This master thesis is entitled:

MODELING OF LULC CHANGES BASED ON HIGHWAYS IMPROVEMENT IN STAVANGER BETWEEN 1968 AND 2019

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Abstract

New transportation infrastructures like the highways E39 and R509 are necessary for any economic boost in Stavanger and they have had great impacts to scatter development from the undeveloped to the developed locations, transition of the area from agricultural to the most important business center and oil center in Norway through the past decades. But this progress has also brought land use conflicts like urban sprawl which is environmentally disruptive and economically costly. If Stavanger wants to achieve carbon-neutrality in the following decades, this phenomenon needs to be addressed. Urban sprawl is not necessary, neither desirable so, a critical issue is how to disentangle urban sprawl from road improvement. We need to understand this phenomenon better to prevent it from happening in the future. Thus, we need to gain insight into how it has been produced in the past and how has the change trend been so far. The new ferry-free E39 will probably bring more urban sprawl if the necessary studies and measures are not taken.

This research methodology employs GIS and Photogrammetry as strong and trustworthy tools to detect land use changes happened before and after the construction of the highways E39 and R509 in 1968 and 2019 in three buffer distances to investigate the impacts of highways improvement on land use change and the effect of distance from the highways. The accurate results of this methodology represent the patterns of land use change in the proximity of the focused highways through the time period and show interactive relationship with different socio-economic factors and a considerable development happened through a transition from a mostly agricultural land to the oil capital and business center for the country between 1968 and 2019.

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Terms and Definitions

Aerial Orthophoto

An orthophoto (also known as an orthophotograph) is a geometrically corrected (ortho rectified) aerial image that is uniform from corner to corner. Terrain effects (what occurs when you take a three-dimensional surface and turn it into a two-dimensional product) and distortions caused by the camera lens and the angle the photo was taken from the plane are removed from orthophotos. The purpose of this correction is to create an image with consistent distance measurements throughout. A geographic reference to the Earth is usually included in a digital orthophoto(georeferenced) so it can be used as a map ("What Is an Orthophoto? – Geospatial Technology," 2019)

Binary

The binary number system was invented by Gottfried Leibniz and consists of only two numbers or digits: 0 (zero) and 1 (one) (one). This numerical system serves as the foundation for all binary code, which is utilized to write digital data like computer processor instructions ("What Is Binary?," 2021).

Cartography

Cartography is the art and science of visually depicting a geographic area on a flat surface like a map or chart. It could entail superimposing political, cultural, or other non-geographical distinctions onto a depiction of a geographical area (T. Editors of Encyclopaedia, 2017).

Coordinate System

It is a way to locate things in a two- or three-dimensional space, various types of coordinates are utilized. Spatial coordinates (also known as global coordinates) are used to locate things on the Earth's surface in three dimensions, or on the Earth's reference surface (ellipsoid or sphere) in two dimensions. Geographic coordinates in 2D or 3D space, as well as geocentric coordinates, often known as 3D Cartesian coordinates, are two examples. Planar coordinates, on the other hand, are used to find items on a 2D map's flat surface. 2D Cartesian coordinates and 2D polar coordinates are two examples (Knippers, 2009) .

Corridor D

Corridor D (U.S. Highway 50), one of the original 23 corridors, was established in 1977 to offer access to major east coast urban areas from the Midwest, while also fostering economic growth in northwest and north-central West Virginia and southeast Ohio (“Project: Corridor D View Case Study | AASHTO,” n.d.).

Datum

The initial step for geographical coordinates is datum or geodetic datum, which is a mathematical model of the earth's shape. Geodetic datums allow us to create reference systems for both spheroid and ellipsoid-shaped earth models, as well as flat maps. In today's world, the word "reference system" is also used to replace the term "datum." The geodetic datum provides the foundation for coordinate systems and map height indications, as well as all map-based measurements (Dick, Rød, & Mæhlum, 2021).

dBA

A-weighted decibels, abbreviated dBA, dBa, or dB(a), are a measure of how loud noises in the air are recognized by the human ear (“What Is A-Weighted Decibels (DBA, or DBa, or DB(a))?,” 2011).

Environmental impact assessment

Environmental Impact assessment (EIA) is the word used to describe the evaluation of a plan, policy, program, or project's environmental effects (both positive and negative) prior to deciding whether or not to proceed with the planned action (Speight, 2017).

GIS

A geographic information system (GIS) is a system for creating, managing, analyzing, and mapping various types of data. GIS ties data to a map by combining location data (where things are) with several forms of descriptive data (what things are like there). This provides a framework for mapping and analysis, which is employed in science and nearly every sector. Users can utilize GIS to better comprehend trends, relationships, and the context of their location. The advantages include enhanced communication and efficiency, as well as better management and decision-making (Esri, n.d.).

Ikonos

The Ikonos satellite sensor is a high-resolution satellite, which was successfully operated as the first commercially available high-resolution satellite sensor on September 24, 1999 at Vandenberg Air Force Base, California, USA. At nadir, it can capture a 3.2m multispectral, 0.82m panchromatic resolution in the Near-Infrared. Its applications include natural resource and natural catastrophe mapping in both urban and rural areas, tax mapping, agricultural and forest management studies, mining, engineering, building, and change detection (Satellite Imaging Corporation, n.d.).

Infrared Spectral Bands

It belongs to the electromagnetic spectrum, which includes light that has a longer wavelength and lower frequency than visible light. It includes a variety of approaches, the majority of which are based on absorption spectroscopy (Radboud University, n.d.).

Landsat 1

Landsat 1 was launched on July 23, 1972, under the name Earth Resources Technology Satellite at the time (ERTS). It was the first Earth-observing satellite to be launched with the specific goal of studying and monitoring the landmasses of our planet (NASA, n.d.-a).

Landsat 5

Landsat 5 was a low-earth-orbit satellite that was launched on March 1, 1984, with the mission of collecting images of the Earth's surface. Landsat 5 was an extension of the Landsat Program, and it was co-managed by the National Aeronautics and Space Administration (NASA) and the United States Geological Survey (USGS). Landsat 5 was formally deactivated on June 5, 2013, after 29 years in space (NASA, n.d.-b).

Land use/ Land cover

Land usage and land cover are two notions that are interrelated. Land use is defined by (Anderson, Hardy, Roach, & Witmer, 1976) as "man's activities on land that are directly tied to the land," which frequently shows economic linkages. Land cover is also defined by Anderson (1976) as "the vegetational and manmade constructions that cover the land surface." As a result, a land use type can also be regarded a type of land cover. Land cover, on the other hand, may not always correctly reflect land usage. In general, remote sensing applications acknowledge land use as a kind of land cover, despite the fact that the two are frequently employed interchangeably or in conjunction with one another (Jansen & Gregorio, 2004; Loveland & DeFries, 2004).

Multispectral Scanner (MSS)

The MSS sensors were perpendicular-to-the-orbital-track line-scanning devices that observed the Earth. A rotating mirror was used to scan the cross-tracks; for each mirror movement, six lines were scanned simultaneously in each of the four spectral bands. The along-track scan line progression was made possible by the satellite's forward motion (NASA, n.d.).

Near Infrared Band

It belongs to the electromagnetic spectrum with wavelength 750 to 2500 nano meters. It is near the visible light spectrum's red end. The temperatures vary from 740 to 3000-5000 degrees kelvin in this spectral band (everything RF, n.d.).

Panchromatic Band

Panchromatic images are produced by the satellites like Landsat and SPOT6/7. The information from the visible bands of blue, green, and red is "combined" in a single band in such photographs. To put it another way, the band is created by combining all of the visible spectrum's light energy (instead of partitioning it into different spectra). It creates a single intensity value per pixel, which is how a greyscale image is often seen (STARS, n.d.).

Photogrammetry

The American Society for Photogrammetry and Remote Sensing (ASPRS) defines photogrammetry as "the art, science, and technology of obtaining reliable information about physical objects and the environment via processes of recording, measuring, and interpreting imagery and digital depictions of energy patterns derived from non - contact sensor systems." (Ebert, 2015)

Pixel

The smallest unit of a digital picture or graphic that may be projected and depicted on a digital display device is the pixel. A picture element (pix = picture, el = element) is another name for a pixel(techopedia, n.d.).

Raster

Raster is a pixel-based spatial data type (also referred to as grid cells). They are normally square and evenly spaced, but they aren't having to be. Because each pixel has its own value or class, rasters frequently appear pixelated. Each raster is made up of one or more bands, each with its own set of pixel values. Rasters have the ability to be georeferenced (each pixel has a specific spatial position with defined coordinate systems) (“Raster,” n.d.; “Vector vs Raster,” 2015).

Region

Since around 1950, urbanists, economists, and urban planners have used the phrase "city region" to refer to a metropolitan area and its outskirts, which is often governed jointly. It usually refers to a city, conurbation, or urban zone with various administrative districts that share resources such as a central business area, labor market, and transportation network, allowing it to operate as a single economic unit (Bafarasat, 2018).

Remote Sensing

The science and art of getting knowledge about an object, area, or phenomenon by the analysis of data obtained by a sensor that is not in contact with the object, area, or phenomenon under examination defined by (Lillesand & Kiefer, 2000).

Shapefile

Shapefiles are currently a widely used format for storing vector GIS data. Non-topological vector data and accompanying attribute data are stored in Shapefiles. Shapefiles were created by Esri, which is the well-known global GIS pioneer, and are now an open standard, are a popular way to data transfer. Shapefiles, for example, may be read directly by a number of GIS software applications, including ArcGIS and QGIS (Dempsey, 2015).

Spatial Resolution

The capacity to discern between two closely placed items on a picture is referred to as spatial resolution (Sabins, 1997).

Supervised Classification

It is a method of image classification in remote sensing (RS) in which, you choose training samples and then classify your image using the samples you choose. Your training examples are crucial since they decide the class each pixel in your image receives (GISGeography, 2021).

Sustainable Development Goals (SDGs)

Sustainable Development Goals (SDGs), also known as the Global Goals, are 17 interconnected goals designed to achieve a better and more sustainable future for all. They were approved by the United Nations in 2015 as a universal call to action to end poverty, safeguard the environment, and ensure that by 2030, everyone lives in peace and prosperity (United Nations, n.d.).

Thematic Mapper (TM)

The Thematic Mapper (TM) is a high-resolution, multispectral scanning Earth resources sensor that outperforms the MSS sensor in terms of picture resolution, spectral separation, geometric fidelity, and radiometric accuracy and resolution. TM data is collected in seven spectral bands at the same time (NASA, n.d.).

Universal Transverse Mercator (UTM)

Universal Transverse Mercator (UTM) is an acronym for Universal Transverse Mercator, a planar coordinate grid system used for map projection and it is based on (Transverse Mercator). The UTM system is divided into 60 zones, each measuring six degrees of longitude. Beginning at 180 degrees longitude and advancing to the east, the zones are numbered 1-60 (U.S. Geological Survey, n.d.).

Unsupervised Classification

It is a method of image classification in remote sensing (RS) which creates clusters based on the image's inherent spectral features. Then you classify each cluster without using your own training samples (GISGeography, 2021).

Urbanization

Urbanization is the process by which cities expand and increasingly large portions of the people move to them to live and work (Society, 2019).

Vector

Vector data structures are used to represent and attribute individual characteristics on the Earth's surface. Vectors are made up of vertices, which are discrete geometric points (x, y values) that determine the shape of a spatial entity. The sort of vector we're working with is determined by how the vertices are organized: point, line, or polygon (Data Carpentry, n.d.).

Abbreviations

ADHS: Appalachian Development Highway System

ARC: Appalachian Regional Commission

CO: Carbon monoxide

dBA: A-weighted decibels

DSS: Decision Support System

EIA: Environmental Impact Assessment

GDP: Gross Domestic Product

GIS: Geographic Information Systems

Ha: Hectare

HC: Hydrocarbons

km: Kilometer

LULC: Land Use/Land Cover

m: Meter

MSS: Multispectral Scanner

NOx: Nitrogen Oxides

Pb: Lead

RGB: Red Green Blue

ROI: Region of Interest

RS: Remote Sensing

SDG: Sustainable Development Goals

SO2: Sulphur dioxide

Sq Km: Square Kilometer

TM: Thematic Mapper

UTM: Universal Transverse Mercator

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1-Introduction

After being settled, humans established transportation networks to link their settlements with agricultural fields and mines and between human settlement to exchange goods. Early examples of human-made roads can be seen in numerous archeological sites from ancient cultures in all continents. But the most unprecedent development of such road network have occurred with the popularization of cars in the 20th century. Roads as a type of transportation infrastructure bring population, and the new population induce development (Mansuroglu, Kinikli, & Yilmaz, 2010). There is a simultaneous relationship between land development and the condition of transportation infrastructures. Unwanted and irregular land development has been an issue for urban planners and policy makers for many years. However, it should be mentioned that the relationship between transportation improvements and land use changes is complex and includes different social, economic, political and environmental elements and this research is particularly focused on how to detect and assess land use changes produced by the improvement of highways from a retrospective (historical) perspective in Stavanger area between 1968 and 2019.

Detecting and recording land use change is a principle to about any resource management or local policy program in order to get estimation of happened change, its impacts and causes, prediction of future change and avoid undesirable alterations. Therefore, local planning organizations need timely and precise information on current land cover and land use. Conventional surveying and cartography methods cannot meet the required information in a rapid and cost-effective way. The progress of computer technology, improved techniques of data provision, enhanced software and falling costs of computer hardware have made it affordable to introduce new methods for spatial data analysis. Moreover, the combination of remotely sensed information and other resources of data enhancement quality have allowed significant effectiveness, rapidity and cost-effectiveness of the land use monitoring systems (Michalak, 1993).

Combination of photogrammetric data and GIS was employed in this research study as the technique to produce land use maps and detect happened changes through the time period. Although in terms of theory, land use change monitoring seems probable but it has been more difficult in reality to automate or predict (Klosterman, 1990). According to (Worrall, 1990), the primary test of the functionality of GIS in land use change should be based on an evaluation of its contribution to the progress of a more reacting policy and to the more efficient planning of urban regions. So, GIS in specific relevant to land use change analysis must meet several standards, such as high quality and accuracy of data (responsibility), incidence of monitoring which should resemble the harmony of urban and regional change (periodicity), regulated data structure (portability), and comfortability of function and recovery (flexibility).

The most difficult and costly part to function an applied GIS is data provision and integration (TROTTER, 1991) as I experienced in this thesis project before I started my analysis. It is evaluated that up to eighty percent of time and expenses related to extending GIS are spent on database provision and integration (Michalak, 1993).

In theory, GIS is specifically useful for land use monitoring research because it can provide and overlay multiple pieces of information in a digital format to link geographic position of the place with different qualitative and quantitative information of the place , so no need for expensive and error-probable analogue methods. The quality and accuracy of land use information obtained from remote sensing (RS) is sometimes low for GIS tasks (C. Lo & Shipman, 1990; TROTTER, 1991) although for this thesis project, aerial photos have been used to extract land use information instead of RS sources due to lack of RS data in 1968 and this led to considerably spend more time for interpretation of black-white aerial photos in 1968 to obtain land use map for that time compared to automated computer algorithms in remote sensing, which are less time-taking to extract land use layers. However, this extra time spent for production of land use of 1968 was quite worth since the output of this method has basically more accuracy and quality than automated computer-based methods in RS.

1-1-Problem framing

New roads may bring progress in underdeveloped areas, sometimes considerably influencing vulnerable environments and the lifestyles of local people. Motor vehicle usage has increased fast which leads to the fact that transportation is currently a main problem for environment and monitoring its effects is inevitable to reach sustainable development goals (Mansuroglu et al., 2010).

Another problematic matter is urban sprawl which is environmentally disruptive and economically costly. If societies want to achieve carbon-neutrality in the following decades, this phenomenon needs to be addressed. New roads and improved roads are most likely necessary. However, urban sprawl is not necessary, neither desirable. So, a crucial issue is how to disentangle urban sprawl from road improvement. We need to understand this phenomenon better to prevent it from happening in the future. Thus, we need to gain insight into how it has been produced in the past. The new ferry-free E39 will probably bring more urban sprawl if the necessary studies and measures are not taken.

The fact is that highway provides more choices to choose for residents than other transportation sorts, so the highway networks and human actions increased interconnectedly. Human actions inside a landscape mostly bring up change or loss of land cover types, breakage of habitats, turning the left land cover into more remote and smaller, interrupting wildlife streams and vegetations. Transportation decisions have impacts on land use forms and arise economic, social and environmental effects. Highways often bring significant economic and social profits, but they can have also considerable adverse effects on settlements and the nature. Any primary highway or other transportation infrastructure affect the environment in various ways. Population and properties might be affected in a dominant way since they are in the direct exposure of road activities. People can also be indirectly influenced by highways, by the interruption of livelihood, change or losing of accustomed travel ways and community linkages, raises in breathing issues because of air pollution, and damage due to accidents. Direct and indirect effects of highways on the environment by the use of transportation facilities and highways themselves can also be assessed in an environmentally concerned research like (Mansuroglu et al., 2010).

There is a rising awareness for highway projects worldwide due to some increasingly adverse environmental effects of highways. Some of these negative effects are ruining ecosystems, noise pollution, loss of agricultural lands, displacement of large number of populations, interruption of local economies, change of demographic patterns, over urbanization and existence of disease. To combat these impacts, a solution that considers the natural properties of highway path and land use developments at planning step is significant (Mansuroglu et al., 2010).

Highways bring accessibility to rural or far businesses faster and create an improvement in the regional service and construction economies. However, they trigger to change land cover by construction and induced development. In result, highway investment policies usually result into land use conflict so to address this issue, it is important to investigate how they have changed land use types (Helling, 1997; Moon, 1994).

Direct effects are made by the highway itself referred to as highway construction processes such as land occupation, loss of vegetation, and cutting of agricultural areas. Indirect effects are referred to as influences on the environment which are not an instant outcome of the project, probably created some extent away from the location of the project so they can have impacts on bigger geographical regions of the environment than predicted through period of time (Mansuroglu et al., 2010).

1-2- Aim of the Thesis and Research questions

The purpose of this Master thesis is mainly how to detect and assess land use changes created by the highway improvements on the area of Stavanger municipality from 1968 to 2019 then investigation of impacts and causes of these changes through the time period. The output of this research can contribute to urban planners and policy makers for Stavanger region to have control and prediction of upcoming changes and actively improve local planning systems and regulations based on learning from the past experiences and existent change trends in harmony with sustainable development goals (SDGs). It has also tried to find the interactive relationship between land use change, population growth and economic development in the area through the time span although this side of the research might be pursued more in further research programs which are particularly focused on socio-economic concepts than land use monitoring techniques.

However, it should be mentioned that the relationship between transportation (highway) improvements and land use changes is complex and includes different factors such as social, economic, political and environmental elements. Additionally, since its results would be specific due to the different Stavanger land development determinants through the period of the time, then they will not be “homogenous through time” like outcomes of a science research. Therefore, the result of this project is more an indication of land use change potential relative to the location and proposed highway improvements than being a general predictive land use model. The procedure of this project can be exerted as a sample for the other municipality areas in Norway or even any area in the world. The result will also matter and can be extended for any further research or interested outsiders in the field of urban change in Stavanger (Checkland & Holwell, 1998; Moore & Sanchez, 2000).

Two research questions have been chosen for this master thesis which are:

1. How have highway improvements changed land use types in Stavanger? What were the drivers of change?
2. What lessons can be learned for other road developments in Norway?

2-Literature review

In this chapter, first, several research fields in the area of land use body of knowledge have been reviewed to get familiarized with different fundamental research concerns in this science. Second, to get inspiration to better structure of research methodology and procedure of analysis for this master thesis, three similar studies have been explained here. Each of them has distinctive methodology, data acquisition and research goals although the topics of land use changes, change detection and impacts of highways on land use changes are common among them.

2-1-Main Research Areas

According to (Elzbieta Bielecka, 2020), three research fields have been mostly observed in the land use science mapping based on academic citations and bibliographic documents as:

1. Land use change documentation, particularly the evaluation of land progress and directions like urban development, deforestation, agricultural changes and the reasons of land use change.
2. Land use alterations related to the changes of environment, such as water, soil, climate and ecosystems.
3. Anticipation of land use in the future regarding socio-economic and geographical factors.

The quantitative and qualitative evaluation of where, when, and why local, land cover alterations have happened has been a main research concept chosen by many researchers. During the last three decades, there has been a rise in the quantity of studies focused on land use changes in an obvious spatial way, particularly urbanization and agricultural intensification, also the results of these processes, like deforestation and loss of agricultural land. Explanatory studies of land use alteration are basically necessary as a first pace into more applied GIS spatial analyses. Satellite images, photogrammetric photos, topographic maps, and land use datasets extracted from remote sensing data were the major sources of land use change category. Scientists emphasized that the collaboration of GIS and remote sensing enables us for an efficient illustration of land use heedless of the place and scale of the research (Elzbieta Bielecka, 2020).

The literature (Elzbieta Bielecka, 2020) presents a wide range of land use change prediction models. Most of them are based on deterministic methodologies that are only concerned with one type of land flow, such as deforestation, urbanization, and agricultural land loss. They adjusted the study procedure to the specific research subject, as (Lambin, 1997) points out. Many articles examine land use change models in detail, as well as providing an overview of the software packages that can be used to run these models (Noszczyk, 2019).

Several papers include in-depth evaluations of the benefits and drawbacks of technologies that utilize a spatially explicit LULC model (Mas, Kolb, Paegelow, Camacho Olmedo, & Houet, 2014; Michetti & Zampieri, 2014). Because of the complexities of land use change modeling, a wide range of methodologies have been used. The aims, assumptions, modeling methodologies and computational techniques, the geographic locations of the investigation, and the data employed all influence the models (Michetti & Zampieri, 2014).

