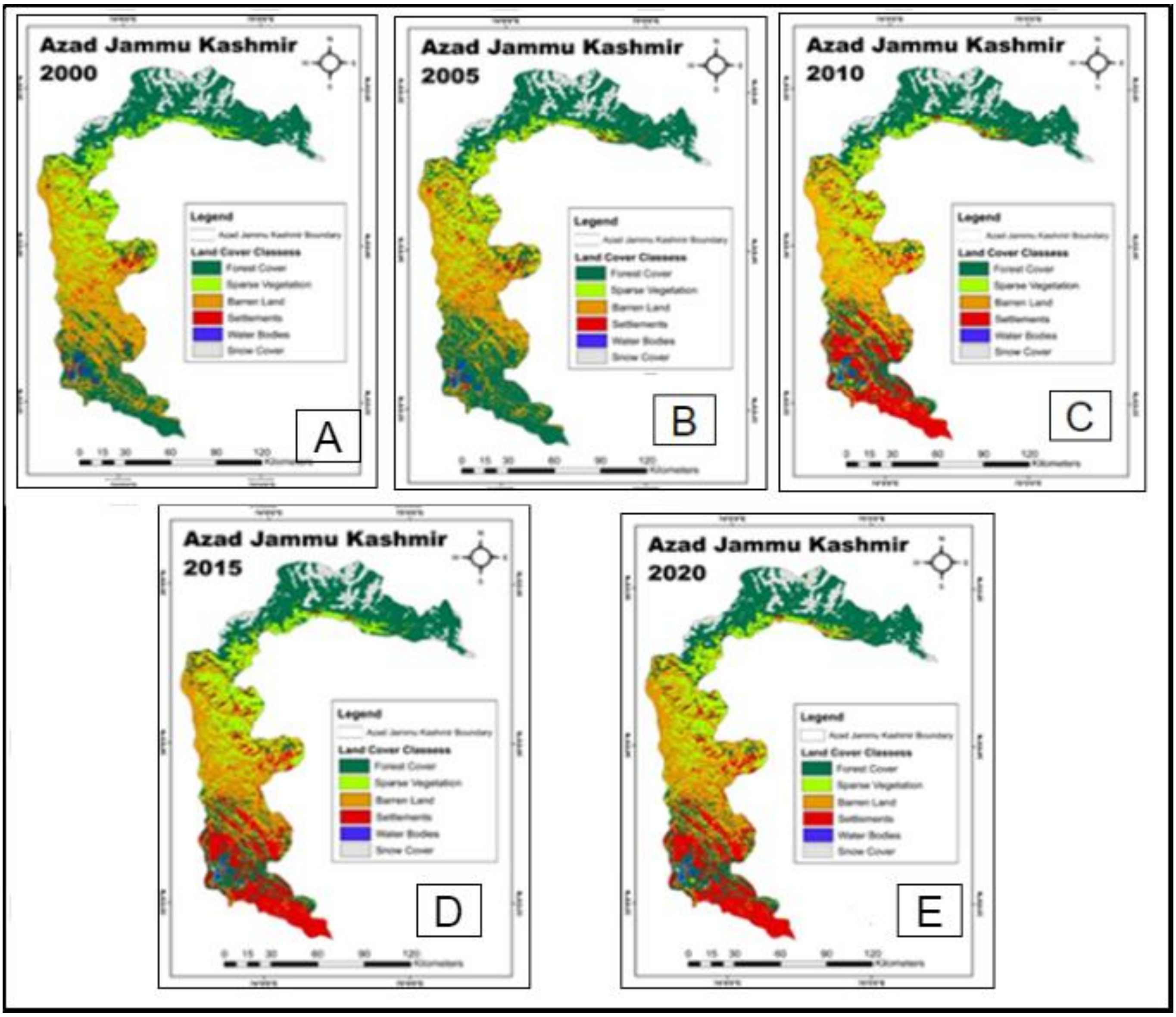

Figure 5. Trend of land cover over these 20 years from 2000 to 2020

Land classes are settlements, forest cover barren land, sparse vegetation, water bodies and snow cover. The forest cover gradually decreases, and settlements are main reason of it and population is core factor behind this decrease in forest cover. The image of year 2000 represents the different land cover classes, you clearly see most of the area is covered with forest, and after that, there is a huge area that is barren and sparse vegetation. Only Mangla dam is visible water body and due to less population, there are no such huge settlements. In northern parts, mountains are covered with snow. Year 2005 map clearly shows that forest cover area decreases. There is small increase in barren land and small decrease in sparse vegetation but there is a change in settlements due to increase in population. There is no such change in snow cover and no such increase in water body. The image of 2010 displays a clear and huge difference in land cover classes from previous years images. This is the image after earthquake and in this image, there is a certain decrease in forest cover and there is a very large increase in settlements due to post earthquake development and population increase. There is no such change in barren land, sparse vegetation and snow cover and sudden increase in water body. The map of 2015 shows that the huge increase is in settlements and only in southern part because these areas are closer to the mainstream Punjab areas and due to these more developed areas and increase in their population. Forest cover is decreasing, and, in this time, sparse vegetation increases, and barren land decreases. The 2020 satellite image of Azad Kashmir shows the increase in density of settlements due to increase in population of the area. The forest cover of the region is decreasing and as compared to 2015, the barren land increases in these 5 years and sparse vegetation decrease. Due to issue of global warming and climate change snow cover slightly decreases and no such changes in water body. In this whole time period only, settlements increase mean built-up area in region increases largely.