(Michetti & Zampieri, 2014) differentiate three types of LULC models: geographic, economic, and connected models. Geographic models' strength is in presenting the spatial dimension and biophysical limits of land use change, whereas constraints originate from a lack of consideration of socioeconomic issues, endogenous land use change determinants, and, lastly, a lack of climate and economic system response. According to the authors of this reference, economic models do not account for geographical differences in biophysical land use since land use allocation is only based on market structure. The connected models are more advanced tools because they take into account human and geographic responses by combining the economy and the geosphere into one framework, and Lastly, they can examine changes in land use on a long-term basis in any geographic location, from local to global (Michetti & Zampieri, 2014; Noszczyk, 2019). Regarding this literature, the current master thesis research comes to first type of models although it is tried to consider relevant socio-economic sides as well.

Land use and land cover are two notions that are interrelated. Land use is defined by (Anderson et al., 1976) as "man's activities on land that are directly tied to the land," which frequently shows economic linkages. Land cover is also defined by Anderson (1976) as "the vegetational and manmade constructions that cover the land surface." As a result, a land use type can also be regarded a type of land cover. Land cover, on the other hand, may not always correctly reflect land usage. In general, remote sensing applications acknowledge land use as a kind of land cover, despite the fact that the two are frequently employed interchangeably or in conjunction with one another in terms, like land use/land cover or LULC (Land Use Land Cover) (Jansen & Gregorio, 2004; Loveland & DeFries, 2004). Land use and land cover data are useful to a wide range of people, including planners, government agencies, policy and decision-makers, the general public, and scholars who use it to better comprehend the intricacies of the earth's surface (Anderson et al., 1976; Campbell, 2002; Kempka, Lackey, & Green, 1994).

To standardize classification standards, (Anderson et al., 1976) develop the land use and land cover classification system. The use of remotely sensed data hinder communication between planning agencies and government authorities, despite its benefits in understanding the earth's surface. This extensive classification method allow a broader audience to analyze and compare information, efficiency in time and budget (Jansen & Gregorio, 2004). (Anderson et al., 1976) identifies nine different categories of land use and land cover: urban or built-up; agricultural land; rangeland; forest land; water; wetland; barren land; tundra; and perennial snow or ice.

The conducted investigations were divided into three main research topics, namely documentary, explanatory, and predictive, according to the systematic literature review. The analysis of land use change, the portrayal of land flows and paths, and the identification of the causes and impacts of land use changes were the focus of documentary (descriptive) research. It also contained a comprehensive analysis of land-use-related landscape changes, such as landscape fragmentation, habitat destruction, and natural ecosystems.

For a first step toward more advanced GIS spatial analysis, descriptive studies of land use change are often required. However, recognizing the observed land use changes and making decisions on effective strategies to deal with the negative implications of these changes is insufficient. Explanatory studies try to fill in the gaps. The relationship between land use change and environmental or ecosystem changes, including climate, soil, water, and ecosystem services, was the focus of explanatory scientific documents. Forecasting research, on the other hand, have focused on simulating scenarios and estimating future land use based on geographic information and socio-economic elements.

Land use change techniques and models range from the most basic to the most advanced, and they all link to geographical space either directly (explicitly) or indirectly by giving their geographical identity to the examined region. In brief, Different techniques to spatial modeling and analysis of land use changes and their environmental effects provide a comprehensive picture of today research trend and unsolved difficulties. The literature (Elzbieta Bielecka, 2020), adds to discussions about GIS-based land use change modeling and the causes of land use change, as well as the implications of these changes and it is expected to generate additional debate about a complicated modeling technique that begins with an assessment of current land use trends and anticipates land use changes using different strategies, as well as the influence of local land use change on the global environment.

2-2-Similar Case Studies

Now after reviewing mainstream research trends and some fundamental study concepts in the area of land use changes, we go through three different case studies relevant to impacts of highways on LULC changes but with different research goals. The first and second one consider more the patterns of physical changes of LULC related to specific distances from roads progress and to some extent, try to find interactive consequences between them and any human processes like infrastructure investments on highways (Day, 2006a) and urbanization (Jedlička, Havlíček, Dostál, Huzlík, & Skokanova, 2019) while the third one is more focused on finding various direct and indirect environmental impacts of a highway in its study area (Mansuroglu et al., 2010).

2-2-1-Assessing the Impact of Highway Development on LULC Change in Appalachian Ohio

Based on the first one (Day, 2006a), As shown in Figure.2. 1, this research followed a methodology that includes five primary phases of analysis: data collection, image processing, image categorization, change detection, and outcomes evaluation. Within these five phases, there were other sub-operations. The research began with the acquisition of six satellite photos taken between 1976 and 2002. In phase 2, these photos were combined and statistically analyzed to create a total of two images depending on their individual projection years. These two photos were categorized in phase 3 to create land use/land cover maps. For change detection, the majority of phase 4 contains various comparisons among maps.

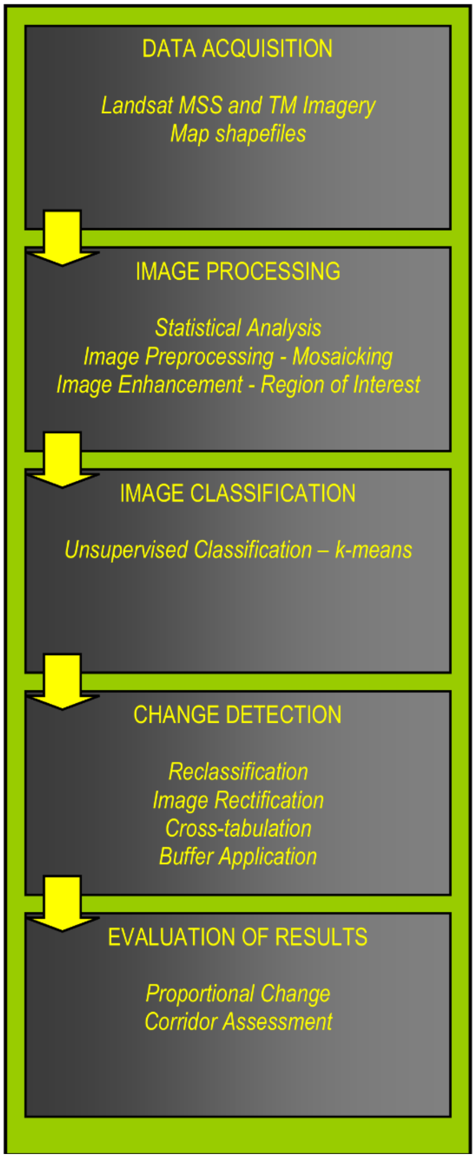

Figure.2. 1.Methodology Schematic in (Day, 2006a)

Several applications were employed to assist in the execution of this investigation.

System	Function
ArcMap 9.0	Creation of Shapefiles; conversion of images to EMF's
Environment for Visualizing Images (ENVI 4.0)	Stacking raw data; mosaicking images; statistical anaylsis; unsupervised classification; buffer analysis
Idrisi Kilimanjaro	Change detection
Nikon Coolpix 7900	Ground photography

Table.2. 1.The systems used in land use investigation and their functions in (Day, 2006a)

2002 *Landsat TM*		**1976 *Landsat MSS***	
Path 18, Row 33	August 10, 2002	Path 19, Row 33	August 8, 1976
Path 19, Row 33	August 1, 2002	Path 20, Row 33	August 19, 1976
Path 20, Row 33	August 8, 2002	Path 21, Row 33	August 20, 1976

Table.2. 2.Image data acquired for LULC detection (Day, 2006a)

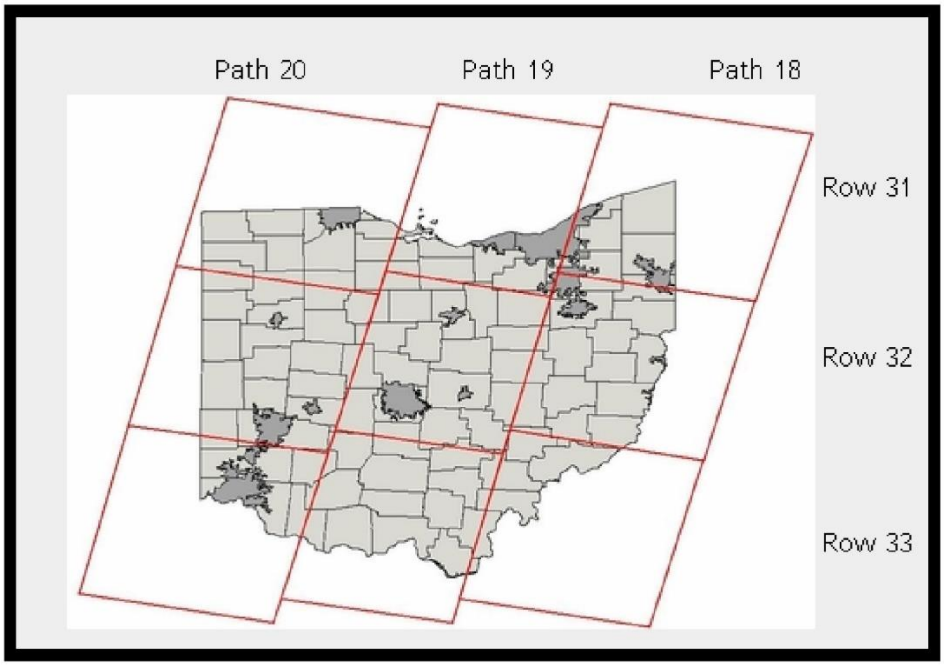

Figure.2. 2.Landsat 5 and 7 Path/Row orientation (Day, 2006a)

To catch contrasts between urbanized development and non-urban regions, this study required leaf-on photos (at a time of year when vegetation is at its peak). Data availability, a similar time gap across study years, limited cloud cover and/or atmospheric noise, and sensitivity to anniversary dates were among the other selection process.

Regarding remote sensing data, two satellite image series were employed in the research. First, Landsat 5 which detects seven color, thermal, and infrared spectral bands, as well as one panchromatic band, as a Thematic Mapper (TM). Second, Landsat 1 (MSS) which collected Red, green, and two near-infrared bands. As seen in Figure.2. 3, when bands are stacked together, composite images are created. This composite of bands 1, 2, and 3 provides a "genuine" representation of the land cover.

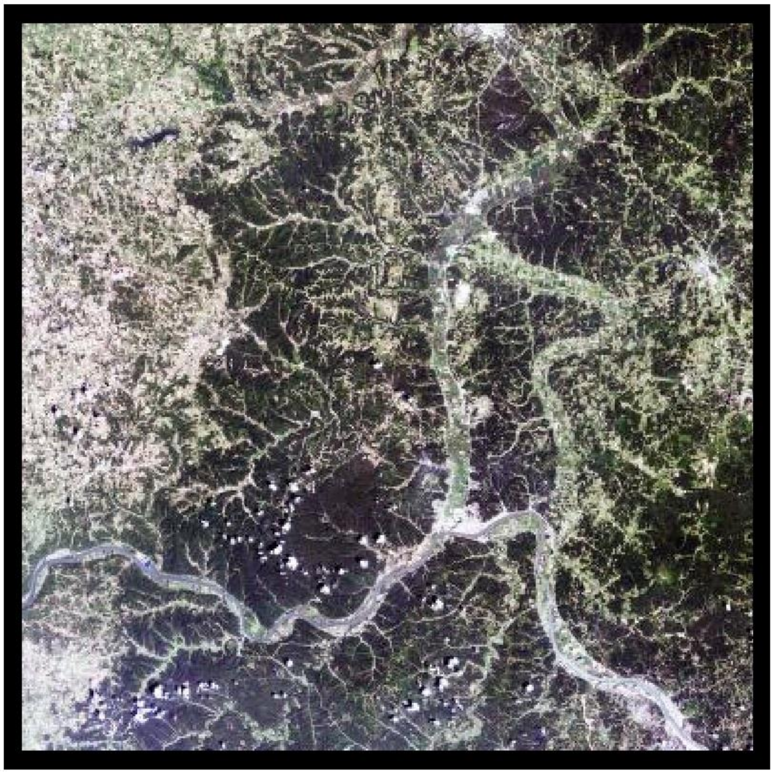

Figure.2. 3.True color composite of path 19/row 33 taken August 1st, 2002 (Day, 2006a)

The previously obtained images required various operations to acknowledge and/or adjust for any possible discrepancies within the raw data in preparation for comparison and change detection. Varied preprocessing algorithms, statistical analysis, and image transformation were required due to the mixed sources of imagery, multiple path/row configurations, and varied acquisition years. In the software ENVI 4.0, chosen bands inside the file were layered to form a path/row image. Layer stacking is essential to compare spectral qualities of each band as well as create composite images from multiple bands. Layer stacking was vital to compare the spectral properties of each band and to build composite images from many bands.

All three photos from each year were combined to make one single image in this study. This procedure, also called as mosaicking, necessitates that all images be projected with identical coordinates (Jensen, 2005). Landsat images were projected in Universal Transverse Mercator (UTM) zone 17 ground coordinates after recording to adjust for any geometric distortions caused by recording errors.

(Lillesand & Kiefer, 2000) also recommended applying radiometric corrections to photos collected at different times of the day or in different places to avoid errors caused by the sun's angle and/or the platform sensor. When comparing photos from California and Ohio, for example, sun elevation and earth-sun distance modifications are required. The photos in this investigation were separated by no significant distance or time. As a result, no radiometric corrections were used in this research.

A region of interest (ROI) was created from county boundaries in Southern Appalachian Ohio to ease processing and establish a more applicable classification of the study area. In the software ArcMap, a shapefile including fifteen of Ohio's 29 Appalachian counties (Adams, Athens, Brown, Clermont, Gallia, Highland, Hocking, Jackson, Meigs, Morgan, Pike, Ross, Scioto, Vinton, Washington) was constructed and loaded into the software ENVI 4.0 based on their closeness to the highway. By cropping the image to the most relevant counties, this ROI provided a manageable data collection when applied to the mosaics. Statistical analysis in remote sensing delivers hidden information that could be beneficial in future processing methods. Two major analyses were incorporated in this methodology: a basic statistical review and feature extraction.

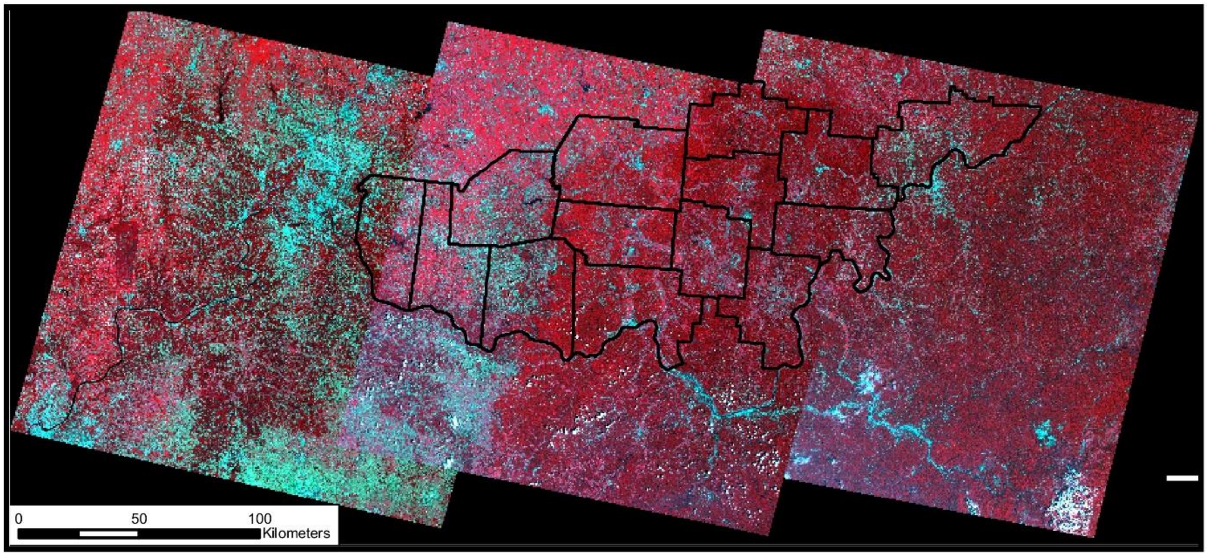

Figure.2. 4.2002 mosaic of paths 18, 19, and 20/row 33 with study area outline

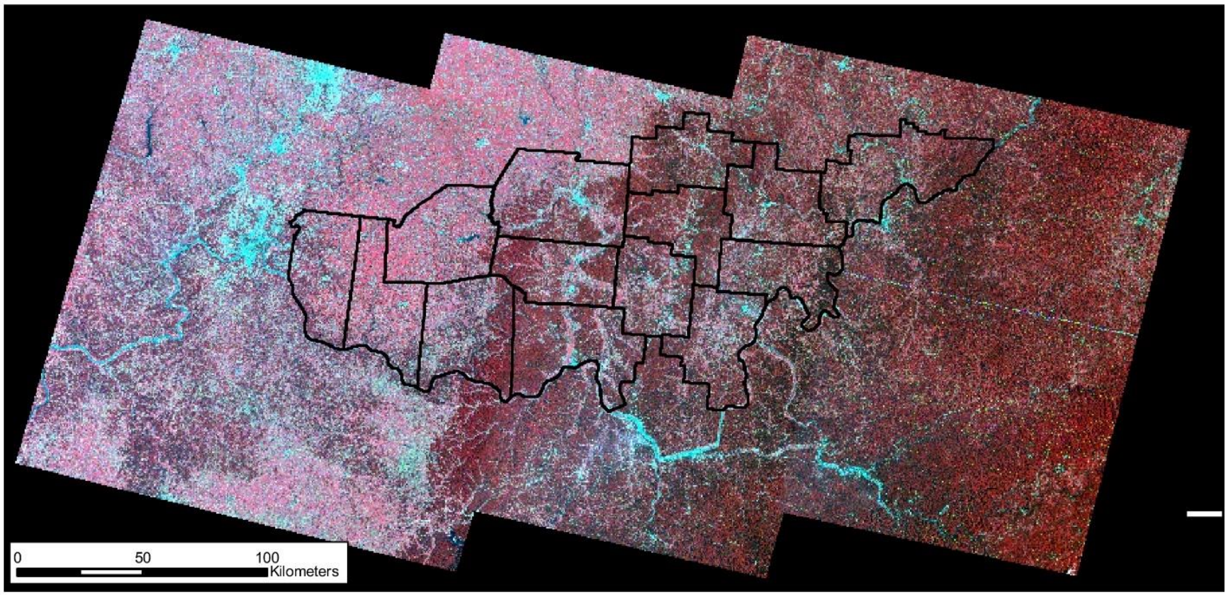

Figure.2. 5.1976 mosaic of paths 19, 20, and 21/ row 33 with study area outline (Day, 2006a)

The translation of spectral classes to informational classes can be thought of as categorization. Patterns or groups of pixels with the same spectral value are defined as spectral classes. The spectral classifications that are recognized as a certain land use/land cover are known as informational classes. However, not all spectral classes correspond to specific informational classes, highlighting the importance of human contribution. Supervised and unsupervised classification are the two most often used classification methods. The study's nature necessitated the use of unsupervised categorization.

Each year produced an image with the required number of spectral classes. Within a reflectance range, each class indicated a land cover. Each spectral class was then classified as one of five distinct land covers or informative classes using ENVI 4.0's class color mapping and image connecting functions: water, agriculture/grassland, high density urban, low density urban, and forest. The classification basis was according to (Anderson et al., 1976).

Clouds and various weather conditions were visible, especially in the photograph from 2002. The clouds can be spotted in the study area's south-central region. Some parts of the clouds were classified as high-density urban land cover using unsupervised classification. Most of the cloud mass was divided into separate categories. These pixels, as well as the region outside the research region, were classed as having no data.

Change detection basically exposes one of two things: the location of the change and/or the pace of change. In this literature example, determining rate would have necessitated the use of additional photographs at particular intervals during the research period. Due to a lack of high-quality images, this analysis was limited to a study of location change alone.

The software Idrisi Kilimanjaro was used to reclassify the pictures from 1976 and 2002. Each spectral class was physically compressed into the five informative classes indicated above using the reclass function. Reclassification yielded statistical findings for each class as well as for the whole image. The preparation for change detection was completed when various spectral classes were merged into five primary informative classes, and cross tabulation began. The 2002 image was utilized as the source image for comparison with the 1976 image. Cross tabulation compares two photographs of exact geographical location depending on their qualitative, or informative, characteristics. This function categorizes data into two categories: change and no change. It was observed what kind of alteration had occurred. Agriculture/grassland to high-density urban; woodland to forest were among the 48 possible class changes or no changes.

State Route 32 was constructed as a shapefile in the software ArcMap 9.0 and spans the length of the study region. The file format was adapted for usage in the software Idrisi Kilimanjaro, mostly to act as a line of reference for equivalent distances. On each side, a 10-kilometer buffer was built (see Figure.2. 6). This marked the boundary between the territory within 10 kilometers of the road and the area beyond the buffer zone. This 10 km buffer was placed onto the final cross tabulation image to show State Route 32's immediate influence on land cover change. Outside of the buffer zone, the data turned into unclassified and didn't fit into any of the land cover categories. A 20-kilometer buffer was used to repeat the process.

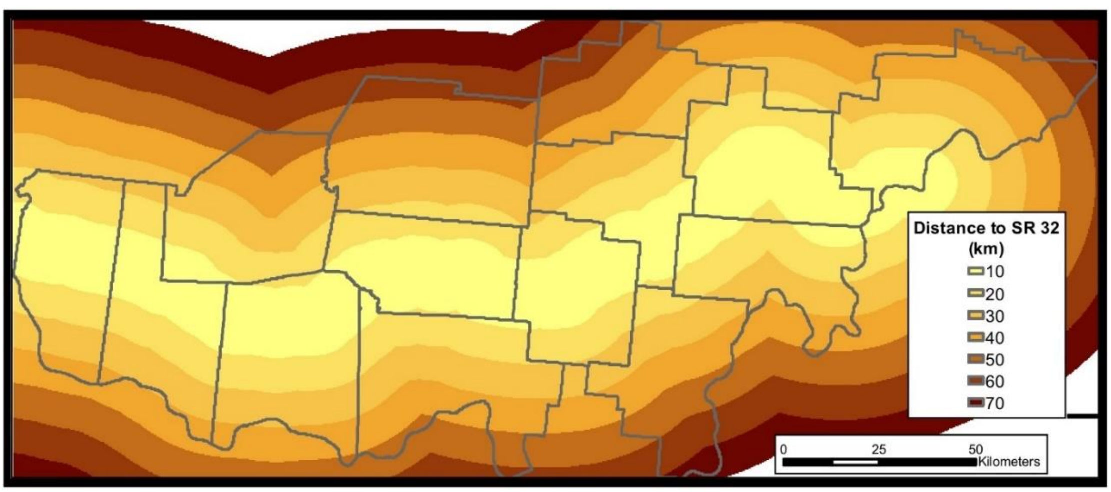

Figure.2. 6.Delineation of buffers at 10 km intervals surrounding State Route 32

This analysis uncovered some intriguing facts about land patterns in Appalachian Ohio during a 26-year span using its change detection methodology. Classification, visual examination, cross tabulation, and the designation of a buffer zone along the corridor were used to reach the results.

The study region was divided into two land use/land cover maps, one for 1976 and the other for 2002. Table.2. 3 shows the components of each map, as shown in Figure.2. 7 and Figure.2. 8.

The results show that the overall area of forest, low-density urban, and water has risen as a result of the comparison of these photos. 664,235 pixels were added to the forest, 26,931 pixels to low-density urban, and 7334 pixels to water. In 1976, agriculture/grassland (3,100 pixels) and high-density urban (332,974) had more pixels than in 2002.

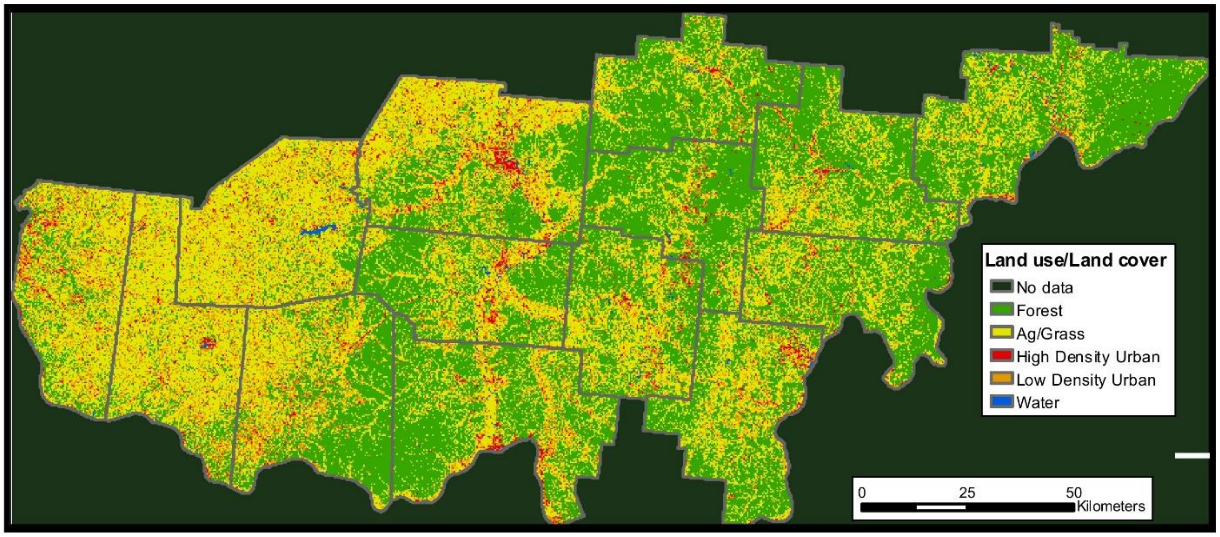

Figure.2. 7.1976 Land use/land cover of study area (Day, 2006a)

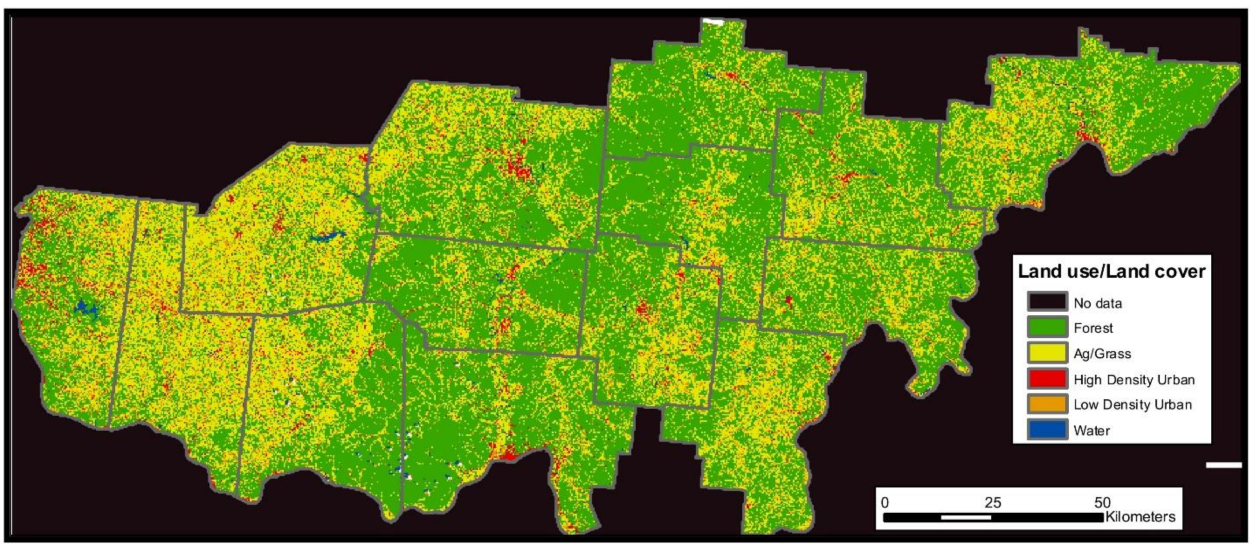

Figure.2. 8.2002 Land use/land cover of study area (Day, 2006a)

	FOREST	AG/GRASS	HDU	LDU	WATER
1976	2600973	2247245	165927	365899	30127
2002	3265208	1914271	162827	392830	37461

Table.2. 3.Density of land use/land cover categories by year (Day, 2006a)

The cross-tabulation findings of raw data from 2002 versus raw data from 1976 are shown in Table.2. 4. The descriptive classes for land cover in the far-left column correspond to land cover in 1976, while the descriptive classes in the top row correspond to land cover in 2002. The data outlines the overall change in pixels over the 26-year study period when put into a matrix. For example, 995,667 pixels shifted from agriculture/grassland to forest land cover between 1976 and 2002, while only 61,753 pixels changed from high-density urban land to forest. The forest category had the most noteworthy "no change," with 1,864,342 pixels remaining forest throughout the research period (see Figure.2. 9). The last row shows how many pixels were used to create each land cover category. The least amount of change occurred in water. The quantity of pixels from a single class that contributed to change in all five classes is shown in the last column of Table.2. 4.

2002 / 1976	FOREST	AG/GRASS	HDU	LDU	WATER	*TOTAL*
FOREST	1864342	558295	35503	110517	11093	***2579750***
AG/GRASS	995667	958429	68918	194529	9539	***2227082***
HDU	61753	68356	15505	16174	1698	***163486***
LDU	267970	290429	32258	62709	4746	***658112***
WATER	11202	6481	2021	1496	4011	***25211***
TOTAL	***3200093***	***1881990***	***154205***	***385425***	***31087***	***5710171***

Table.2. 4.Raw cross-tabulation of 2002 (columns) against 1976 (rows) (Day, 2006a)

Idrisi Kilimanjaro was also used to provide proportional cross-tabulation findings. The influence of each between-class alteration (or no change) on the total change is depicted in these illustrations. For example, as indicated in Table.2. 5, the transformation of forest to agriculture/grassland stood for 0.0978, or 9.78 percent, of all change between 1976 and 2002. Moreover, over that same 26-year period, 32.65% of the forest remained forest. The most noteworthy "no change" conversion is this one. Agriculture/grassland remained agriculture/grassland by just under 17%, the only other major "no change" response between classes.

2002 / 1976	FOREST	AG/GRASS	HDU	LDU	WATER	*TOTAL*
FOREST	0.3265	0.0978	0.0062	0.0194	0.0019	***0.4518***
AG/GRASS	0.1744	0.1677	0.0121	0.0341	0.0017	***0.3883***
HDU	0.0108	0.0120	0.0027	0.0028	0.0003	***0.0286***
LDU	0.0469	0.0509	0.0056	0.0110	0.0008	***0.1152***
WATER	0.0020	0.0011	0.0004	0.0003	0.0007	***0.0045***
TOTAL	***0.5606***	***0.3295***	***0.0270***	***0.0676***	***0.0101***	***1.0000***

Table.2. 5.Proportional change and no change among the land use/ land cover categories (Day, 2006a)

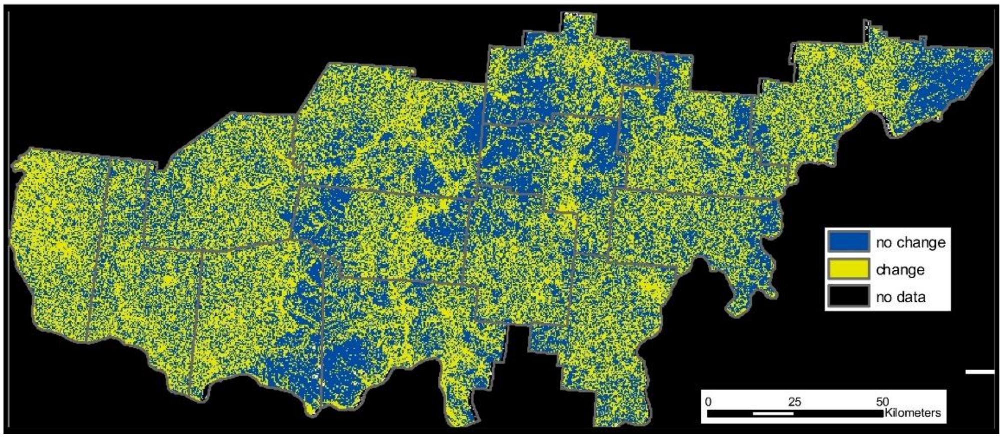

Figure.2. 9.Cross-tabulation change versus no change (Day, 2006a)

A 10- and 20-kilometer buffer were used to the cross-tabulation outcomes to connect frequency of change to highway proximity (applied to 2002 land cover images in Figure.2. 10 and Figure.2. 11). The 10 km buffer statistics would have increased in the 20 km buffer area assuming all class changes were uniform across the research region although change was not uniform. These findings have consequences for the efficacy of State Route 32's route across southern Appalachia.

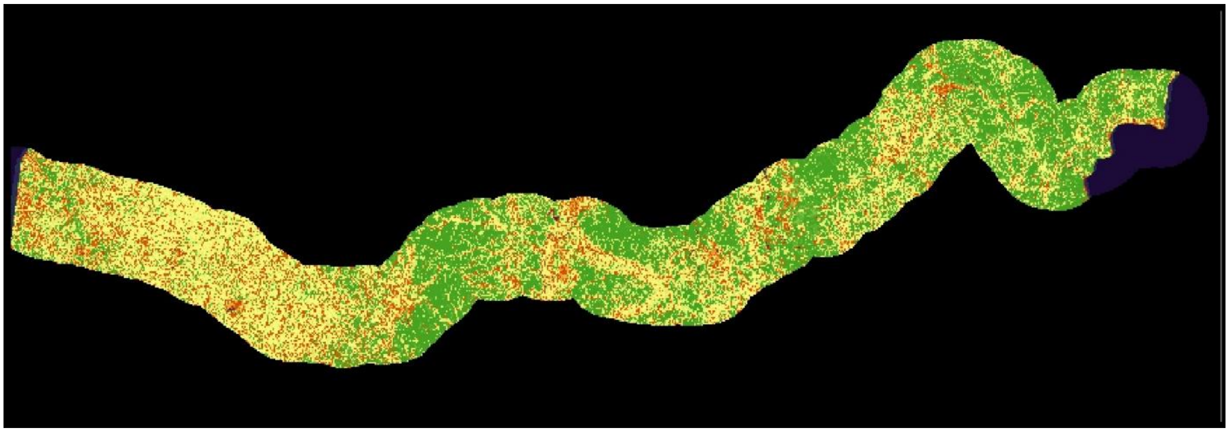

Figure.2. 10.2002 land cover present within 10 kilometers of State Route 32 (Day, 2006a)

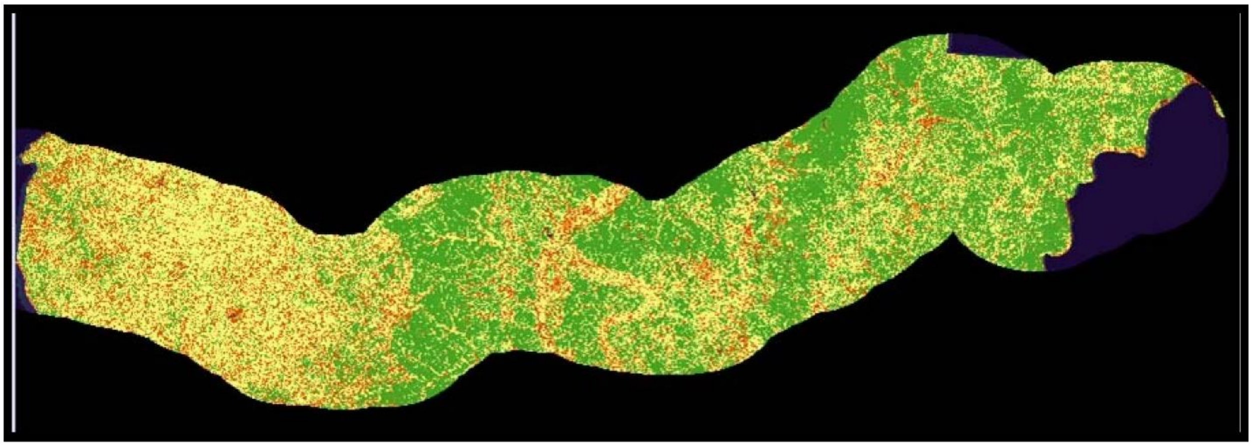

Figure.2. 11.2002 land cover present within 20 kilometers of State Route 32 (Day, 2006a)

In the cross-tabulation exercise, the far-left column denotes a change in class. The left number in the second column reflects the land cover in 2002, while the right number indicates the land cover in 1976. The frequency of occurrence is indicated in the third, fourth, and fifth columns. The 10 km buffer column displays the number of pixels that fell into each of the 48 land cover change classes. The projected 10 km column is simply the former column multiplied by two to reflect change if it were uniform across the research area.

Take note of the rows that have been highlighted in yellow. When the projected or predicted values in the 10 km buffer region were compared to the actual change in the 20 km buffer region, the class changes were bigger in the 10 km buffer region. In the remaining two rows, however, more change happened in the 20 km area when compared to the 10 km predicted or expected values, as noted in green. When agriculture/grassland became forest and forest stayed forest, for example, change was more prominent in the greater buffer region. Ultimately, the 10 km corridor zone had more urbanization, but the 20 km corridor zone saw more conversion from urbanized or barren land to forest.

		FREQUENCY		
CLASS CODE	2002 | 1976	10-km (buf1)	*(PROJECTED) 10-km AREA x 2*	20-km (buf6)
15	forest | forest	412846	*825692*	870259
16	ag/grass | forest	154976	*309952*	301488
17	HDU | forest	11434	*22868*	20105
18	LDU | forest	31137	*62274*	59563
22	forest | ag/grass	168531	*337062*	512989
23	ag/grass | ag/grass	276450	*552900*	525700
24	HDU | ag/grass	24990	*49980*	40296
25	LDU | ag/grass	60093	*120186*	110003
29	forest | HDU	16456	*32912*	30657
30	ag/grass | HDU	19779	*39558*	35933
31	HDU | HDU	4738	*9476*	6653
32	LDU | HDU	5100	*10200*	8582
36	forest | LDU	70975	*141950*	138350
37	ag/grass | LDU	84310	*168620*	158789
38	HDU | LDU	11328	*22656*	17629
39	LDU | LDU	19184	*38368*	34395

Table.2. 6.Ten and twenty Kilometer corridor frequencies according to class changes

In the late 1960s, the Appalachian Regional Commission (ARC) started work on the Appalachian Development Highway System (ADHS), a 2,300-mile highway system designed to address the historical disparities that exist in Appalachia. The ADHS was designed to reduce physical isolation by increasing access to areas with development opportunities for people and enterprises.

However, the ARC's aim of increasing development as a result of infrastructure investment seems not to have been met in comparison to the amount of funds spent on Corridor D. Corridor D is not likely to be declared a “economically feasible” motorway even by 2025. This is in line with the study's results, which showed that the highway has had little overall impact on growth in Appalachian Ohio. These statistics, however, were purely theoretical because they were based on current economic trends (Day, 2006a).

The goal of this inquiry was to discover the pattern of land use change along the constructed roadway, as well as any consequences for infrastructure investment as a means of economic improvement. Investment on State Route 32 in southern Ohio has resulted in an irreversible commitment of resources and the environmental characteristics, as seen by the land use/land cover change outcomes. The physical impact of State Route 32 might be evaluated by examination of these results, the likelihood of future change, and the possibilities for further inquiry.

Additional explanations for the study's findings arose, some of which were unknown. As a result, change in Appalachian Ohio will need to be closely monitored in the next decades. However, as a result of these conclusions, a constant flow of information may impact or change the ARC's operations in order to carry out the ADHS's objectives.

2-2-2-Assessing Relationships between Land Use Changes and Development of a Road Network in the Hodonin Region (Czech Republic)

The research has examined the evolution of land use and a road network in the Hodonin region from 1836 to 2016. (Czech Republic). The purpose of this article was to see if there was a link between road building and land use changes in the area. At varied distances from roadways, the intensity of land use change processes between neighboring periods was computed by employing Geo-statistics and geographic information systems from the well-known GIS software developer ESRI.

This aided in determining the importance of the impact of road proximity on land use changes. Due to the lack of historical records, the time intervals for comparison ranged from 25 to 80 years. Approximately 20% of the region was influenced by land use changes in each time and following the construction of the roadways, the intensity of land use changes in the area increased.

It has been established that the presence of a road was one of the main reasons for long-term land use changes in this area. Urbanization and other human activities, agricultural intensification, and grassing were all affected by this so-called technological driving factor. Its importance was growing as a result of urbanization, industrialization, motorization, and increased mobility. Their findings from the Hodonin region showed that the distance from main roads had the strongest link with urbanization and other human processes.

Aerial images and ancient topographic maps were used to investigate long-term alterations in land use across Central Europe. Since the 1840s, old topographic maps can be used to analyze land use changes (Fuchs, Verburg, Clevers, & Herold, 2015b; Skokanová et al., 2012). Regarding that time, maps from Central Europe (the former Austrian Hungarian Empire and the Kingdom of Prussia) began to be based on extensive geodetic surveys and are consequently highly accurate.

Abiotic circumstances, landscape protection and ecological networks, the growth of water sources, visual aspects of the landscape, as well as the evolution of the food industry and other factors have all been studied in the context of long-term land use changes in Central Europe (Jedlička et al., 2019).

However, despite the fact that the development of road networks was regarded a crucial stimulus for the ongoing growth of towns and industrial locations, there were few studies relating the long-term growth of land use with road networks.

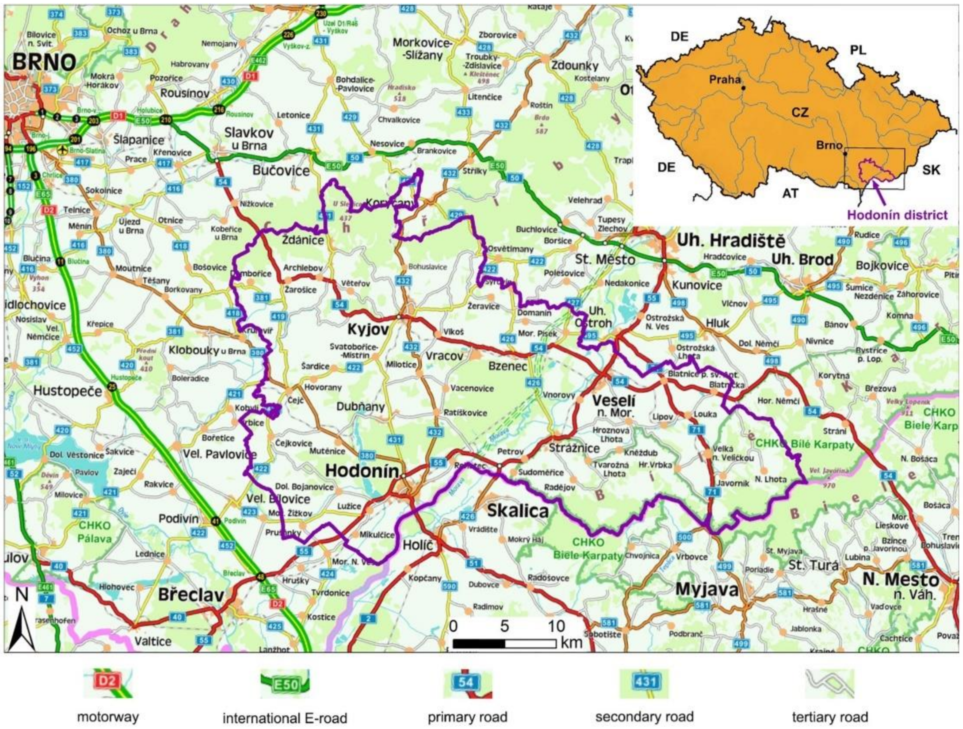

Figure.2. 12.The Hodonin model region and surroundings with important roads (Jedlička et al., 2019)

Using geographic information systems, changes in land use were examined using ancient and new topographic maps. For the analysis, five sets of topographic maps were employed to illustrate the situation in the 1840s, 1880s, 1950s, 1990s, and 2010s (Table.2. 7). Because these data sets cover the whole Czech Republic, the studies described here can be replicated using land use and road data from the same time frames in any other area in the Czech Republic.