Figure 6 graph represents the percentage of forest cover in Azad Kashmir over 20 years. In this graph it is represented that how forest cover decrease with passing of the time. In year 2000 the percentage of forest cover is higher than ever, it continuously decreases, and from 2005 to 2010 the forest cover changes drastically due to post Earthquake and in year 2020 the percentage is lower than all past years (Table 1).

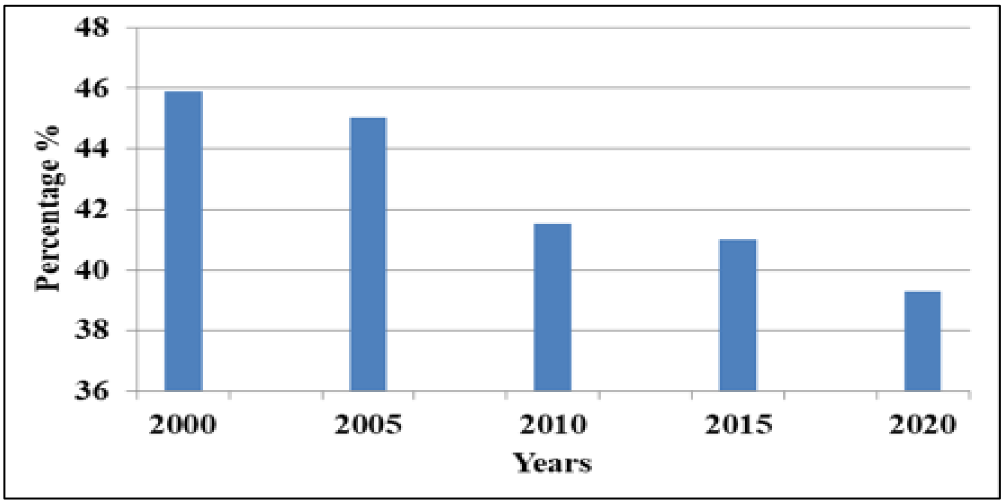

Figure 6: Forest cover variation from 2000 to 2020

Table 1. Total Areas and Area Percentage of Land Cover Classes

Classes	Year 2000		Year 2005		Year 2010		Year 2015		Year 2020	
	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)
Forest Cover	6102.54	45.89	5990.25	45.04	5521.90	41.52	5450.46	40.99	5226.36	39.30
Sparse Vegetation	2960.35	22.26	2900.72	21.81	2851.90	21.44	2725.50	20.49	2690.91	20.23
Settlements	193.60	1.45	482.80	3.63	991.70	7.45	1095.40	8.23	1390.42	10.45
Barren Land	1980.00	14.89	1888.21	14.20	1880.70	14.14	1960.74	14.74	1870.81	14.06
Water Bodies	328.10	2.46	327.70	2.45	329.80	2.48	326.69	2.45	326.90	2.45
Snow Cover	1732.41	13.02	1700.82	12.79	1721.00	12.94	1737.92	13.34	1791.60	13.47

4.2. Causes for the variations in land cover

This study has indicated the on-going trend of forest cover change. This underlines the changes in in the forest cover and other land use classes such as built-up area, snow cover, barren land, water body and some others. This shows that how increase in population is main cause of changes in forest cover in Azad Kashmir but there are many other factors that are responsible for decrease of forest in Azad Kashmir. That includes illegal logging, dependency of people on the forest for livelihood. Almost 400 hectares of forest have lost or destroyed in past 20 years. In 2000, there is approximately 46 % area is under forest cover, in 2005 it decreases to 45 %, in 2010 it decreases to 41 %, in 2015 it decreases to 40 % and in 202o it decreased to 39 %. From 2005 to 2010 major change in forest cover was seen in this 5 year time and there was a huge drastic change in land cover classes of Azad Kashmir because this was post-earthquake time and for the rehabilitation phase there were start of billion dollar investment and that are the reason of huge increase in settlement land. Further passing of time population increases. The current rate of deforestation is also very high than past years. There are some drivers that are causing deforestation in these years. Expansion of settlement area tends to be the major cause of deforestation. Although increase in population is biggest reason but it has boosted other drivers. Pressure on forests increases due to absence of facilities and people have to fulfil their need of livelihood from forests. Construction and development for local and tourism purpose also responsible for decline in forest cover. Azad Kashmir is also the tourist destination and tourism is the huge contributor to the economy of Azad Kashmir. Due to this, many development projects are being construct and new hotels and resorts are being made by removing forests. Roads are being constructing and these roads gave access to people to the different remote destinations of Azad Kashmir. So these areas are now under the pressure of anthropogenic activities. Forests in Azad Kashmir consist of much type of rare trees and plants, which include medicinal plants and shrubs and other precious wood. Some woods like timber that has very high demand in the market. Due to this reason, illegal logging cutting of timber and other such wood is also factor that cause change in forest cover. Degradation in forest cover area has many side effects and one of biggest and currently facing is climate change. The other issues we face are the change in weather patterns, increase in emission of carbon dioxide and destruction of biodiversity in forests of region. The forest cover kept decreasing with passage of time. There are many factors that are responsible, and many other things got affected but wildlife is most affected by these changes. Because they are inside the forests and some of their species are at brink of extinction.

5. Conclusion

This study helps to understand the trend of change in forest cover of Azad Kashmir that it is decreasing at very fast speed. This is very dangerous for the environment, biodiversity and people of the region. In this research it is find out that increase in population, expanding of settlements and agricultural land, illegal cutting down of trees are causes behind the change in forest cover. Also, people of region are very much dependent on the fuel wood for livelihood is the main driver behind change in forest cover. Despite there is a separate forest department in the region and in presence of rules and regulations about forests the trees are being cut down and forest area decreases. This happened due to negligence and lack of monitoring and check and balance on forest areas. Failure on institutional level is also behind issues like deforestation. As population is increasing the need for the settlement and agricultural land rises and demand of timber and other important woods rises. The decline in forest cover has also affects our environment. Due to this reason the region, face the problems like climate change. That has unpleasant impacts on area. It affects the population and other life and has also affects the vegetation and weather pattern. Forests are main source behind sustainable environment but decrease in forest lead to problems.

The study further concludes that land cover particularly forest cover has significantly changed in the last two decades and affected ecosystem services. Location specific management strategies are highly recommended to reduce the rapid decline in forest cover. Strategy must also consider the population growth and traditional forest conservation strategies. Alongside, keeping in view the agricultural activities and infrastructural development in the dense forest cover areas are also recommended.

Author Contributions

The contributions of the authors of this article is equal.

Statement of Conflicts of Interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

Research and publication ethics were complied with in the study.

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Valuation of commercial real estate in Ankara middle east industry and trade center (MEITC)

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ABSTRACT

Commercial real estate is an important part of the real estate sector. In the commercial real estate market, value estimates are made with the help of the characteristics of the samples that are subject to purchase and sale, and they are used in transactions such as taxation, insurance and privatization. In this study, collective valuation processes are aimed by applying the Multiple Regression Analysis (MRA) statistical method to the commercial properties offered for sale in the Middle East Trade and Industry Center (MEITC) in Yenimahalle district of Ankara. In this direction, 31 office sales data were collected for valuation, 29 criteria affecting the value were determined, and a mathematical model was developed according to independent variables. R^2, Root Mean Square Error (RMSE), Mean Absolute Error (MAE), and Mean Absolute Percent Error (MAPE) were considered. Their results were found as 0.938; 0.00; 0.04; 0.42 respectively. Based on these values, it has been concluded that the regression method, which is seen to produce high accuracy, can be used in commercial real estate valuation. Geostatistical analyzes were made using market values and estimated values, and value maps were produced in the Geographical Information Systems (GIS) environment.

1. Introduction

Real estate comes first among the basic needs that people need in order to continue their lives (Özkan & Yalpır, 2005). It is the part of the earth where shelter and other activities are carried out, especially food. With the state tax, citizens provide economic income with their production on real estate. This situation reveals the necessity of presenting real estate values in an accurate, objective, reliable and transparent manner. Objective real estate valuation can be made with the help of standard criteria determined by legal basis and the most appropriate method. The sound and good operation and maintenance of a real estate valuation system is one of the most important duties of the country's administration (Erdem, 2017). Real estate valuation; It is used in many transactions such as taxation, expropriation, insurance, nationalization, privatization, zoning practices, consolidation, sale and leasing.

Real estate valuation is defined as the art or science of estimating the value for a specific purpose of the property at a given time, considering all its characteristics and also taking into account all key economic factors (Millington, 2001). Real estate valuation is seen as a complex process because there are many criteria that affect the value (Yomralioglu, 1993). Scientific, objective, quantitative, practical and sensitive methods should be used in determining the real estate values. However, local needs and personal preferences vary according to the technical and legal characteristics of the land, plots and buildings within the scope of the real estate (Yomralıoğlu, 1997; Tanaka & Shibasaki, 2001).

Current mass appraisal studies are mostly concentrated on residential real estate (Tecim & Çağatay, 2006; Cˇeh et al., 2018; Dimopoulos & Bakas, 2019). However, mass appraisal studies on commercial property remained limited. Commercial properties play an important role in urban planning (Lau & Li, 2006). In addition, commercial properties have unique characteristics that differ from residential properties (Fisher et al., 1994). One of the most important features of commercial properties is spatial autocorrelation (Kato, 2012). The properties of commercial properties are geographically dispersed and therefore models

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should be established to explain their prices (Hajime et al., 2013).

There are various criteria that can be used for every commercial property, but are not the same. Eboy & Jurah (2021) used the ordinary least squares method (OLS) in a study that showed a modeling and valuation comparison between two commercial property areas of Putatan and Limbang, which represent the city's suburbs in Sabah and Sarawak. They aimed to find an effective approach to develop a suitable model for commercial real estate valuation and to identify criteria that affect commercial properties for both fields of study. OLS results for Limbang and Putatan region are compared. OLS model for Limbang area, 6 criteria consisting of market, gas station, public toilet, recreation park, position and office; In the Putatan district, 5 criteria, namely renovation, road, main dump site, shopping complex and hotel, were found to be the criteria that most affected the property value. As a result, Eboy & Jurah (2021) stated that this study will benefit local authorities, investors and businessmen in determining the property value impact and estimated value using this approach with low cost, less time and less people needed.

Zhang et al. (2014) conducted a case study in Shenzhen's Huaqiang business area for a collective assessment of commercial properties based on spatial analysis. To achieve high precision and reduce valuation cost, they propose an innovative framework through the introduction of an improved spatial error model (SEM), fuzzy mathematics and econometrics. In the study; They considered criteria such as area, street front, number of floors, width of the property's proximity to the street, height of the property, vacancy rate, depth of the property, and commercial level. As a result of the study, Zhang et al. (2014) stated that the model applied in the analysis could be widely adopted in China, provide data support for fiscal decentralization, provide technical support for the ongoing property tax reform, and provide data supporting macro regulation of the real estate market. They also stated that the evaluation results can be used as a benchmark for the market equilibrium price.