Name of the map set	Scale	Year of publishing	Time period
The 2nd Austrian Military Survey	1:28,800	1836–1841	1840s
The 3rd Austrian Military Survey	1:25,000	1876	1880s
Czechoslovak military topographic maps	1:25,000	1953–1955	1950s
Czechoslovak military topographic maps	1:25,000	1991	1990s
Czech topographic base maps	1:10,000	2016	2010s

Table.2. 7.Topographic maps covering the Hodonin region (Jedlička et al., 2019)

Only essential routes were included in the road network, which was plotted using the above-mentioned topographic maps. Imperial roads were the most significant roads in the 19th century, but 1st class roads have been the most important roads since the 20th century. As a result, mapping focused on imperial (primary) and provincial (secondary) roads displayed in maps from the 2nd and 3rd Austrian Military Surveys, as well as roads of the 1st (primary), 2nd (secondary), and 3rd (tertiary) classes displayed on Czechoslovak military topographic maps and Czech topographic base maps (Figure.2. 13).

Figure.2. 13.Examples of the road network around the town of Veseli nad Moravou on maps from 184, 1876, 1953, 1991 with the addition of road classification to the map (Jedlička et al., 2019)

Arable land, permanent grassland, orchard, vineyard, and hop-field, woodland, water area, built-up area, recreational area, and other area were among the nine basic land use types considered (Skokanová et al., 2012). The ArcGIS software was used to build analytical digital land use maps. The Hawths Tools for ArcGIS was used to generate a hexagonal grid with 100 m between hexagonal centroids, giving each hexagon a 0.866 ha area (Figure.2. 14). In total, 164,714 polygons were produced, with only those that covered more than 50% of the model area being used for further analysis. Then, for each polygon, the prevalent land use class for each timeframe was calculated (Figure.2. 14).

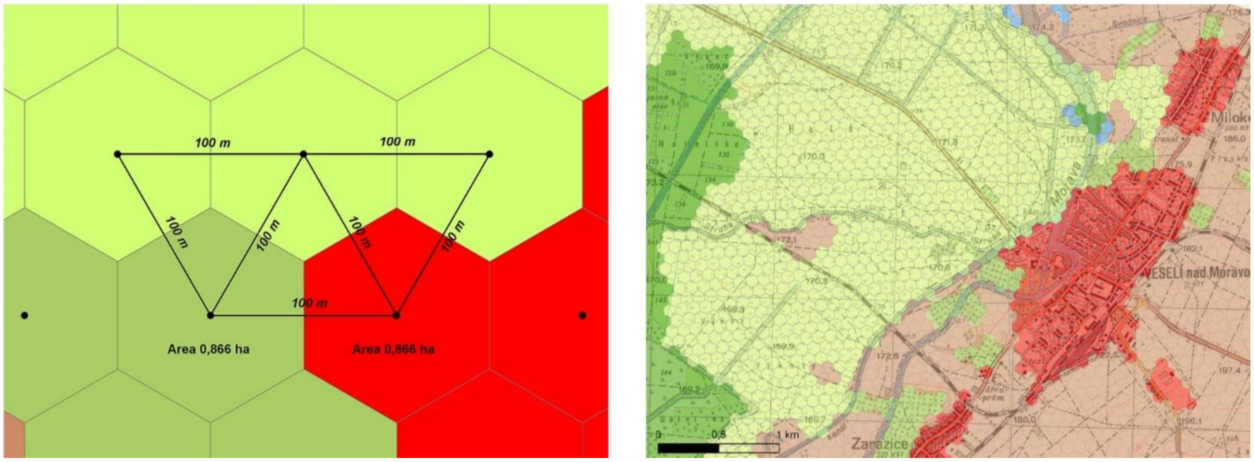

Figure.2. 14.Example of a hexagonal grid and the interpreted land use map from 1955 (Jedlička et al., 2019)

The use of a hexagonal grid to categorize land use maps allowed for land use interpretation to be more generalized, as well as the elimination of land use inaccuracies created by varied map scales and positioning errors. This prevented the development of narrow polygons, which usually depict land use changes that are driven by incorrect map drawing or interpretation rather than real changing situations.

Six types of processes were identified by analyzing land use changes between two neighboring time intervals: afforestation – the transformation of one of the land use categories into forest; grassing – the transformation of one of the land - use types into permanent grassland; agricultural intensification – the transformation of one of the land use types into arable land, orchard, or vineyard, and hop-field; the construction of water areas – the transformation of one of the land use types into water area; urbanization and other anthropogenic processes – the transformation of one of the land use types into built-up area.

At different distances from roads, land use types and land use change processes were examined using the distance ranges: 0–100 m, 100–250 m, 250–500 m, 500–1000 m, 1000–2000 m, and outside of the area of road network (more than 2000 m from a road). Land use change was evaluated in connection with highways from the same timeframe (i.e. land use from the 1880s corresponded with the road network from the 1880s). The process maps were matched to the road network from the first examined period when examining land use change processes in the neighborhood of a road network (i.e. land use change processes between the 1840s and 1880s were connected to the road network from the 1840s).

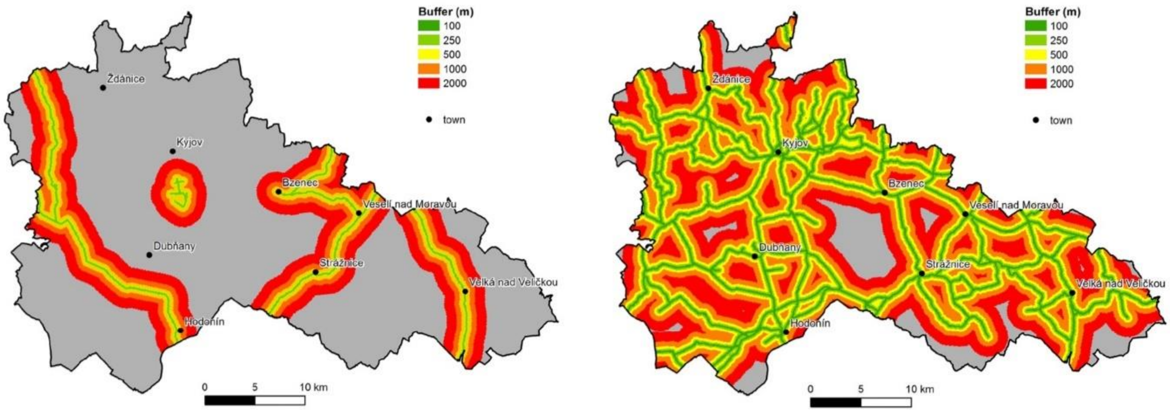

Figure.2. 15.The road network in the Hodonin region in the 1840s (left) and 2010s (right) with distance zones from a road axis

This considered the possibility that significant land use changes occurred along an existing road network. It investigated the association between the level (class) of a road and the related land use change as well as merely examining the association between land use changes and the road network. Roads and their surroundings in each period were grouped into three fundamental groups based on their prominence during that time.

Road class	Primary	Secondary	Tertiary	Total
1840s	59.5	16.8	24.6	100.9
1880s	88.3	6.4	155.0	249.7
1950s	85.2	99.3	327.8	512.3
1990s	122.1	163.3	247.8	533.2
2010s	114.4	171.8	247.8	534.0

Table.2. 8.Lengths of road classes in the Hodonin region (in km) in the 1840s, 1880s, 1950s, 1990s, and 2010s (Jedlička et al., 2019)

In the Czech Republic, the Hodonin region is a significant agricultural region. In all times, the share of agricultural land was the highest (Table.2. 9, Figure.2. 16 and Figure.2. 17). The share of agricultural land climbed to 55 percent in the 1880s, thanks to the agricultural revolution in the second half of the nineteenth century and the expansion of the food industry. In the 1950s, the collectivization of agriculture as a sort of agricultural intensification was linked to a further rise in agricultural land (by 3%). This happened not just in lowlands and hilly areas, but also in the White Carpathians and Chiby highlands. Agricultural land was changed from permanent grassland in the majority of cases. The share of arable land fell in subsequent decades (1990s and 2010s), owing to a shift to built-up areas or vast vineyards and orchards.

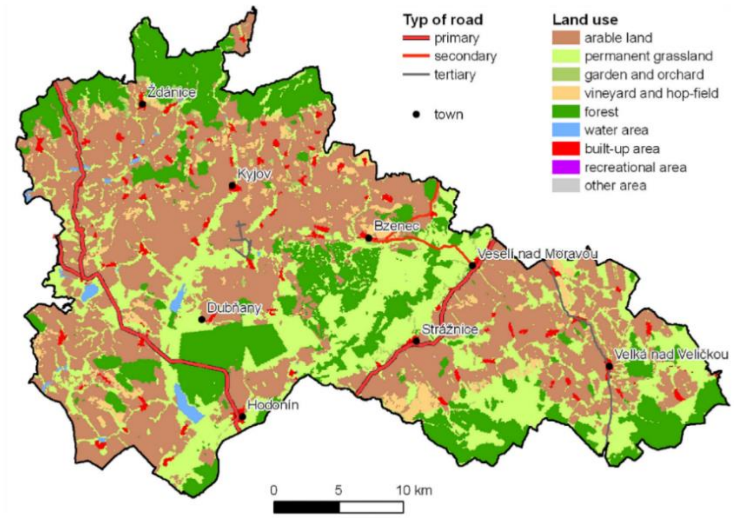

Figure.2. 16.The road network and land use in the Hodonin region in the 1840s (Jedlička et al., 2019)

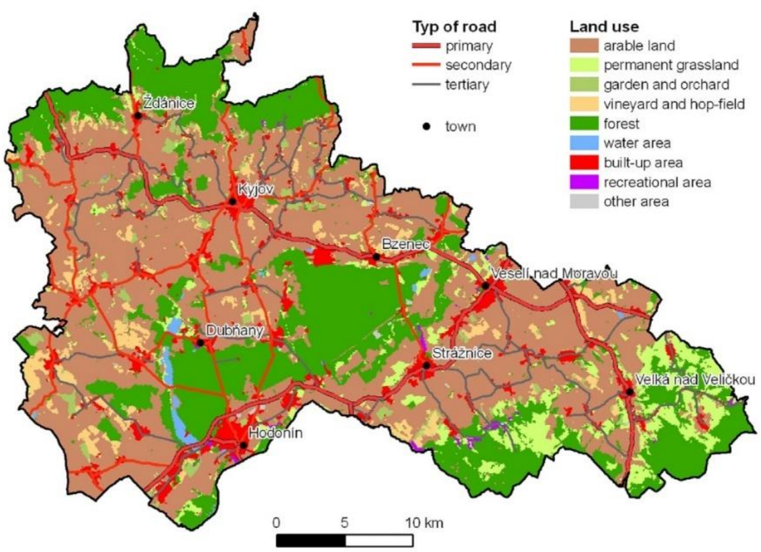

Figure.2. 17.The road network and land use in the Hodonin region in the 2010s (Jedlička et al., 2019)

Land use	1840s	1880s	1950s	1990s	2010s
Arable land	45.60	54.45	57.56	51.28	50.94
Permanent grassland	26.24	16.66	8.71	6.48	6.85
Garden and orchard	0.85	0.42	1.52	2.15	2.36
Vineard and hop-field	3.50	3.00	2.18	5.22	3.93
Forest	20.93	22.96	24.93	26.30	27.10
Water area	0.67	0.05	0.46	0.57	0.66
Built-up area	2.21	2.44	4.49	7.53	7.68
Recreational area	0.00	0.00	0.02	0.29	0.34
Other area	0.00	0.02	0.13	0.18	0.14
Total	100.00	100.00	100.00	100.00	100.00

Table.2. 9.Land use in the Hodonin region (proportion in %) in the 1840s, 1880s, 1950s, 1990s, 2010s (Jedlička et al., 2019)

Land use change techniques were used to examine changes in land use. Plots in stable use considerably outperformed plots in other periods (Figure.2. 18), with a share of nearly 80% in the first three periods. Due to the lack of historical records, the time intervals for comparison ranged from 25 to 80 years. Approximately 20% of the region was influenced by land use changes in each time. Despite the fact that the time between the two periods was only 25 years, land use changes occurred in around 12% of the region.

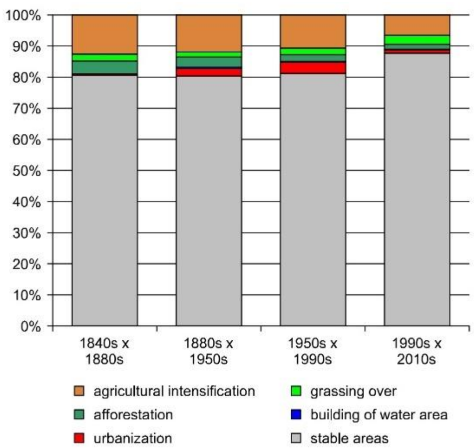

Figure.2. 18.Land use change processes in the Hodonin region in four comparative periods (Jedlička et al., 2019)

Conversion to agricultural land, orchards, and vineyards, was traditionally one of the most significant trends in the processes. Between the 1840s and 1880s, as well as between the 1880s and 1950s, when it was coupled with the afforestation of the so-called Moravian Sahara near Hodonin, afforestation was also high. Additionally, During the twentieth century, urbanization and other anthropogenic factors dominated (Figure.2. 18).

The findings from the Hodonin area showed that the distance from main roads had the strongest link with urbanization and other human processes. The connection between this category of land use change processes and road development was established, and its significance was growing with time. The need for high-quality transport linked via roads was driven by the establishment of settlements, industrial buildings, and sites, and conversely – the development of major roadways promoted the construction of settlements, industrial, and business centers.

At distances up to 1000 m from a road, which can be regarded the usual distance between built-up regions, the strongest correlation between urbanization and roads was discovered. The historical significance of road construction was confirmed as one of the driving factors of urbanization in the 19th and 20th centuries, with the dynamic expansion of population. Other authors have underlined the importance of urbanization and population mobility linked to the growth of motorization in Europe as one of the key driving factors of land use change (Ágnes, Jombach, & Filepné Kovács, 2012; Kanianska, Kizeková, Nováček, & Zeman, 2014).

In the Hodonin region, road development had a significant impact on agricultural intensification. The intensity of this process was strongest in the near vicinity of roads (up to 100 m) during the first comparison time period, between the 1840s and 1880s, but was also highly evident at other distances up to 2000 m. In the second part of the nineteenth century, the presence of good roads was seen as a benefit for transporting technical crops to industrial facilities (such as sugar plants, distilleries, and mills), and then to the nearest railway stations.

The position of scales for weighing agricultural items directly next to imperial and provincial roads demonstrated the necessity of good public transportation and incentives to convert permanent grassland to arable land. Agricultural intensification prevailed at a distance of 250–500 meters from roadways throughout the 1880s and 1950s. This was owing in part to the fact that property near roadways had already been exploited for agricultural reasons, and partly because of rapid urbanization (Jedlička et al., 2019). For all eras, there was a reduction in agricultural intensification at distances more than 2000 meters from roadways. Because such distances are remote or hilly, they were employed as constant grassland and woodlands. The outcomes of agricultural intensification in the Hodonin region matched those of (Schneeberger, Bürgi, Hersperger, & Ewald, 2007).

2-2-3- Impacts of highways on land uses: the case of Antalya–Alanya Highway

According to (Mansuroglu et al., 2010), in Turkey, highway planners' disregard for natural and cultural conditions during the planning stage has resulted in a spate of negative environmental consequences. Economic solutions usually win out over natural responsibilities. The landscape planning for the roadway is confined to plantation work that occurs after the roadway is completed. The Antalya–Alanya highway is one of Turkey's most important highways since it travels through several tourist sites, agricultural regions, communities, and natural areas.

The study area was the first 37 kilometers of the Antalya–Alanya motorway. The Antalya–Alanya motorway is divided into four phases and stretches 134 kilometers. Stage I was completed in 2001 and begins 6 kilometers south of Antalya's city center and ends at the Kopru stream's crossing. Based on data from the Turkish General Directorate of Highways, over 36 000 cars pass through this section every day.

When examining the implications on land usage, an area of 10 kilometers north and 8 kilometers south of the highway was initially considered a research area. The study area was 69 265 hectares (Figure.2. 19). Because of the study area's flat topography, as well as the large volume of traffic and abundance of secondary roads, the highway's environmental impacts have increased. For example, pollution damages could be seen up to 10 kilometers away from the road (Mansuroglu et al., 2010).

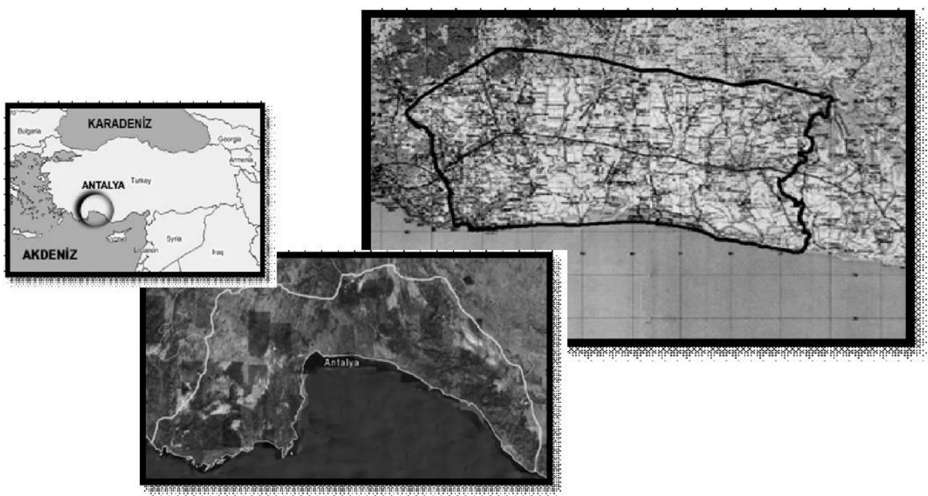

Figure.2. 19.Research area (Mansuroglu et al., 2010)

Agricultural areas were the most prominent land use category in the study region. The highway runs across plains with 1st, 2nd, and 3rd class alluvial soils. The Aksu, Kopru, Duden, and Acisu rivers, as well as their branches, were the main streams in the highway's effect area. Because travertine is the major geological layer, rainfall is easily absorbed into the soil, so the study region has a lot of subsurface water.

The study was carried out in three stages between 2005 and 2007, utilizing the landscape analysis–assessment–synthesis technique (Mansuroglu et al., 2010). The ecological and cultural structure of the area was examined in the first step. The present land uses were identified in the second step. In the third step, GIS technology was utilized to examine the highway's and highway-related land use developments' implications. The study area's 1:25 000 topographical maps were obtained from the local survey authority and manually digitized into a computer, while the 2005 Ikonos satellite image was classified using Arc GIS 9.1 software to depict the land use type. Finally, direct and indirect implications of the Antalya–Alanya route on land use were investigated.

Transportation planning decisions have a direct and indirect impact on land use. Current land uses were plotted with the Ikonos 2005 satellite image to assess the environmental implications of the

Antalya–Alanya motorway. When mapping land uses, the research area's ecological, socioeconomic, and physical aspects were taken into account, and ten different land use categories were identified (Table.2. 10). Agricultural fields, greenhouses, orchards, urban and rural settlements, tourism, protected areas, maquis, forests, and airport are among the land uses. Agricultural fields account for 61.74 percent of the research area (42 389 hectares), woodland for 11.10 percent (7623 ha), and greenhouses for 7.24 percent (4973 ha).

Current land uses	Area (ha)	Rate (%)
Agricultural fields	42389	61.74
Green houses	4973	7.24
Orchards	2435	3.55
Urban settlements	3491	5.05
Rural settlements	2175	3.20
Tourism	1593	4.27
Protected areas	708	1.03
Maquis	1926	2.80
Forest	7623	11.10
Airport	1343	1.96

Table.2. 10.Current land uses of study area (Mansuroglu et al., 2010)

Direct effects were created by the road itself that is to say, by road construction procedures such as land consumption, vegetation removal, and severance of agricultural areas. Because the cause-and-effect relationship was frequently evident, direct consequences were generally easier to analyze, assess, and regulate than indirect consequences.

The loss of the productive potential of the soil covered by the roadway and the fragmentation of agricultural regions were the most immediate and evident effects of highways on soil (Angold, 1997; Rodríguez-Flores & Rodríguez-Castellón, 1982). Most of the best highway expansion locations (flat and stable) were also good for agricultural. The research area was 42.389 acres and comprised 61.74 percent agricultural lands. The Antalya–Alanya motorway (Figure.2. 20) runs across alluvial soils of the first and second classes. There were 475 ha of 1st class, 2008 ha of 2nd class, and 657 ha of 3rd class agricultural soils in the area of study 0–500 m from each side of the roadway where the consequences were severe.

This rich soil was harmed during the building and use of the roadway, resulting in the loss of topsoil. The physical structure of the soil was changed via the use of heavy machinery in construction, the opening of service roads, and surface cover operations.

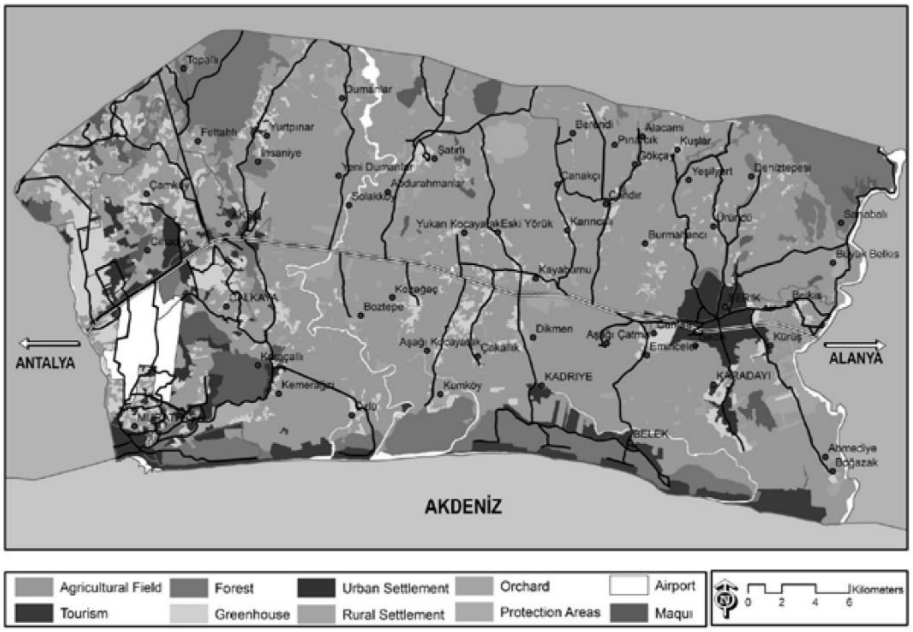

Figure.2. 20.The Antalya-Alanya highway land use map (Mansuroglu et al., 2010)

One of the immediate effects was air pollution, which was produced by vehicle emissions of pollutants. Motor vehicle pollution had a significant impact and was a serious issue. Carbon dioxide and water are the primary byproducts of motor fuel combustion, but inefficiencies and high temperatures intrinsic in engine operation encourage the creation of a wide range of additional pollutants with variable effects. Nitrogen oxides (NOx), hydrocarbons (HC), carbon monoxide (CO), Sulphur dioxide (SO2), lead (Pb), aldehydes, and other particles are the main contaminants. Although no measurements of heavy metal concentration in the vicinity of the highway were taken during the research, it might be assumed that with a daily vehicle intensity of 36 000 vehicles, heavy metal has accumulated in the agricultural fields. Because agricultural fields and orchards were located near highways, air pollution were trapped on their leaves, and heavy metals were washed into the soil by rain.

Indirect effects (also described as secondary or tertiary consequences) were often strongly connected to the project and might have a greater environmental impact than direct impacts. As a result of this literature, indirect effects are more difficult to quantify, but they are also more important and harmful. They have the potential to impact bigger geographical areas over time. A potential lowering of a water level induced by a road scheme that affected a wetland, producing an influence on the ecology of that wetland, was a case of an indirect influence. Environmental consequences were created not just from road structure, but also from sites related with the new highway, such as deposit and borrow locations, materials treatment areas, quarries, access roads, and project worker facilities. Air, soil, water, plants, animals, and people were all affected in some ways.

Because the highway crossed so many roads and streams, there were a lot of engineering projects. The shape of the terrain was altered as a result of these engineering projects. The filthy air simply settled down on the agricultural fields due to the research area's flat topography, humid and rainy climate, lack of strong winds, and abundant fog.

The nearby flowing waters were polluted as a result of the roadway, and the water cycle was disrupted. Damaging elements to the water in the construction and operation procedures were the deposit of construction materials in the installation places, change of running surface water in borrow areas, surface cover activities, social and infrastructure demands of the employees, severe vehicle circulation, operation of service facilities and gas stations, rise of vehicle maintenance and fixing centers, the use of chemicals and mineral substances on the roads and rise of industrial works along the highways. Too many tiny quarries were placed near the rivers, and because they take materials from rivers, the volume of particles in the rivers grew, causing the rivers' beds alteration.

Noise is one of the most noticeable effects of daily vehicle use in many regions. However, because its impacts are rarely apparent and difficult to measure financially, they are generally given less attention than economic or other environmental concerns. Another harmful environmental impact that might be considered is noise. The Antalya–Alanya highway's equivalent noise level was computed using both existing vehicle intensity and the prediction of doubling intensity in the close future (Table.2. 11, Table.2. 12 Table.2. 13).

	$L_{eq}(n) = L_{max} + 10 \lg [(d_o^2 \times 3.14 \times Q \times B)/(d \times 180 \times V)]$
$L_{eq}(n)$	equivalent noise level (dBA)
L_{max}	max. noise level (dBA)
d_o	distance from max. noise level (15 m)
Q	number of vehicle (vehicle/h)
B	angle between noise source and receiver (90^o)
d	distance between receiver and noise source (200 m)
V	average speed of mobile source (100 000 m/h)

Table.2. 11.Formula of the equivalent noise level (Mansuroglu et al., 2010)

Vehicle type	Vehicle/day	Vehicle/h	Maximum noise level (dBA)	Equivalent noise level (dBA)
1st class (automobile)	29483	1229	70	53.36
2nd class (autobus)	1677	70	82	52.93
3rd class (truck)	1858	77	85	56.34
4th and 5th classes (trailer)	3914	163	90	64.59

Table.2. 12.Noise levels of the Antalya-Alanya highway, Antalya Aksu part (Mansuroglu et al., 2010)

Vehicle type	Vehicle/day	Vehicle/h	Maximum noise level (dBA)	Equivalent noise level (dBA)
1st class (automobile)	26002	1083	70	52.79
2nd class (autobus)	1076	45	82	51.00
3rd class (truck)	1409	59	85	55.17
4th and 5th classes (trailer)	3181	133	90	63.71

Table.2. 13.Noise levels of the Antalya-Alanya highway-Aksu Serik part

The average noise levels measured were below the permitted limits at the time of the research. However, as cities grow and the number of industrial businesses rises, noise may become a concern. The literature claimed that overall noise level of the Antalya airport and motorways, particularly between Antalya and Aksu, could create health issues.

Highways are fundamental economic and social change agents. Highway construction has the potential to change indigenous people's cultural, social, political, and economic integrity. Losing conventional sense of identity, damage to livelihoods, violation of traditionally executed land rights, health and social concerns, and violation of rights to engage in development are some of the indirect effects of highways on original inhabitants. With the development of the tourism and agriculture industries in the study area, the land uses, and demographic composition of the area altered.

Highway construction can have a variety of direct and indirect effects on land usage. These effects are frequently significant and should be taken into account when evaluating a program or initiative. However, in Turkey, the economic benefits of highway development come first, and as a result, improper route decisions might harm the environment. In addition, improper implementations during the construction phase might worsen the deterioration. Agricultural fields were split up, some fertile lands were ruined, erosion was intensified, the concentration of harmful chemicals in the soil was ramped up, some land uses changed, population increased, and air, water, and noise pollution emerged as a result of the construction of the Antalya–Alanya highway.

The Antalya–Alanya roadway, which costs 12 million dollars to build and maintain, cannot be eliminated or rerouted at this time. However, the literature suggested several steps that could be performed to mitigate its consequences. In the case of the Antalya–Alanya highway, the following procedures have been introduced by this literature to be be considered during the planning and implementation phases of motorways in order to minimize their environmental impacts (Mansuroglu et al., 2010):

- It is necessary to use a planning method that takes into account the natural structure of the place in question and incorporates the fundamentals of ecology, sociology, urban planning, and especially landscape design (particularly in path selection) into the planning process.
- Environmental pros and cons must be factored into project cost-benefit evaluations.
- Highway projects must follow the Environmental Impact Assessment (EIA) method.

- To bring safety, comfort, and aesthetic value to drivers, aspects like terrain, visual properties, and environmental factors must be examined altogether.
- Along the corridor, industrial and urban expansion must be restricted.
- To improve the efficiency of plantations, the expropriation space on both edges of highways should be held greater.

2-3-Conclusion

To sum up literature review and assessment of three similar case studies, it should be mentioned that first, major research concerns and trends were reviewed to familiarize with the main concepts of land use knowledge. Second, three different case studies relevant to the matter of land use change with different research purposes and methodologies, were introduced to get inspiration to structure this thesis study's methodology. First similar case study (Day, 2006a), had an approach for analyzing the spatial representation of growth or physical development along highway corridors supported by a combination of remote sensing and GIS technology. This research used this methodology to investigate land use/land cover change in relation to infrastructure investment along the ADHS's Ohio segment (Corridor D/State Route 32 in southern Ohio). Landsat images from two time periods, 1976 and 2002, were selected to depict the physical change that has occurred from the highway construction over a 26-year period. The findings of this study demonstrated the pattern of change along this corridor, as well as the level of urbanization.

This study was a good example to learn how to detect changes in different classes of land use working with remote sensing data as input data and representing area of changes based on image pixels (each pixel had specific dimension on the land) while the input data used in this master thesis is aerial photos due to unavailability of remote sensing data in 1968 and the areas of changes are shown in square kilometers in order to simplicity of this unit to understand.

Next similar case study was (Jedlička et al., 2019), examines the evolution of land use and a road network in the Hodonin region (in Czech Republic) from 1836 to 2016. The purpose of the literature was to see if there is a link between road building and land use changes in the area. At varied distances from roadways, the intensity of land use change processes between neighboring periods was computed by employing Geo-statistics and geographic information systems from ESRI. Aerial images and ancient topographic maps were used to investigate long-term alterations in land use across Central Europe. To represent area of change, the Hawths Tools for ArcGIS was used to generate a hexagonal grid with 100 m between hexagonal centroids, giving each hexagon a 0.866 ha area. Making use of hexagonal polygons were proper for generalization, especially when it came to use of different old maps with different scales. The outcome of this research was land use monitoring around the road network in the area during several time intervals and finding impacts of them on urbanization, agricultural intensification and any anthropogenic processes and They were quite inspirational to follow in this thesis research.

The last similar research study was (Mansuroglu et al., 2010), during which range of negative externalities of highways were explored in this study, covering environmental problems that developed as a result of route design and those that rose as a result of their use. Direct impacts included road construction procedures such as land consumption, vegetation removal, and disconnection of agricultural areas. Indirect impacts were defined as environmental effects that were not immediately caused by the project and may have occurred some distance away from it, causing them to affect wider geographical areas of the environment over time than planned. This case was a good example to consider particularly environmental impacts of highways progress and land use changes. However, its focus was not on just land use change detection ,and different environmental impacts were considered beside land use change caused by highway progress while this thesis study is focused more on land use change detection and change trends in different buffer distances from the highways in a retrospective (historical) perspective.

3-Case Study

3-1-Study Area

For the study area, Stavanger municipality area was chosen firstly because I have been living here for three years, so I had good overview of the area. Secondly, because the region has experienced significant infrastructure improvements in recent years particularly after becoming the oil center for Norway in the end of 60s, which has imposed substantial land uses changes on the area. Before Stavanger, Jæren region was chosen but because of the big size of the area, including eight municipalities (involving Stavanger) with different regulation plans and limited access to the input data, it was practically not approachable for the limited time of this master thesis. Stavanger was chosen as the most populated and urbanized municipality in the region.

Figure.3. 1.Satellite image of Jæren area from NASA Landsat series in 2019

Figure.3. 2.Aerial photos including Stavanger municipality area in 2019 ("Norge i Bilder," n.d.)

Forty three percent of the population on Jæren live in Stavanger area (143 574 out of 330 982 in 2020) which is the country's fourth largest after Oslo, Bergen and Trondheim ("Befolkningen," n.d.) (Thorsnæs, 2021).

Stavanger is a city and municipality in Rogaland county located in southwestern Norway Stavanger municipality neighbor to Randaberg, Sandnes , Sola , and in the north to Bokn. Stavanger is the administration center in Rogaland county and it is regarded as the administrative, economic and cultural center in the Rogaland county. Stavanger is nowadays the center of the oil industry in Norway and is one of Europe's energy capitals and is often called the "oil capital". As a result, the city is regarded to be very international, with an immigrant distribution of about 23 percent (33 047 out of 143 574 in 2020). ("09817: Immigrants and Norwegian-Born with Immigrant Parents, by Country Background, Statistical Variable, Year and Region. Statbank," n.d.)

3-2-Norwegian road classification and the chosen routes

Among different types of routes in the area, two most important roads, which have the highest rank in the Norwegian road classification, were chosen. They are known as national or state roads, but many kilometers of national roads were transferred from the state to the county municipality in 2010 through the administrative reform in 2010 then now there are just two important state roads, E39, R509. To understand better this classification, we can have a brief look at this classification.

		Area code 47	Common abbreviation N		Last updated 15-12-2019	
Road class	Syntax explanation	Administrative subordination	Sub classes	Zones	System	Remarks
European road	E(v)[0-9] <2-3>	Europe	See Europe, all E roads are also Riksveg			Sequential exit numbers
National road (Riksveg)	(Rv)[0-9] <1-3>	national		Determined by first digit of 2- and 3-d numbers	Common system of former national roads	green numbers
County road (Fylkesveg)	(Fv)[0-9] <1-3>	national	Primary county road (primær fylkesveg)			white numbers
	F(v)[0-9] <2-3>	county	Secondary county road (sekundær fylkesveg)			numbers only on small km signs
Municipal road (Kommunalveg)	(Kv[0-9] <1-5>)	national				for administration only

Table.3. 1.Norwegian Road Numbering System (“Norway - Road Numbering Systems,” n.d.)

They come to four general categories of: European road, National road (Rikseveg), County road (Fylkesveg) and Municipality road (Kommunalveg). The first two categories owned by the Norwegian government and the responsibility for them and their maintenance is with the national government.

Figure.3. 3.Example of Norwegian Road numbering System (“Norway - Road Numbering Systems,” n.d.)

Riksveg referred to as highways are the most important roads in the country beside the European roads, e.g. 2, 3, 5, 7, 15, 20, 23, 52 and 80.

Figure.3. 4.Example of Norwegian Road Numbering System (Statens Vegvesen, n.d.)

Road signs:						
Road/destination type	Background	Text	Road numbers			
			Class	Shape	Background	Text
Motorways	Blue	White	Riksveg	Rectangle	Green	White
All other roads	Yellow	Black	Primær Fylkesveg	Rectangle	White	Black
Local destinations	White	Black	Sekundær Fylkesveg	Only on white km signs		

Table.3. 2.Norwegian Road Signs description ("Norway - Road Numbering Systems," n.d.)

Based on this classification, there is mostly E39 in Stavanger area and small part of R509 placed on the south of the area.

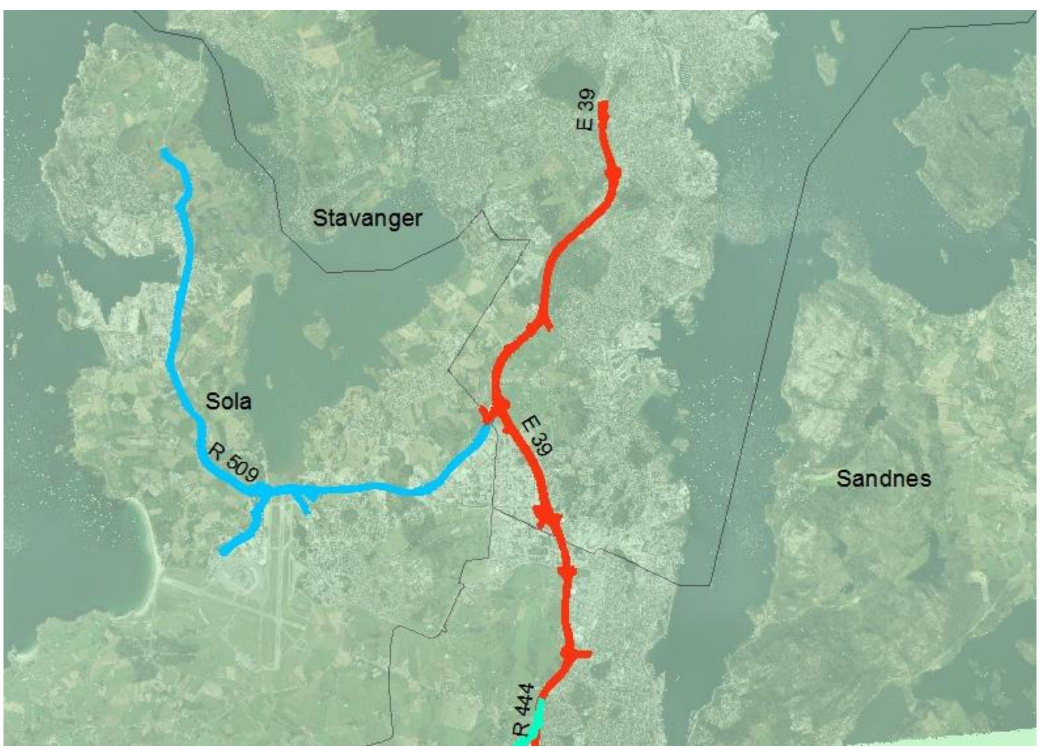

Figure.3. 5.The highways chosen in the case study

3-2-1-E39

Europavei 39 , usually called E39 or Kyststamveien , is a Norwegian national road placed between Trondheim and Kristiansand and is the most important road in our focused area. The road is part of Europavei 39 which goes from Kristiansand to Hirtshals and Aalborg in Denmark . In the north, the road brgins at Klettkrysset in Trøndelag , where it intersects the E6 . From Klett it extends west and south through Møre og Romsdal , Vestland and Rogaland until it is finished in Kristiansand in Agder . The length of the road in Norway is about 1125 kilometers, including ferry routes (Committee, 1961; “Google Maps,” n.d.)

Figure.3. 6.E39 path including seven ferry crossings (L. M. Donoghue, 2020)

E39 has seven ferry crossings inside, all of which are among the country's busiest . The road includes about 90 tunnels, and over 6 percent of the total length of the road is in a tunnel . Bømlafjord tunnel is the road's deepest spot with 262.4 meters under sea level and was the world's second deepest at the time it opened. When Rogfast after the plan is completed about 2030, the deepest point of the road will be 390 meters under sea level. (Solberg, 2016)

E39's highest spot is in Romarheimsdalen , where the road rises to 400 meters above sea level. (“Map of Norway,” n.d.) The road standard on E39 changes from motorway to narrow, winding western roads without yellow central stripes. There is also plans to replace all seven ferries with a bridge or tunnel through the project called Ferry-Free E39 .(“The E39 Coastal Highway Route,” n.d., p. 3)

The section Trondheim – Ålesund – Bergen – Stavanger – Kristiansand got signed *E 39* between 1997 - 2000 . The section Kristiansund – Ålesund – Bergen – Stavanger was previously named *national road 1*, while the section Stavanger – Kristiansand was E18. Before 1992, the part Ålesund – Bergen – Stavanger got signed *national road 14*. The E39 partly follows the same route as the Trondhjem postal route established in 1785(from1786 in Stavanger) . (Torvik & Møre og Romsdal fylkesbåtar, 2000)

3-2-2-R509

Highway 509 (Rv509) is coincided with small part of the area but the part inside the area is considered for the analysis. Rv 509 has the length of 19.5 km running from Tasta in Stavanger to Tananger, passing Stavanger airport , Solakrossen and Forus to European road 39 at Jåttå ("Vegkart," n.d.). Before the regional reform was exerted on 1 January 2010, county road 509 (Fylkesvei 509) was part of the road.

On 18 December 2012, the new motorway Solasplitten was built as a new main road to the east, north of Forus to European road 39. In 2020, the part between Tasta and Tjensvollkrossen was transferred from E39 to Rv509. ("Vegkart," n.d.)

Figure.3. 7.The highway R509

3-3-LULC overview in Stavanger area

According to recent aerial photographs of Stavanger from ("Norge i Bilder," n.d.) and shapefiles data from ("Geovekst," n.d.), the main LULC class is urban concentrated on the north and center of area with farm lands mostly to the west close to Sola municipality and to the south close to Forus district. The class of water often as lakes are about placed near the center and close to the west and the class of tree is sporadically scattered around the area.