In their study in the USA, Ghysels et al. (2007) considered a log-linearized version of the discounted rent model to price commercial real estate as an alternative to traditional hedonic models. First, they confirmed an important implication of the model, namely that ceiling rates predict commercial real estate returns. They did this using two different methodologies: time series regressions of 21 US metropolitan areas and aggregated REIT returns and mixed data sampling (MIDAS) regressions. They also explored the source of predictability. According to the study, Ghysel et al. (2007) concluded that the economic conditions used in the hedonic pricing of real estate cannot fully explain the future movements in returns, commercial real estate prices are better modeled as financial assets and the discounted rent model may be more appropriate than the traditional hedonic models, at least collectively.

Clayton et al. (2009) examined the role of key factors and investor sentiment in commercial real estate valuation. In real estate markets, heterogeneous properties are traded in illiquid, highly fragmented, and information-inefficient local markets, and the inabilityto short-sell private real estate limits the ability of knowledgeable traders to enter the market and eliminate mispricing. They report that these features appear to make private real estate markets highly susceptible to sentiment-induced mispricing. Using error correction models to carefully model potential delays in the adjustment process, this paper extends previous work on capital ratio dynamics by examining the extent to which fundamental principles and investor sentiment help explain time series variation in capping rates at the national level. As a result, they found evidence that investor sentiment affects pricing even after controlling for changes in expected rental growth, stock risk premiums, T-bond yields, and lagged adjustments from the long-term equilibrium.

Fisher et al. (2021) examined the effect of hurricanes on the value of commercial real estate in their study in the USA. It is the first study to examine all major hurricanes that have occurred since 1988, including 19 storms that affected different parts of the United States. After controlling for property size, age, location, time (market conditions), and occupancy, they found that hurricanes had a significant impact on property values, value growth (excluding investments), and overall returns. Fisher et al. (2021) emphasize that it is especially important for investors who decide whether to allocate additional capital if the risk of additional hurricanes is increasing in an area due to climate change. They note that the impact on property values and returns they found goes beyond any impact from physical damage to properties. They noted that the depreciation appears to last up to 5 years after the hurricane occurs, and is likely the result of higher risk premiums and lower tenant demand after a hurricane has occurred.

Hoesli & Malle (2021) analyzed the effects of the 2019 coronavirus disease (COVID-19) epidemic on commercial real estate prices in their study, focusing especially on European markets. The authors reported that retail and hospitality facilities and, to a lesser extent, office buildings were most affected by COVID-19, with the residential and industrial sectors less affected. They argued that the future course of prices will vary between sectors, and the type and location of assets will become increasingly important in their valuation.

In the study of Yomralıoğlu (1997), it has been determined that local, environmental, legal, spatial and local characteristics are among the widely accepted criteria as well as the purpose of use of the real estate in determining the value.

GIS; it is a computer-based system used to obtain, process, control, store, display and analyze spatial data such as climate, landforms, population. In this context, it is possible to benefit from GIS technology in collecting, controlling, analyzing and presenting the data related to the criteria affecting the real estate value in certain standards. In the application of multi-criteria decision-making analysis in real estate valuation studies, first of all, accurate, reliable, up-to-date, spatial and non-spatial data of the real estate are collected and correlations are established between them. The criteria affecting the value of the immovable are determined and entered into the system together with their previously calculated weights. In order to make location-based decisions with the data stored in the GIS base, operations such as viewing and querying are performed with the help of analyzes, and new information is obtained from the data collected as a result of the analyzes to be made (Erbil, 2014). This system allows the database prepared with GIS to be analyzed with mathematical models, making valuation and producing value maps (Tanrıvermiş, 2018).

The aim of this study is to analyze the performance analysis results and value maps by estimating the market values of commercial real estate in the MEITC region of Ankara with MRA. Commercial buildings, which are rarely seen among the studies on valuation, are considered as immovable type. MRA was applied by arranging the market value of the commercial places put up for sale in Ankara Yenimahalle district Middle East Trade and Industry Center (MEITC) as the dependent variable and the criteria affecting the value as the independent variable. It is important that it can be used in many transactions such as mass appraisal in commercial areas, taxation, insurance, sale and rental as in residences.

2. Material and Method

2.1. The study area

Ankara is located in the Central Anatolia Region and is the capital of Turkey. It is the second most populated city in the country and the third largest city in terms of surface area. Its population is 5,747,325 people in 2021 (TUIK, 2021). This population; He lives in 25 districts and 1425 neighborhoods connected to these districts. Approximately 72.13% of the population works in civil service, transportation, communication and trade, which can be defined as the service sector, 24.64% in industry and 3.23% in agriculture (Report, 2018).

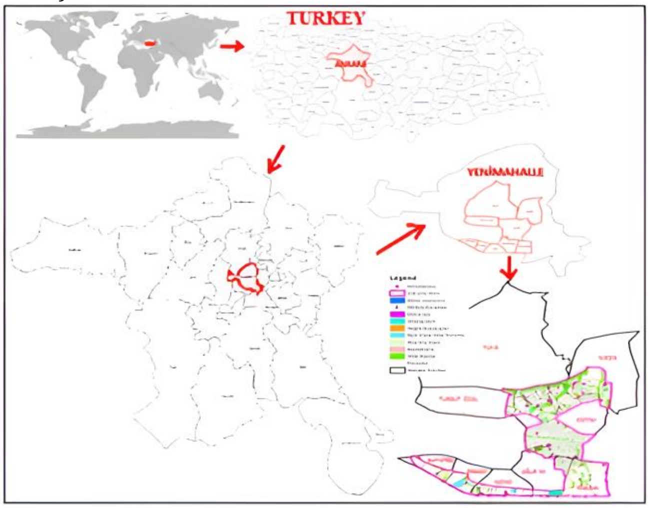


Figure 1. Ankara MEITC study area

The industry is especially concentrated in the textile, food and construction sectors. Middle East Industry and Trade Center, or MEITC for short, is an industrial site in Ankara. MEITC is Turkey's largest small and medium-sized industrial production area (Figure 1). More than 2500 workshops, approximately 1400 workplaces and offices and 1800 residences were built through the MEITC Small Industrial Site Building Cooperative. There are 5000 companies that are members of MEITC. 31% of the companies are trading, the rest are manufacturing. Manufacturing areas are 62% metal processing, 20% plastic-rubber, 8% electricity and 4% chemical production (Erdoğan et al., 2007).

2.1.1. Data

Commercial offices were offered for sale on the internet, and a data set was created between March-April 2021 from 31 offices with a homogeneous distribution by conducting research for market values and other information one by one. The data collection process was completed by verifying the island and parcel information on the Parcel Inquiry website of the General Directorate of Land Registry and Cadastre. In order for the study conducted in a region to reflect that region and to be statistically significant, it is necessary to collect data as much as a certain sample number. It is stated that an increase in the sample size at a certain level will decrease the margin of error and error rate (Patton, 2014). Since it is not always possible to control the variables that affect the process in studies in the field of science and engineering, the confidence interval is accepted as 95% in many studies (Karasar, 2007). In parallel with this situation, sampling error is preferred as 5% (Glantz, 2012).

In literary studies; area, street front, number of floors, property width near street, property height, vacancy rate, property depth, commercial level, repair, main roads, secondary roads, education centers, entertainment centers, banks, police stations, post offices, bus stops or taxis, ferry terminals, public toilets, places of worship, gas stations, parking lots, shopping complexes, office complexes, sports complexes, farmers' markets were used as criteria (Zhang et al., 2014; Eboy & Jurah, 2021).

In this study; the zoning plan of Ankara province, Yenimahalle district, MEITC study area was used. Considering the office features in the literature and in MEITC, criteria have been determined under 4 main headings and 11 subheadings in the form of legal, structural, physical and spatial features. As a result, a total of 29 independent variables that affect the office value are discussed (Table 1).

2.2. Preparing data for analysis

The criteria; There is no standard on how it is used in mass appraisal and in what form it is converted into digital form (Ünel, 2017). However, quantitative data is needed to perform analyzes for value estimation. For this reason, when the studies in the literature were examined (Nişancı, 2005; Demirel et al., 2016; Doldur & Alkan 2021) it was seen that coding was done (Figure 2).

Table 1. Criteria affecting the commercial real estate value

Address	Legal Feature	Building Feature	Physical Feature	Location Feature (Distance)
District	Setback Distance	Net Building Area	Road Width	Healthcare Provider
City Block	Number of Floors	Building Age	Transportation Facilities	Secondary Education
Plat	Land Area	Number of Rooms	Frontage	Municipality
Site		Floor Location	Direction of Facades	Open Penitentiary İnstitution
Ad Number		Office Type		SubwayStation
		Number of Balconies		Bus Station
		Heating System		Shopping Area
		Dues		Green Area
		Parking		Worship Place
		Elevator		Town Center
		İnterior Features		
		External Features		

Internal features are determined ADSL, kitchen, steel door, bathroom, white goods, toilet, parquet, ceramics, central satellite system, furniture, cloakroom, suspended ceiling, industrial electricity, sound insulation, fire alarm system, cable TV-satellite, jacuzzi windows.

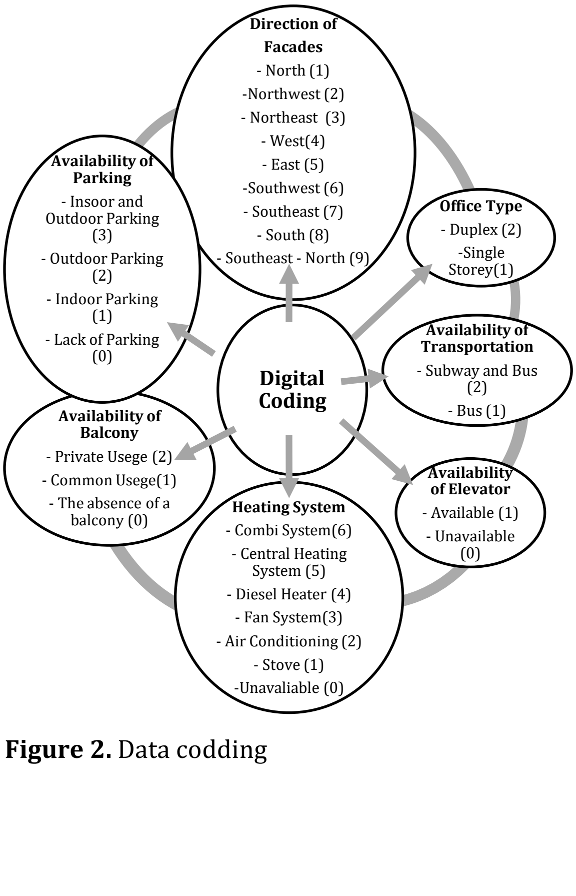


Figure 2. Data codding

Except for the toilet and the bathroom, all of them are coded to be numerically expressed as 1. In the toilet and bathroom criteria; Existence of a bathroom was expressed as 1, absence of it as 0, private use of toilet as 2, common use as 1, and absence as 0 and added to interior features.