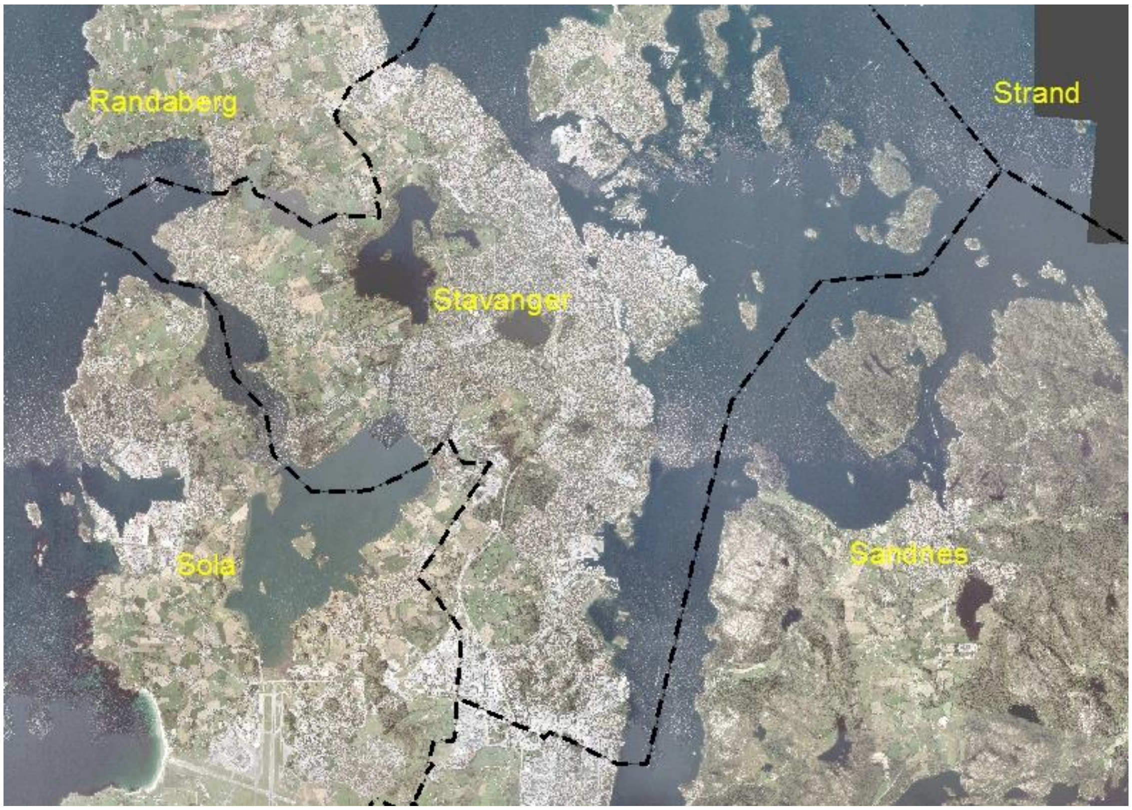

Figure.3. 8.Overview of Stavanger land use types in the aerial photos in 2019 ("Norge i Bilder," n.d.)

A regional land use strategy is at the center of the region's growth. A tight-knit and interconnected urban structure is included in the concept. The primary urban area is located in the city centers of Stavanger. The territory surrounding Forus has likewise expanded into a big employment center, with several interconnected growth axes. Stavanger city center and Forus/Lura in particular, have strengthened their status as employment centers as a result of land use and location trends. Stavanger, on the other hand, has a large residential population in proximity to the city center. The settlement increase in the Forus/Lura area has not been matched. Conversely, in recent years, the city center of Sandnes has lost its appeal as a place to work. It will be difficult to transform the Forus/Lura area from a car-oriented environment to one with significant market proportions of public, pedestrian, and bicycle transportation (*Cities of the Future City of Stavanger - Free Download PDF*, 2018).

4-Methodology

Over time, changes in the land use types surrounding roadways happen due to both anthropogenic and natural pressures. There are many methods for monitoring these alterations. Combining together, remote sensing, geographic information systems (GIS), and photogrammetry can contribute to measure earth's dynamic properties over time. These geospatial techniques improve the knowledge of land use and land cover change by visualization or mapping. (Day, 2006b)

Although change happens by natural cycles or events, human pressures also have impact on land cover face. (Loveland & DeFries, 2004) Therefore, continuous monitoring of the earth's surface might determine causes of change from their effects. Geospatial technologies can monitor land use and land cover change over time as a result of highway investments and try to bring the conflicts into vision with decision makers.

In the past, land use/land cover change detection was restricted to aerial photography and field investigation (Campbell & Wynne, 2011) (D. Donoghue, 2000). These methods need quite time commitments and experienced personnel. The advent of space-based remote sensing extended the horizon of environmental observation (Kempka et al., 1994; Loveland & DeFries, 2004) because it provides analysts with an easily available, repetitive, and trustworthy stock of images (Haack & Bechdol, 2000; Loveland & DeFries, 2004).

Nowadays, it is more tended to use remote sensing data to extract land use information from a region and it is faster and more flexible since it is using some automated computer algorithms to extract land use classification and it can cover bigger areas compared to the aerial photos before. However, there is limitation when it comes to a retrospective approach like this case study because there is no remote sensing data for a few decades before in many locations. So in the case of this research, it was first tried to make use of remote sensing data for the analysis, but it was not possible due to availability of remote sensing data for the time origin of case study since change detection of land use compared to the chosen highways should be considered before and after construction of the highways as the drivers of land use change. And in this research study, for example E39 was built in 1974 and there were no satellite images covering the area for that time so the earliest source of data before 1974 was digitized black-white aerial photos from 1968 collected from the relevant authority in Norway ("Norge i Bilder," n.d.). Additionally, three buffer distances, 400 m, 800 m, 1200 m were defined along the highways E39 and R509 to investigate effectiveness of distance from the highways on the land use change similar to (Day, 2006b). The buffer zones were defined based on two criteria. First, not to intersect neighboring municipality areas to narrow down on the case study area of Stavanger and second, having equal intervals in between to have better understandable comparison scale among three buffer zones. However, small part to the south and west of the case study crossed Sandnes and Sola municipality areas and it was kept in order to maintain the biggest buffer distance 1200 m from the highways.

Areal unit to represent LULC classes and changes was chosen as square kilometers (Sq Km) in order to ease the understanding of the areal sizes in the LULC polygons and changes.

In brief, the function of photogrammetry and a GIS platform showed the pattern of spatial land use/land cover change coming from development along E39 and R509 in Stavanger. This investigation has focused more on change detection and major socio-economic causes of change in the area; although population, economic or other such elements may determine the results, and further research analyses with diverse economic and demographic indices integrating together are needed with current analysis of this research to find the correlation among them and deliver more comprehensive approach of impacts and causes of change.

The schematic flowchart indicates an overview of the methodology procedure used in this project. In brief, it starts with data collection, following with creation of LULC layers for three buffer zones around the highways for both time slots 1968 and 2019. Based on the outputs from the created LULC data, change layers were built up and then statistics were calculated from the results of the previous steps. Next, discussions about significant happened changes and the major relevant socio-economic impacts and causes rose from these results and finally, conclusions were introduced related to the findings of the analysis.

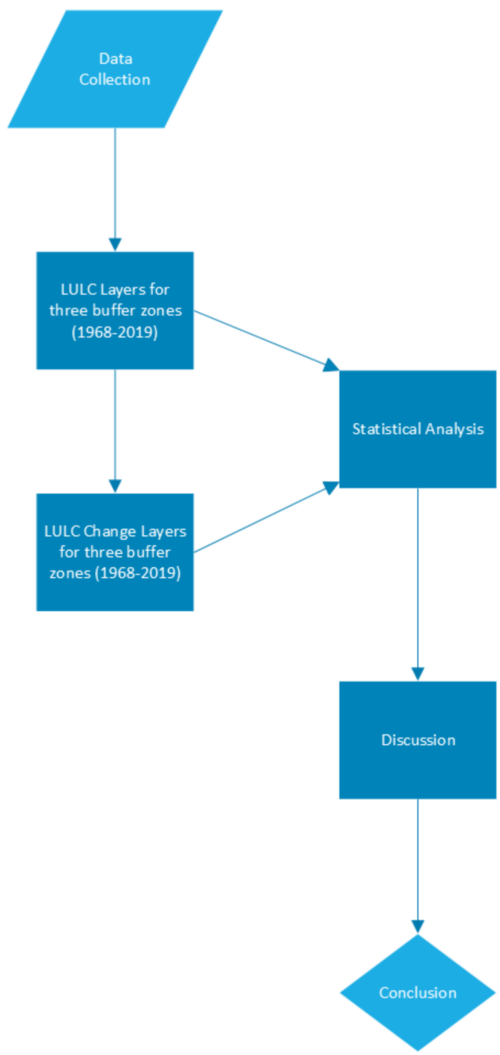

Figure.4. 1.Schematic flowchart of the methodology used in the research study

A Geographic Information System (GIS) is used to overlay different quantitative and qualitative layers of data and extent of the land development for Stavanger over the period (extracted from aerial photos) to represent the location of land development. Historical highway progress information can be overlaid on land change patterns derived from aerial photos to investigate the coincidence of changes in land use-land cover compared to highways progress (Sanchez, 2004).

It should also be mentioned that this research will be limited to the availability and quality of the aerial photographs for Stavanger, the precision of land development estimation techniques in GIS software, the availability and reliability of highway data, and the resolution and extent of region data. So enough relevant, accurate and precise data is a critical element in this master thesis (Sanchez, 2004).

4-1-Analysis

In brief, there are four steps forming the analysis of this project. The first step was for data collection for the required input of the analysis. Creating LULC layers data and LULC change layers for the defined buffer zones through the time were the second and third steps and the fourth and last, was the statistical part. Each step’s results were used for next steps, so they were interconnected to each other.

Basically, to detect the changes of LULC based on highways improvement, it is needed to compare different time situations in the same location. First before the construction of highways and second, after the construction of highways. The location should be defined which is a buffer zone around highways also inside the focused area Stavanger. For this project, three buffer distances were determined based on covering the case study area and not disrupting with the neighboring municipality area beside having equal intervals in between as it has been explained before. They were 400, 800- and 1200-meters buffer distances around the focused highways E39 and R509. So LULC changes beyond these buffer zones are not considered to emphasize the physical effects of highways on LULC as they distance gradually from the highways.

4-1-1-Data Collection

To make buffer zones, well-known ESRI software product, Arc GIS was used and initial highway data were received from Statens Vegvesen (The Norwegian Public Roads Administration) and they were sorted out in the software to keep the ones inside the area. Apart from this, some recent GIS vector data with their different attribute data linked to them were collected from different authorities in Norway. For example, some shape files representing land resources for the Stavanger metropolitan area, as defined by Statistics Norway ("About Us (Statistics Norway)," n.d.). The shape files also include various attribute and meta data can be opened and used in different GIS platforms. The data source of this data was *Geovekst* ("Geovekst," n.d.).

The other vector data source showing the current geographic extends and administrative details of all municipalities in the area called Jæren included Stavanger municipality area, and its authority source was *Norwegian Mapping Authority* ("About The Norwegian Mapping Authority," n.d.).

Apart from vector type of data, raster type was also needed as the aerial orthophotos of Stavanger for 1968 and 2019. They were obtained from ("Norge i Bilder," n.d.) as the official authority in Norway. It should be mentioned that the coordinate system and datum for the all data overlaid in the software should have been the same and since the coordinate system for the preliminary vector data was UTM zone 32 with the datum ETRS-89, the same characteristics for needed aerial photos were requested. The aerial photos for 1968 were black and white while the aerial photos received for 2019 were colorful and had three bands of colors red, green and blue in brief called RGB.

4-1-2-LULC layers for 1968 and 2019

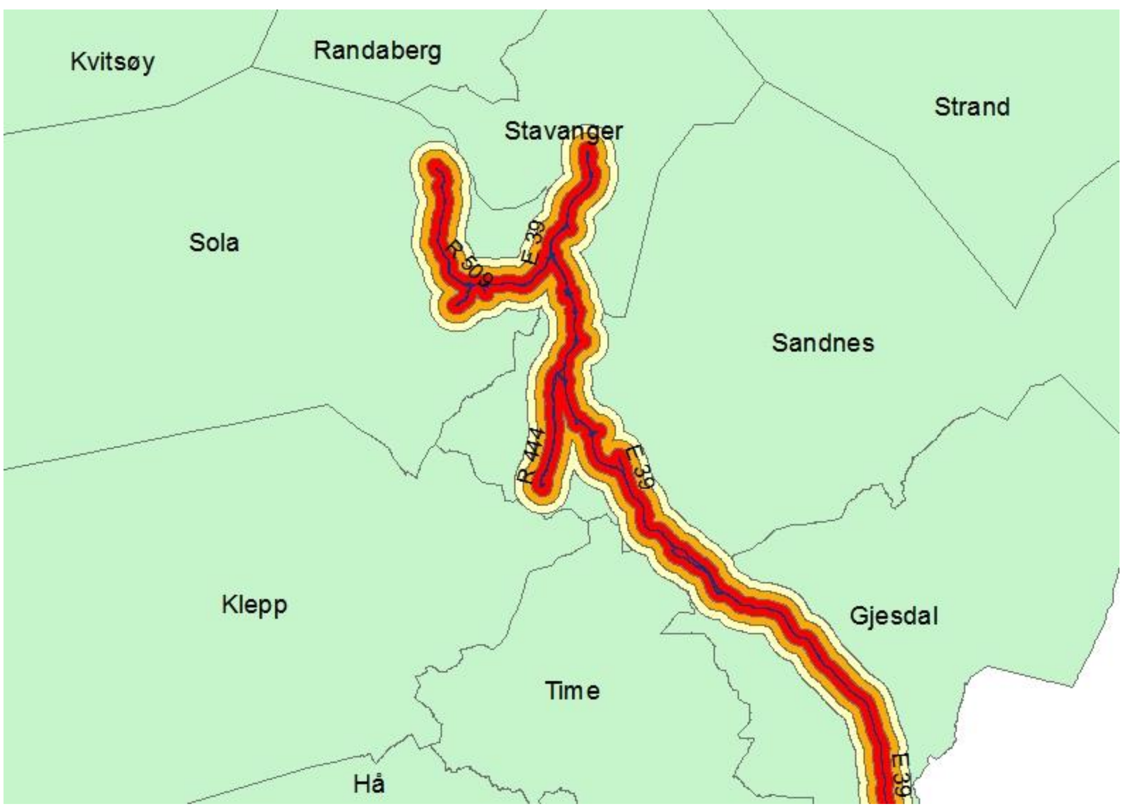

Figure.4. 2.Three buffer zones (1200m, 800m and 400m) around highways E39 and R509

To start with this step, it was needed to just keep the buffer zones inside our focused area where was Stavanger then buffer zones layers were clipped by the Stavanger municipality layer. But after this, some parts of buffer zone 1200m common between Stavanger, Sola and Sandnes were lost so in order to maintain width of the buffer zone 1200m, the common area between the three municipalities was kept for the analysis.

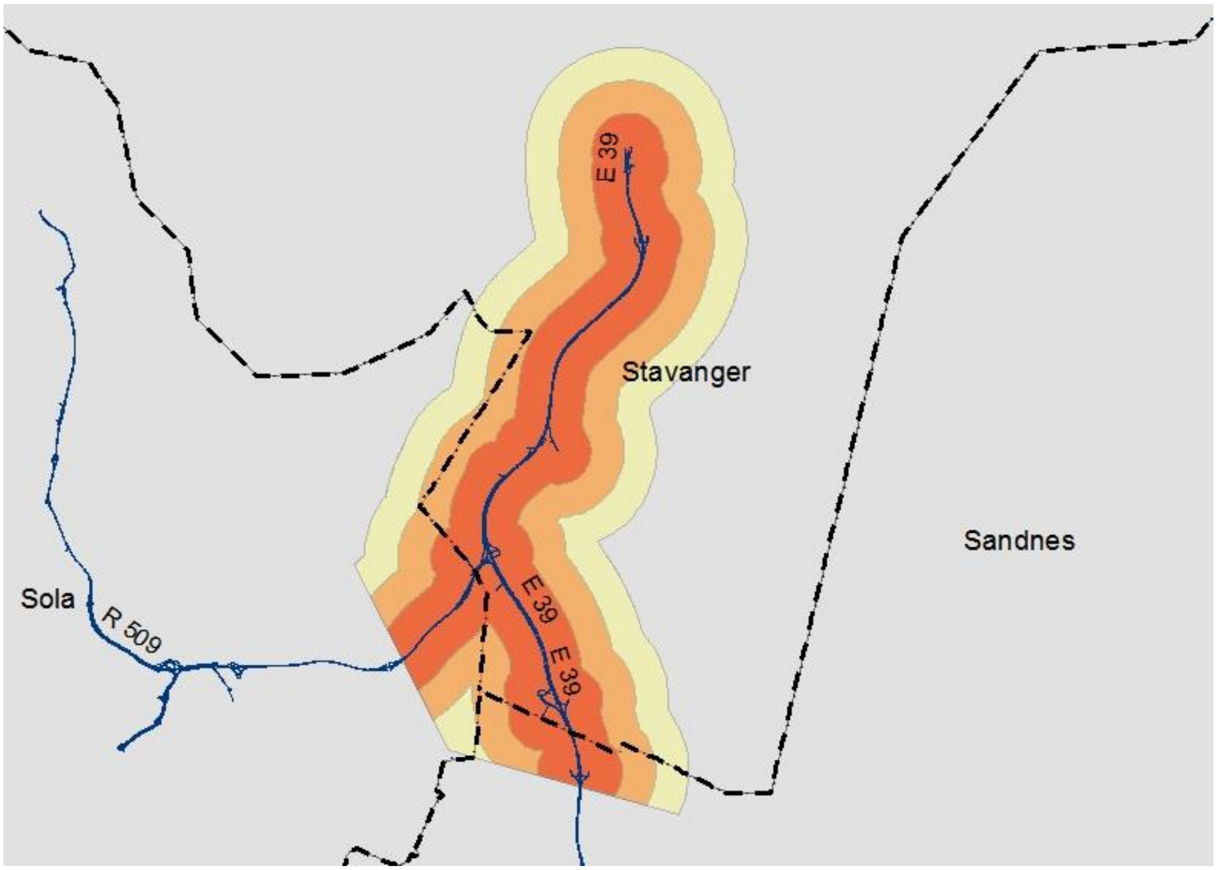

Figure.4. 3.Three buffer zones (1200m, 800m and 400m) along highways E39 and R509 in the case study area

Next step was extracting the LULC map for 2019 and 1968 inside the defined buffer zones. For 2019, there was classified LULC map received from *Geovekst* and the LULC classification was based on the table below:

Arealtype (ARTYPE)		
11	Bebygd	Urbanized (highly modified territory)
12	Samferdsel	Transport and communication territories **it includes all roads and railroad infrastructures*
21	Fulldyrka jord	Fully cultivated soil (land for growing food)
22	Overflatedyrka jord	Surface cultivated soil
23	Innmarksbeite	Cultivated pastures
30	Skog	Forrest

50	Åpen fastmark	Open land
60	Myr (linjeskravur)	Swamp
70	Snøis(bre)	Snow glacier
80	Vann	Water resources
99	Ikke kartlagt	Not mapped

Table.4. 1.Preliminarily LULC classes for the case study Stavanger (“Geovekst,” n.d.)

As it shows there were eleven types of land use at the beginning but in order to simplify the process of analysis, the three categories of 21, 22 and 23 ,which were from one single family, merged together and the new merged category received the code 23 showing the farm class. Moreover, there were no spots in the area with the categories of 70 (Snow) and 99 (Not mapped) so they were removed from the classification. The attribute Forest for the category 30 changed to Tree to consider also small groups of the trees in the area for the both time slots. About the definition of the category 50 (Open land), all the soil lands, rocks and public not-built areas were regarded as this class.

Finally, seven categories were come up as below and they were also used later for producing LULC map in 1968:

Arealtype (ARTYPE)		
11	Bebygd	Urbanized (building)
12	Samferdsel	Transport and communication territories **it includes all roads and railroad infrastructures*
23	Bondegård	Farm
30	Skog	Tree
50	Åpen fastmark	Open land
60	Myr (linjeskravur)	Swamp
80	Vann	Water resources

Table.4. 2.LULC classification for the research study

After LULC classification for this research project, it was needed to clip the primarily 2019 LULC map, which included the whole area called Jæren into the focused research area which were three buffer zones. To start with that, initial LULC map was clipped by 1200m buffer polygon and the result was LULC map for 2019 in the proximity of 1200 meters from the highways as below:

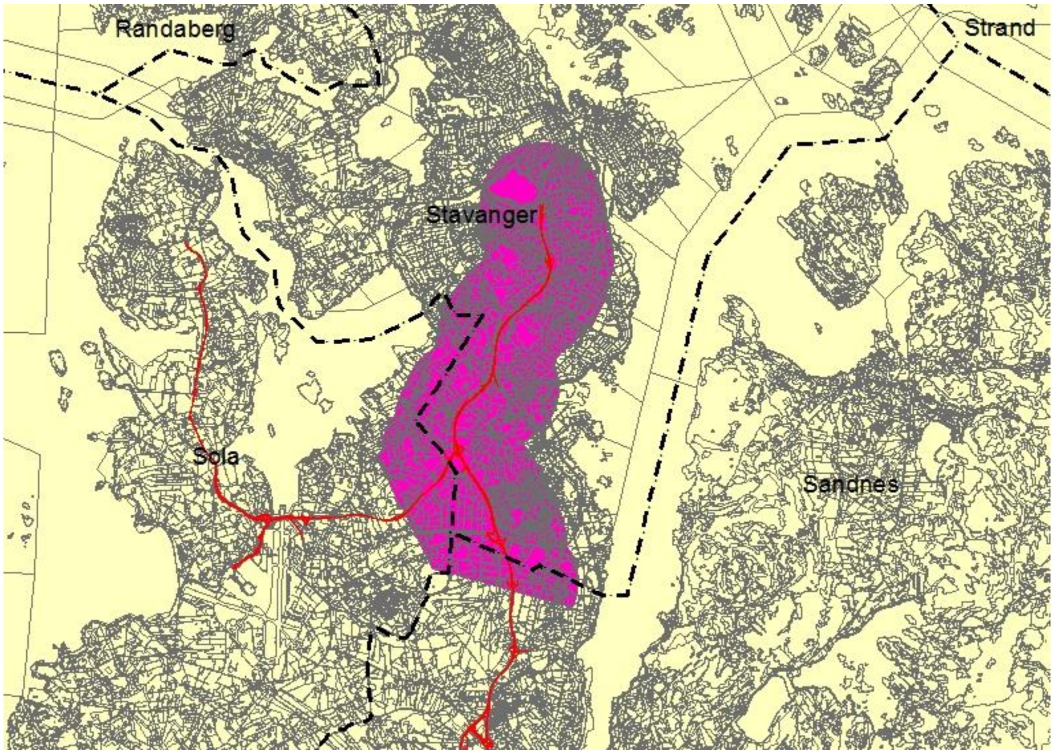

Figure.4. 4.The clipped LULC data of Jæren 2019 into the focused area

The output's attribute table for this step included more than five thousand records and this could have complicated the process for further analysis so the tool Dissolve in Geoprocessing toolset in Arc GIS was used to dissolve all the 5779 records into 7 records based on seven classes of LULC.