As external features, fire escape, security, heat insulation, water heater, generator, glass cladding, garden, camera system, information service, warehouse, card access system, system room, open area are listed as. All of them are expressed numerically as 1 according to their existence status.

2.3. Method

In mass real estate valuation, peer comparison, income and cost methods, which are called traditional valuation methods, are insufficient (Pagourtzi et al., 2003). While seeing that the use of statistical and modern methods in mass appraisal has increased its contribution to valuation studies, it offers the opportunity to give objective results instead of subjective findings (Nişancı, 2005). In studies in the literature, the multiple regression method is generally given as a comparison method in the performance and accuracy analyzes of the method to be developed (Zurada et al., 2011; Yalpır & Tezel 2013; Kartal & Corum, 2020; Esen & Tokgöz 2021; Tabaret al., 2021). In this study, "Multiple Regression Analysis" was used as the valuation method of commercial real estate. The data contain differences in terms of unit and value ranges, and normalization process was performed to standardize the data. In addition, performance analyzes were made to examine the differences between the prices of commercial real estate and their estimates, that is, the amount of errors.

2.3.1. Normalization

Normalization can be named as the process that enables the data sets that have been converted to digital to be standardized [0,1], [1,2] or [-1,1] by pulling them to a certain range and used together in value estimation by converting them to values in the same unit. Normalization methods enable them to be examined together by converting existing values to values without units (Özdağoğlu, 2014)

In this study, Min-Max Normalization method was applied. The Min-Max Normalization method de-unitizes a data and reduces it to the range of 0 to 1 with Equation (1).

- Normalization in the range of $\boldsymbol{0 \leq X \leq 1}$

$$X_N = \frac{X_i - X_{min}}{X_{max} - X_{min}} \quad (1)$$

Where X_i is the value in row $i$for the relevant criterion of the dataset. X_{min} and X_{max} are the smallest and largest values of the relevant criteria.

Criteria affecting the value of commercial real estate located within the borders of Ankara MEITC have been determined and the criteria data together with the market value have been recorded in matrix format. A numerical coding system was applied to the recorded criteria. The numerical values used in the regulations do not mean that they increase or decrease the value of the real estate at the same rate. A coding system has been created, taking into account the fact that it affects the value of the immovable and that it is accepted under legal conditions. For example; Considering the explanation in the table showing the square meter normal construction cost values of the buildings published based on the Real Estate Tax Law, if the presence of an elevator is evaluated according to the absence of an elevator, it is given as 1 because it will positively affect the price, and 0 if there is no elevator (Figure 2). The normalization process in the range of [0-1] was applied to the numerically coded data. Thus, each criterion had a value between 0 and 1.

2.3.2. Multiple regression analysis

MRA method is one of the most used methods in real estate valuation because the number of criteria affecting the property value is more than one. In MRA, it is aimed to make functional sense of the relationship between the variables and to explain this relationship with a model (Chatterjee & Hadi, 2015). In the MRA method, there is only one dependent variable and there is more than one independent variable affecting this dependent variable. The dependent variable is the market value, and the independent variables are the legal, structural, physical and spatial features that affect the market value (Figure 3). In this method, the closest estimation of the market value to reality is tried to be made (Türeoğlu, 2008).

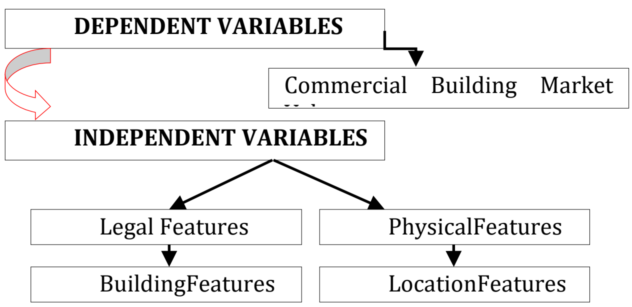


Figure 3. The dependent and independent variables

The process of determining the $y = f(x)$ function between the independent x and dependent y variables given by the values $(x_1 y_1)$,$(x_2 y_2)$,......$(x_n y_n)$ is called balancing function determination, relationship research or regression analysis (Şişman & Şişman, 2016). A first-order linear regression Equation (2),

$$y = a_0 + \sum_{i=1}^{k} a_i x_i + \varepsilon \qquad (2)$$

It is a model with dependent and independent variables. Here y; dependent, x_i; independent variables, a_0; constant value, a_i regression coefficient, ε; represents the random error term.

F test and R^2 found as a result of MRA are important tests that should be checked first (Altunışık et al., 2010);

- The F test is a test with ANOVA to examine whether the regression model is significant.
- The significance level corresponding to the F value obtained as a result of the ANOVA test helps in the decision whether the model is suitable or not.
- It is interpreted that the result of the F test is significant (p<.05), and that the model in question makes a significant contribution to explaining the dependent variable.
- The R^2 value indicates what percentage of the variance in the dependent variable is explained by the independent variable.
- The closer this value is to 1, the better the model is explained by the independent variables.

2.3.3. Performance analysis

Performance analysis is the evaluation of the work done, seeing the deficiencies and taking measures to eliminate them, revealing the factors affecting the performance and controlling them and arranging the resources accordingly (Bayyurt, 2007).

Three parameters are considered for the performance analysis. In order to compare the model values obtained from all and reduced criteria with the market values, the results of Root Mean Square Error (RMSE), Mean Absolute Error (MAE), Mean Absolute Percent Error (MAPE) were used in performance analysis.