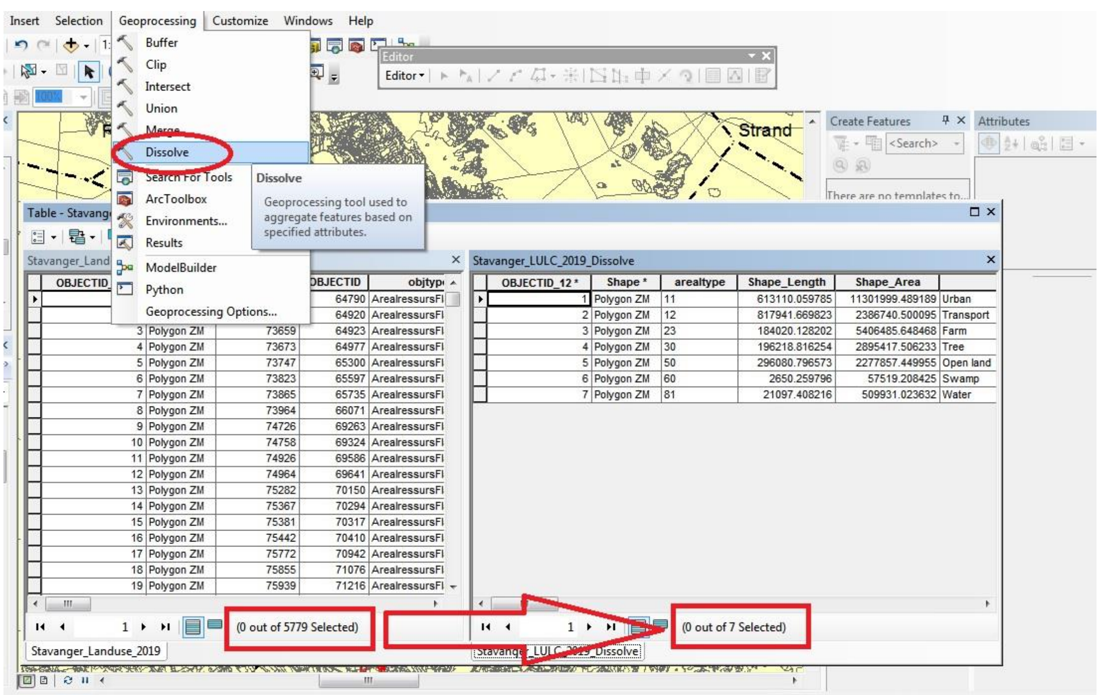

Figure.4. 5.Dissolve of 5779 LULC records in 2019 into the 7 defined LULC types

And then the symbology was also be determined for better visualization beside having LULC map in 2019 as follows:

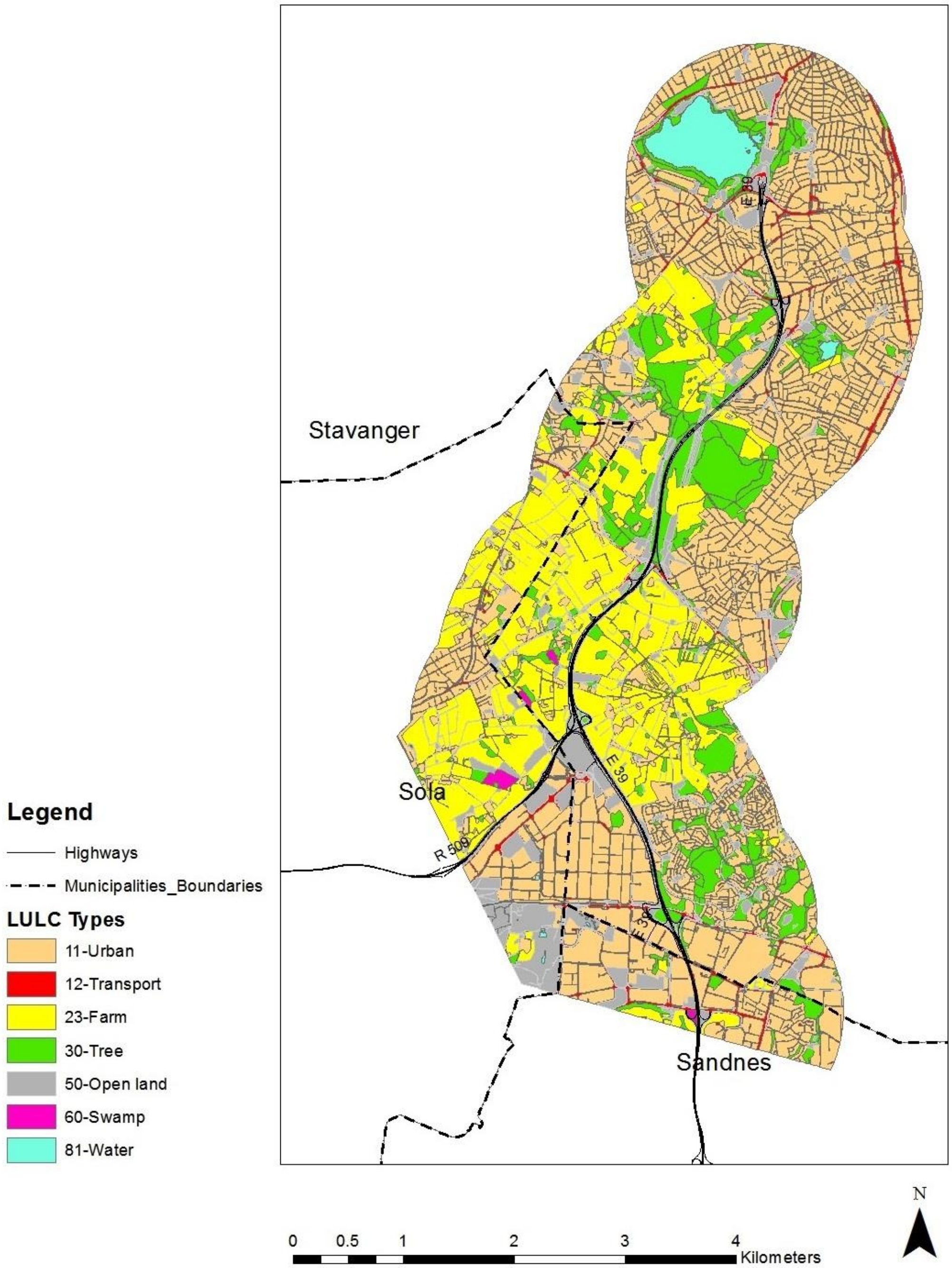

Figure.4. 6.Stavanger LULC map for the buffer zone 1200m along the highways in 2019

The same procedure was done for 800- and 400-meters buffer zones to get LULC layer data and respective dissolved attribute data as well.

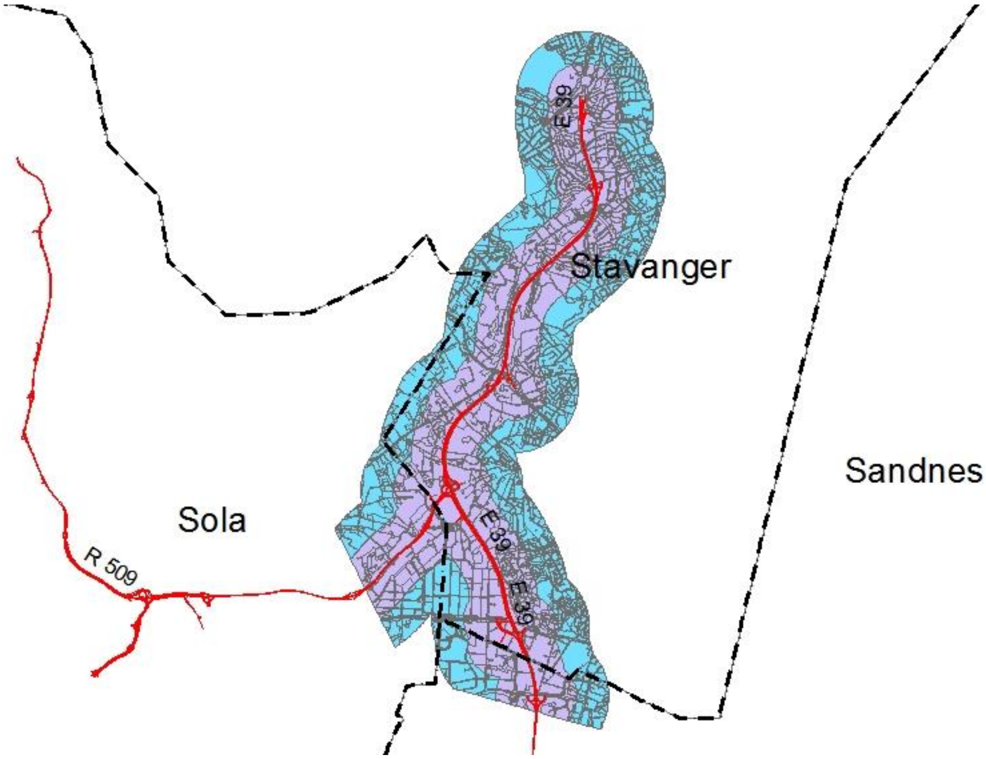

Figure.4. 7.Stavanger LULC layers data for the buffer zones 800m and 400m in 2019

So far, there were three LULC layers data for the time 2019 ready for further analysis but LULC layers data for the time 1968 were needed to follow up to the change detection part of the analysis and there was no available vector data for 1968 and they had to be produced for this project.

Theoretically, they could be produced by remote sensing data like satellite images, photogrammetric data like aerial photos or making use of old paper maps. Remote sensing method might have been much faster and more flexible but there was not available satellite image covering the area in 1968 so photogrammetric data which was black white ortho photos had to be used for 1968 to produce LULC map. Creating LULC parcels from old aerial photos was basically a time-consuming process and it needed also good interpretation of the geography of the area.

To make it faster and more accurate, a solution initiated which was making use of new RGB aerial photos of the area (2019) and comparing with the old black-white aerial photos simultaneously in Arc GIS to have good interpretation of the land features and the differences in the both time slots. Additionally, the built LULC layer for 2019 in previous step, was used as the same time with the aerial photos in order to draw only the differences observed between 1968 and 2019. All the mentioned data layers overlaid together in Arc GIS to draw and extract LULC layer data for 1968.

First, it was started with making the category 11 (urban) in 1968. For that aim, the same category was extracted in 2019 as a separate data layer and overlaid it with aerial photos (both 1968 and 2019) to just focus on differences of the two time slots for the class of urban.

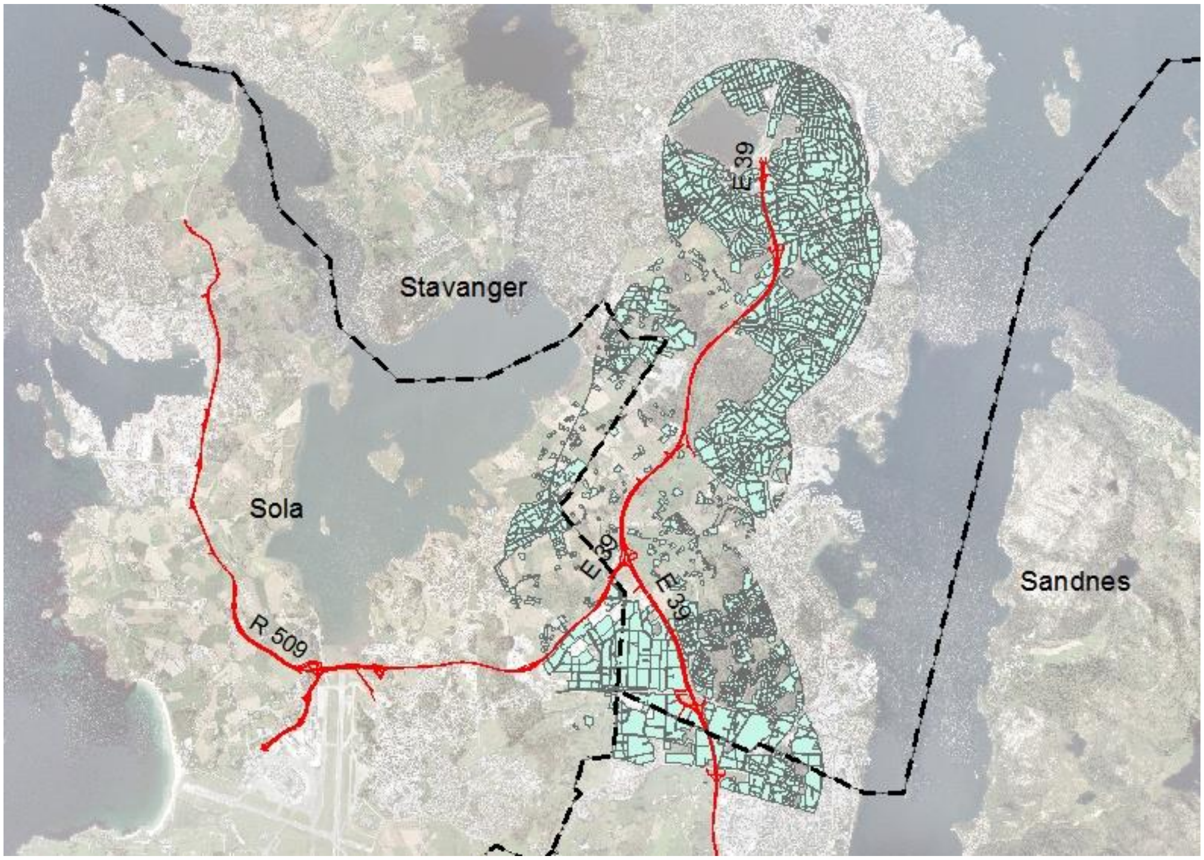

Figure.4. 8.The urban class of LULC of Stavanger in the buffer zone 1200m in 2019

And after drawing the differences, they were overlaid by the urban layer data of 2019 and used Erase tool in Arc GIS to get unchanged urban parcels from 1968 to 2019. At the end, this layer was merged by new drawn parcels to form urban class for 1968.

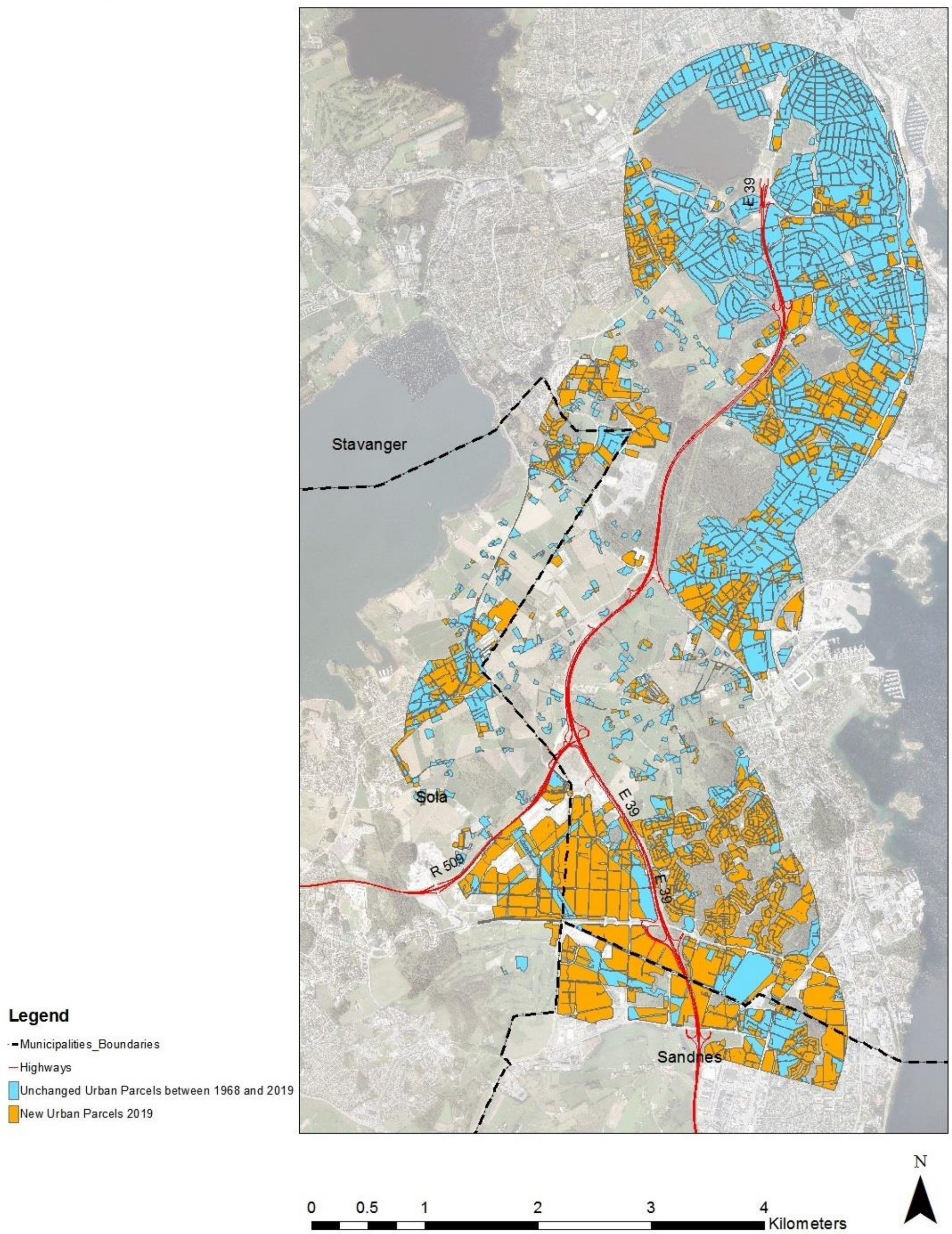

Figure.4. 9.The urban class change between 1968 and 2019 in the buffer zone 1200m

To create parcels for the classes farm, tree, open land, swamp and water the same procedure was repeated and at the end all the classes were built except transportation roads class.

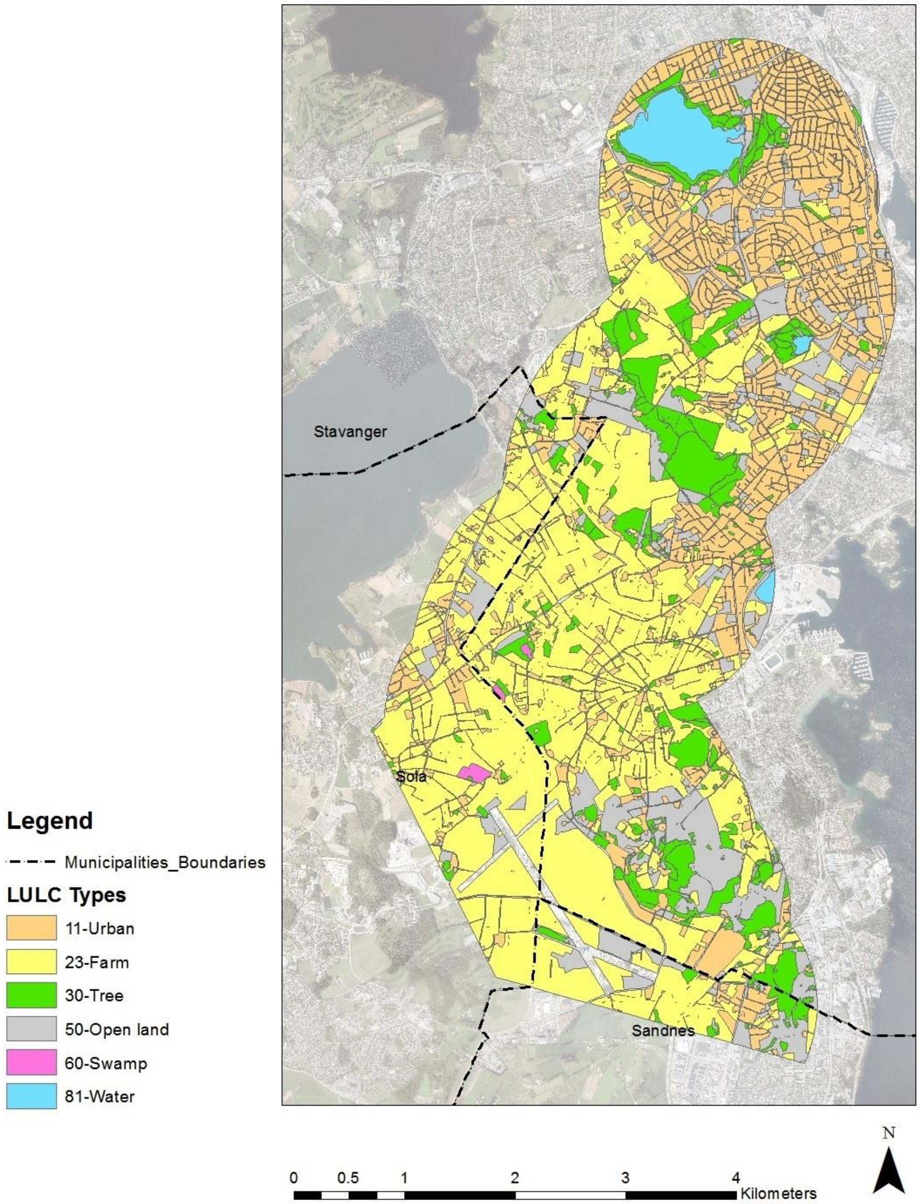

Figure.4. 10.The LULC map for 1968 except the transportation class in the buffer zone 1200m

Regarding the last LULC class transportation roads, it was not practical to do the same approach as the other classes since they were too much differences in road shapes and their displacement between 1968 and 2019. So after finishing all the other parcels, the output LULC layer created was reduced by the use of Erase tool in Geoprocessing toolset in Arc GIS from the 1200m buffer zone polygon created at the start and the result became transportation roads class in 1968 although it was still needed to edit and check the accuracy of all new output parcels based on aerial photos in 1968. It should be mentioned, there was a former airport located in the area used as a military airport in the second world war which was taken into use by Helikopter Service since 1966. The parcels for this location was considered as part of the transportation roads class (“Forgotten Airfields Europe,” n.d.).