The RMSE was calculated by squaring the estimation errors and subtracting their mean from the square root (3), and the MAE was calculated by averaging the absolute values of the estimation errors (4). MAPE is calculated by taking the average of the ratio of the absolute value of the estimation errors to the market values (5) (Akgüngör & Doğan, 2010; Aslay & Özen, 2013)

The value of R^2 (6) was examined to examine how much the estimated values reflect the market values. Equations (3-6) were used for Performance Analysis;

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2} \qquad (3)$$

$$MAE = \frac{1}{n}\sum_{i=1}^{n}|y_i - \hat{y}_i| \qquad (4)$$

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\frac{|y_i - \hat{y}_i|}{y_i} \qquad (5)$$

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{\sum_{i=1}^{n}(\hat{y}_i - \bar{y})^2} \qquad (6)$$

y_i market values, $\hat{y}_i$ model values, $i = 1,2,3,\ldots n$, and n represents the selected sample number.

3. Results

Independent variables based on the market value of the dependent variable in the Statistical Package for the Social Sciences (SPSS) software developed by IBM using normalized data; area, drawing distance, number of floors, direction of facades, etc. MRA was performed by assigning values.

ANOVA test was used to determine whether the F test was p<0.05 and the R^2 value was close to 1 in MRA. Among the results of the ANOVA test, the significance of the F test was 0.000, and it was determined that the value estimation model made a significant contribution to explaining the dependent variable (Table 2).

Table 2. ANOVA test

ANOVA[a]						
Model		Sum of Squares	Mean Square	F	Sig.
1	Regression	1.632	.056	13.795	.000[b]
	Residual	.118	.004		
	Total	1.751			

In the regression equations coefficients, the positive sign (+) has an increasing effect on the real estate value, while the negative (-) coefficient has a decreasing effect. Considering the sign of the model coefficients, the criteria that have the most positive effect on the value are; net building area (0.669), floor (0.102), dues (0.244) and metro station (0.116). The criteria that have the most negative effect on the value are; external features (-0.198), distance to Yenimahalle Municipality (-0.232) and open penalty execution distance (-0.356) (Table 3).

The mathematical model of the MRA is presented in Equation (7) using the coefficients in column B of Table 3;

$$\boldsymbol{Market\ Value} = 0.566 + 0.006 * landarea - 0.114 * setbackdistance + 0.074 * numberoffloors + 0.669 * netarea - 0.085 * buildingage - 0.003 * numberofrooms + 0.102 * floorlocation + 0.094 * officetype + 0.052 * numberofbalconies + 0.006 * heatingsystem + 0.244 * dues + 0.075 * parking - 0.026 * elevator - 0.051 * interiorfeatures - 0.198 * externalfeatures - 0.017 * roadwidth + 0.019 * transportationfacilities + 0.018 * frontage - 0.005 * directionoffacades - 0.052 * healthcareprovider - 0.086 * secondaryeducation - 0.232 * municipality - 0.356 * penitentiaryinstitution - 0.158 * shoppingarea - 0.064 * towncenter + 0.050 * greenarea + 0.116 * subwaystation - 0.031 * busstation - 0.121 * worshipplace \quad (7)$$

The market value was estimated with the model obtained as a result of the MRA. Since the data were normalized, the predicted value was calculated in the range (0, 1).

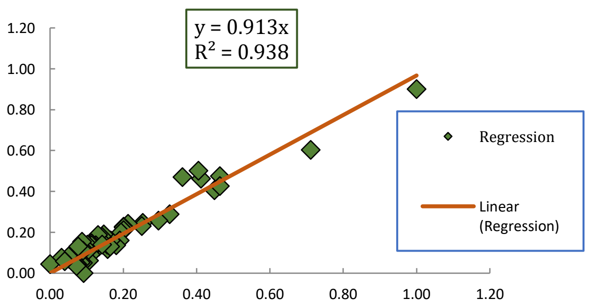


Figure 4. Comparison of Market Value and Prediction Value

Table 3. Regression Analysis Coefficients

Coefficients[a]					
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Constant	.566	.180		3.142	.004
Land Area	.006	.091	.011	.065	.949
Setback Distance	-.114	.094	-.133	-1.206	.238
Numberof Floors	-.074	.068	-.108	-1.090	.285
Net Building Area	.669	.070	.670	9.629	.000
Building Age	-.085	.060	-.120	-1.402	.171
Number of Rooms	-.003	.044	-.005	-.064	.949
Floor Location	.102	.090	.114	1.141	.263
Office Type	.094	.054	.164	1.725	.095
Number of Balconies	.052	.036	.139	1.430	.163
Heating System	.006	.051	.008	.121	.904
Dues	.244	.076	.304	3.229	.003
Parking	.075	.062	.178	1.212	.235
Elevator	-.026	.067	-.049	-.395	.695
Interior Features	-.051	.063	-.062	-.818	.420
External Features	-.198	.079	-.339	-2.494	.019
Road Width	-.017	.040	-.037	-.424	.675
Transportation Facilities	.019	.033	.050	.581	.566
Frontage	.018	.077	.029	.236	.815
Direction of Facades	-.005	.038	-.009	-.120	.905
Healthcare Provider	-.052	.061	-.076	-.855	.400
Secondary Education	-.086	.063	-.147	-1.377	.179
Yenimahalle Municipality	-.232	.237	-.242	-.980	.335
Open Penitentiary İnstitution	-.356	.220	-.503	-1.616	.117
Shopping Area	-.158	.090	-.283	-1.766	.088
Town Center	-.064	.123	-.085	-.523	.605
Green Area	.050	.095	.061	.522	.606
Subway Station	.116	.132	.180	.877	.388
Bus Station	-.031	.073	-.045	-.426	.673
Worship Place	-.121	.068	-.167	-1.777	.086

a. Dependent Variable: Market Value

Performance analyzes were performed to compare the difference between the market value and the prediction value found as a result of the MRA. For this, R^2, RMSE, MAE and MAPE were calculated and it was examined how close the prediction values were to the market value. R^2 is close to 1 with a value of 0.938, showing that the predicted value approximates the market value very well (Figure 4).

As a performance analysis, it was determined that the estimation values of RMSE (0.00), MAE (0.04) and MAPE (0.42) ratios approached the market values very well (Table 4).

Table 4. Performence Analysis Results

Performence Analysis Method	Value
Root Mean Square Error (RMSE)	0.00
Mean Absolute Error (MAE)	0.04
Mean Absolute Percent Error (MAPE)	0.42

3.1. Value maps

The entire area included in the MEITC was determined as the study area and the samples were shown on the map by placing dots on the plots where the samples were located. Since commercial real estate is a structure built for office and bureau use, the sample points on the map and unit values are associated with the ArcGIS program. The unit values were also found by dividing the market and prediction values by the net building area. Therefore, each point gives the value of one square meter construction area belonging to the samples. This value includes the land share.

The value map was produced using the inverse distance weighting method. It has been determined that the maps produced from the market and prediction unit values are visually very close to each other. In the market unit value map, the southwestern facade displays a more valuable spatial distribution than the northeast (Figure 5a). The prediction unit value map is also very similar to the market unit value map, with little change in value on the southeast front (Figure 5b).

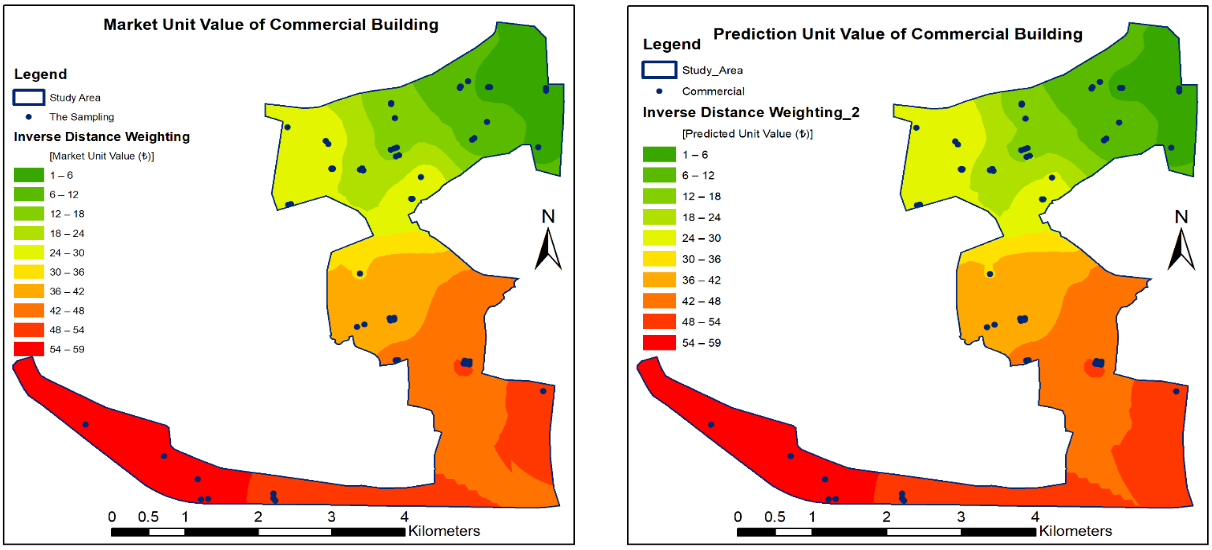
Market and prediction unit value maps also help to obtain information about the values of real estates outside of our samples in the study area.

4. Conclusion

In this study, which focuses on the valuation of real estate, which is one of the most important parts of social and personal wealth, an examination has been made on determining the criteria affecting the real estate value and generating estimated value.

In order to measure the effects of independent variables, in other words, qualitative ones at the classification measurement level, on the dependent variable, all qualitative and quantitative variables were made suitable for analysis.

The regression model obtained in this study revealed the relationships between the real estate values and the criteria affecting the values for the study area. According to the estimated results, the root mean square error of the values found as a result of the performance analysis was 0 (zero) and the R^2 value was found to be 0.938, and it was determined that the mathematical model was significant and very close to the market value.



(a) The market unit value

(b) MRA prediction unit value

Figure 5. Value map

The prediction values of commercial real estate and their market values were matched in the GIS environment and value maps were produced. The estimated values of the regions outside the samples are also shown on the maps.

With the pandemic, a trend towards horizontal architecture has started in people's life and housing preferences. It is seen that the transaction volume in the real estate sector has decreased due to the changing office preferences of the shop and office market after the pandemic and the transition of many companies to the flexible working system. The prolongation of the epidemic has created a great risk for the world economy and all sectors in a chain way. The stagnation in commercial real estate sales during the pandemic period also made the data collection phase difficult. Despite the possible price changes during this period, a high level of accuracy was achieved. The results of the study showed that the method used can be used in real estate valuation applications and a suitable model can be created for the study area by considering the criteria, and valuation studies can be done quickly and objectively. In future studies, it is planned to increase the number of samples and apply different modern valuation methods.

Author Contributions

GY: Data collecting, writting, analyzing, visualization; **FBU:** Designing, editing, mapping; **AU:** Editing.

Statementof Conflicts of Interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

Research and publication ethics were complied in the study.

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