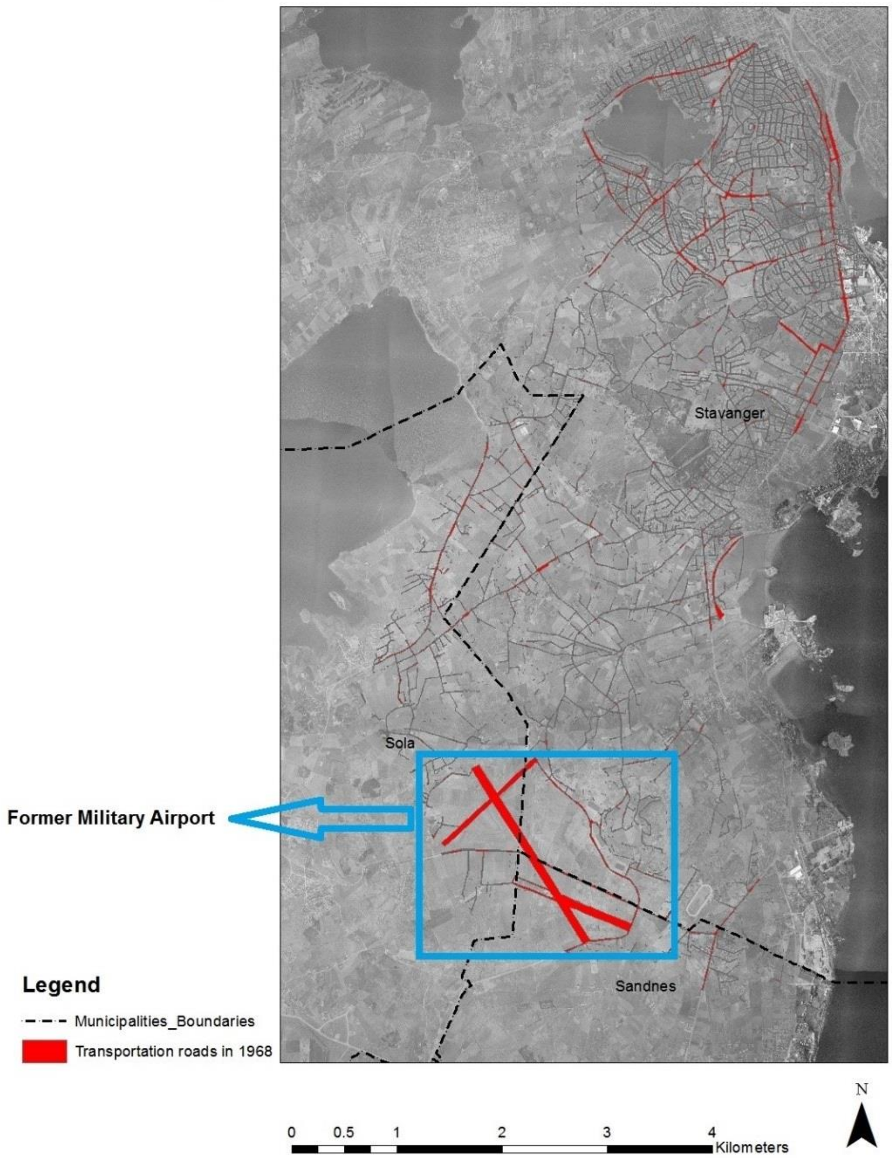

Figure.4. 11.The transportation class of Stavanger in the buffer zone 1200m in 1968

After editing and checking all the created parcels in this step, Transportation roads class was built up and merged to the previous LULC classes for the 1200m buffer zone in 1968 to complete it.

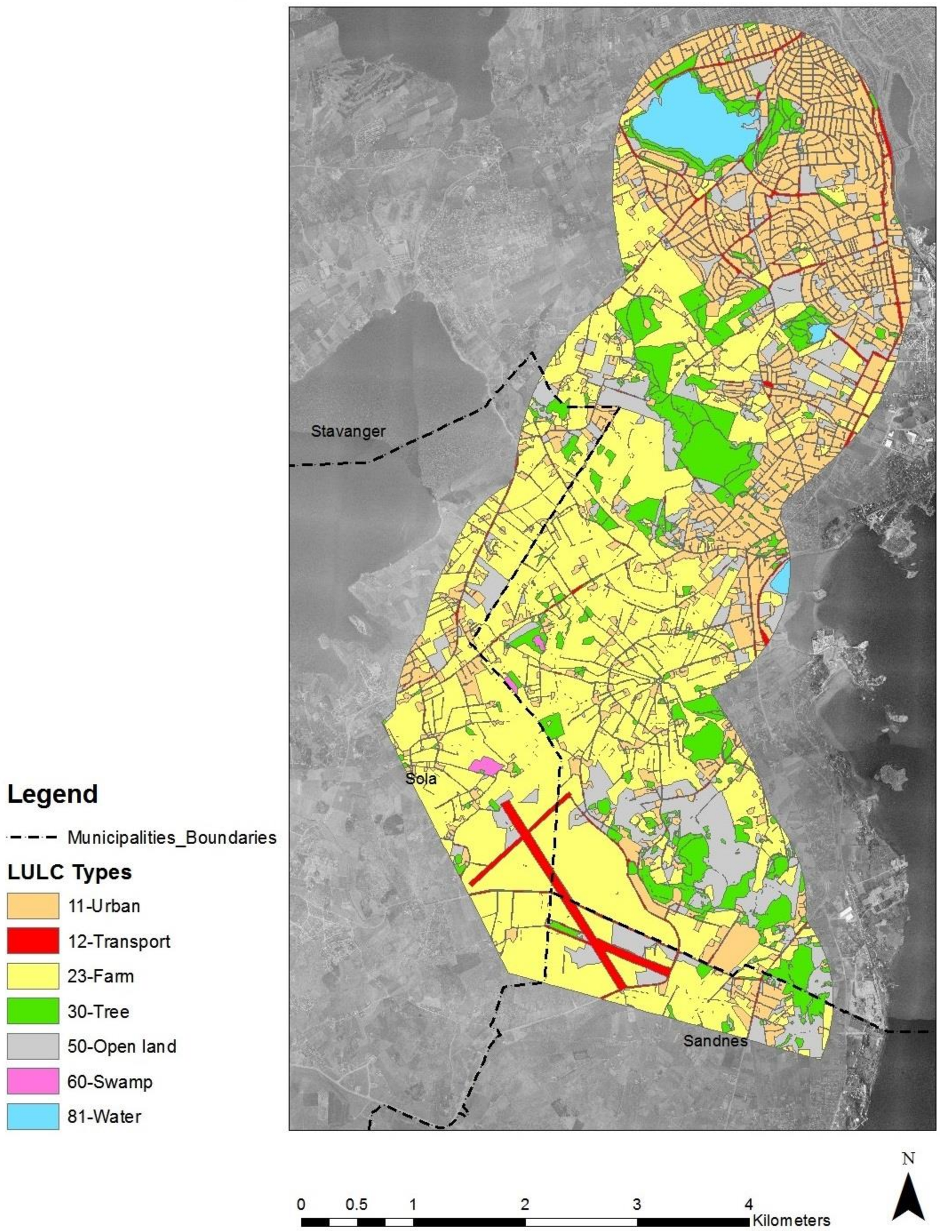

Figure.4. 12.Stavanger LULC map for the buffer zone 1200m in 1968

Next, buffer polygons for the distances 800 and 400 meters from the highways were used in the tool Clip in Geoprocessing toolset in Arc GIS to produce LULC layer data of the area for the respective buffer zones in 1968.

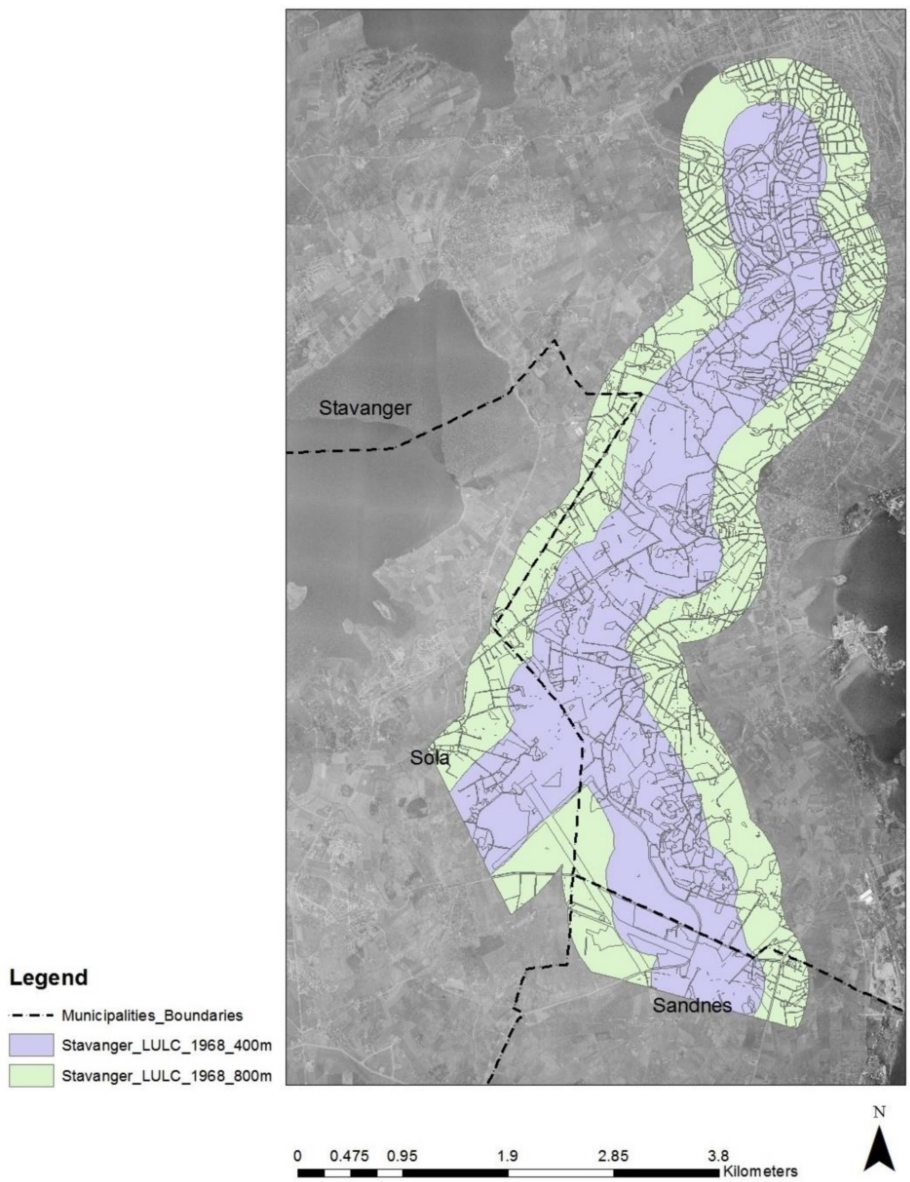

Figure.4. 13.The Stavanger LULC layers data for the buffer zones 800m and 400m in 1968

4-1-3-LULC Change layers for 1968 and 2019

At this step, all the LULC layers for the three buffer zones in 1968 and 2019 were created and it was needed to compare each pair of buffer zones in the two time slots to acquire LULC changes through the time period. Starting with LULC changes in buffer zone 1200m, the Intersect tool in

Geoprocessing toolset in Arc GIS was used to intersect each pair of LULC layers in 1968 and 2019. The result was a from-to layer data representing changes from each class of LULC to another. Two fields (Change_Class and Change_Area) in the final attribute table were also created by Field Calculator and Calculate Geometry in Arc Map to reach area of change as square kilometers as well as an index showing origin and destination layers of change.

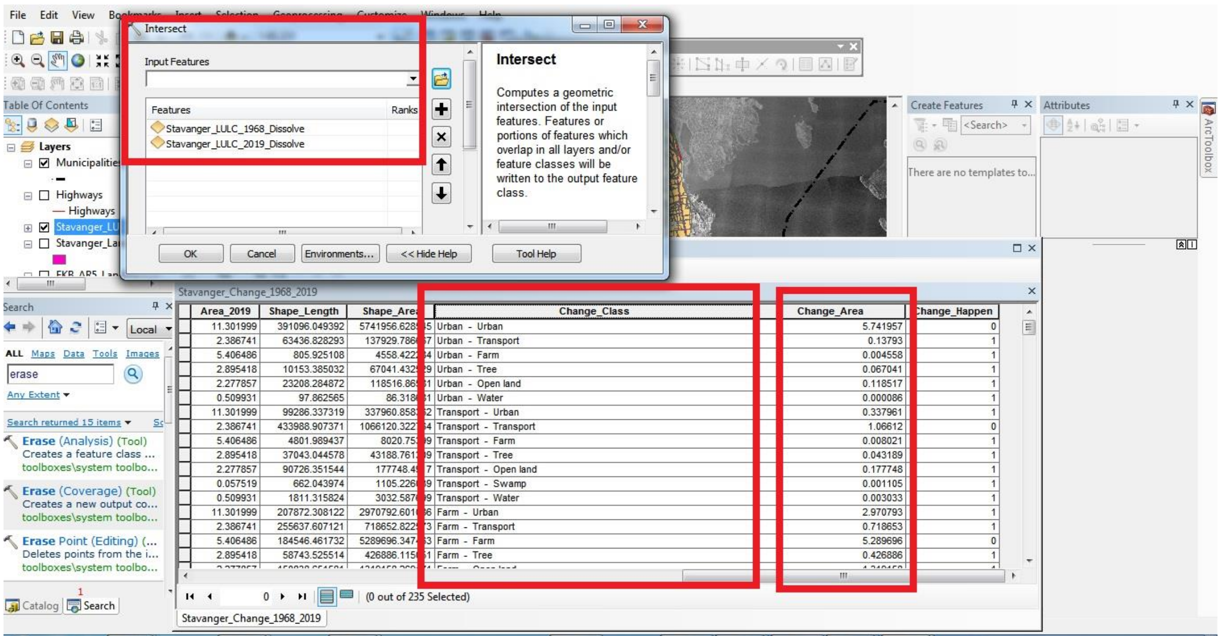

Figure.4. 14.Intersection of the LULC layers for 1968 and 2019 to create the from-to change layer

To better visualize the from-to changes of LULC between 1968 and 2019, a symbology was used based on the field Change_Class as below:

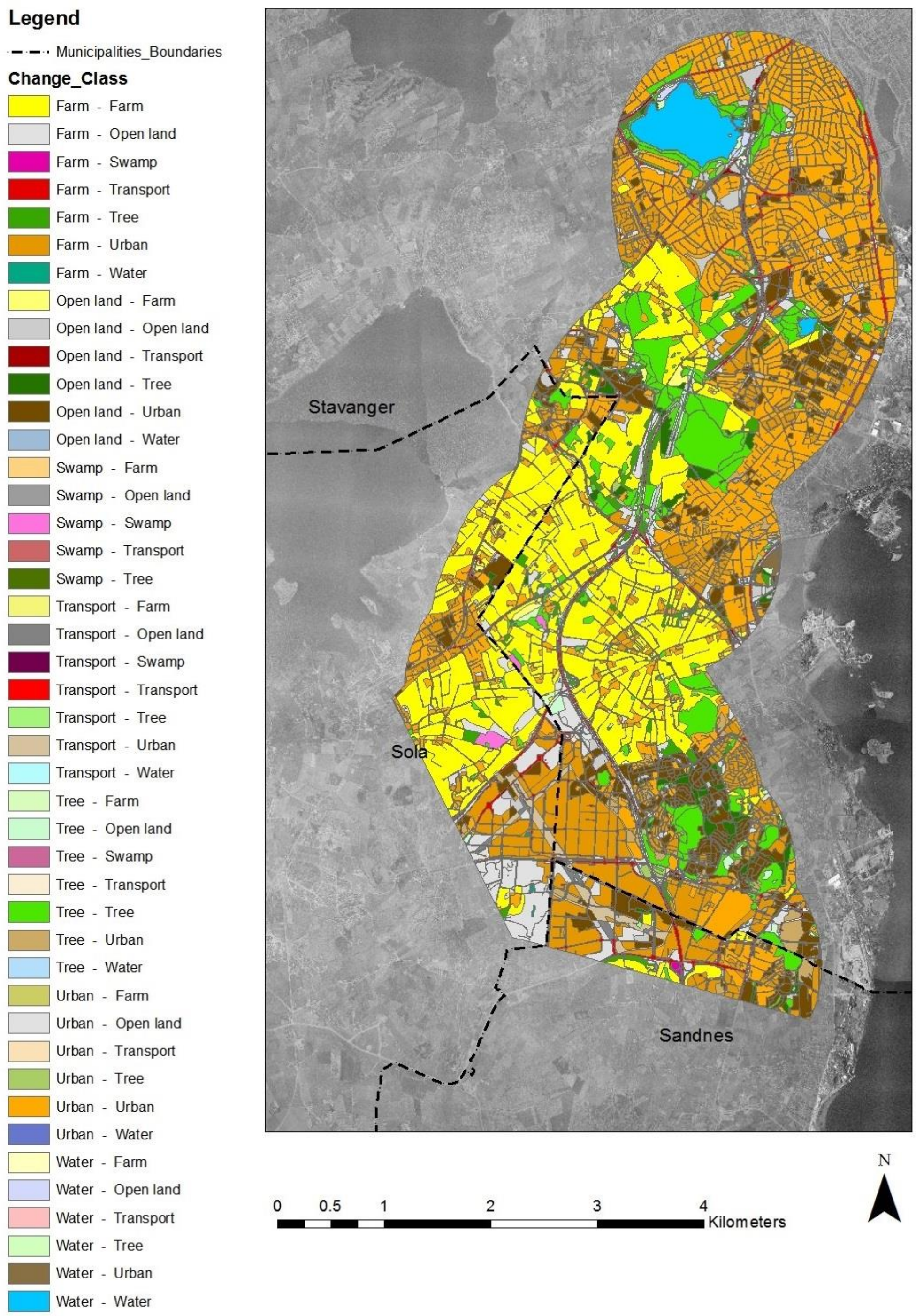

Figure.4. 15.The Stavanger from-to map of LULC change for the buffer zone 1200m (1968-2019)

Another approach to represent the matter of change is dividing the area into just two conditions: Changed or Not-changed specifically when we observed change from one class to another class. To reach this approach, a new field was initiated into the attribute table of LULC change layer for the 1200m buffer zone called: Change_Happen and two steps were passed in order to fill the values of this field. First, all the changes, with the same origin and destination classes, were selected by use of Select By Attributes in Arc Map which was meant no class change happened in this case.

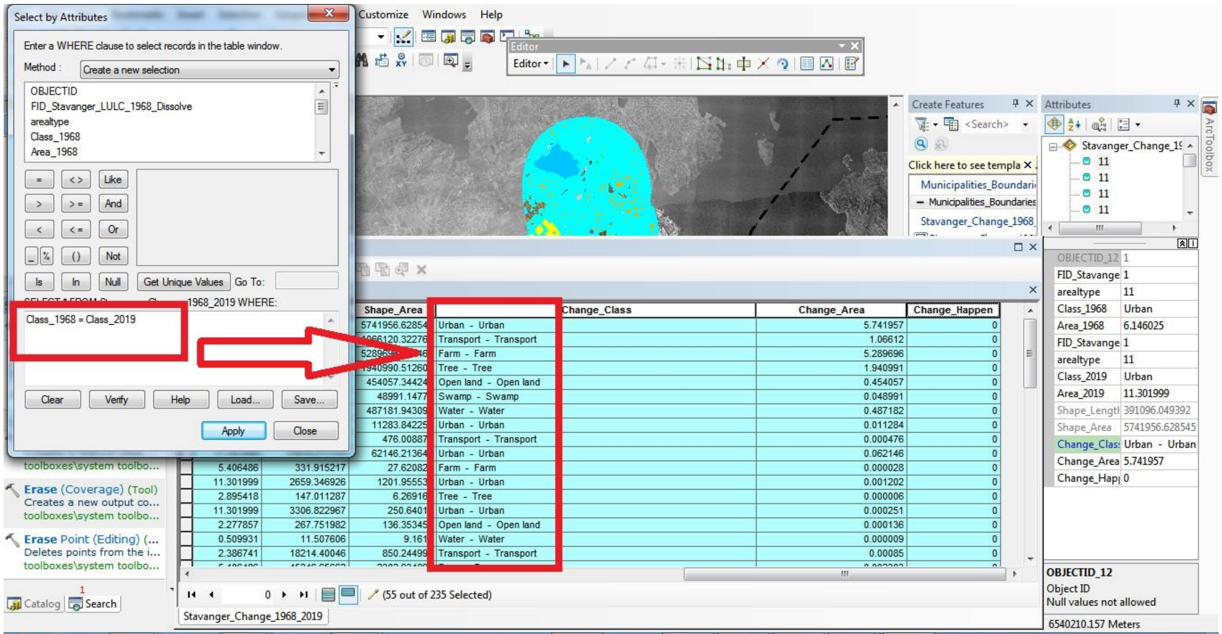

Figure.4. 16.The assignment of the records with no from-to change

Second, the value 0 was assigned to the all selected records showing the classes of origin and destination for change were the same and then for the rest of records, whose origins and destinations were not the same, the value 1 was assigned.

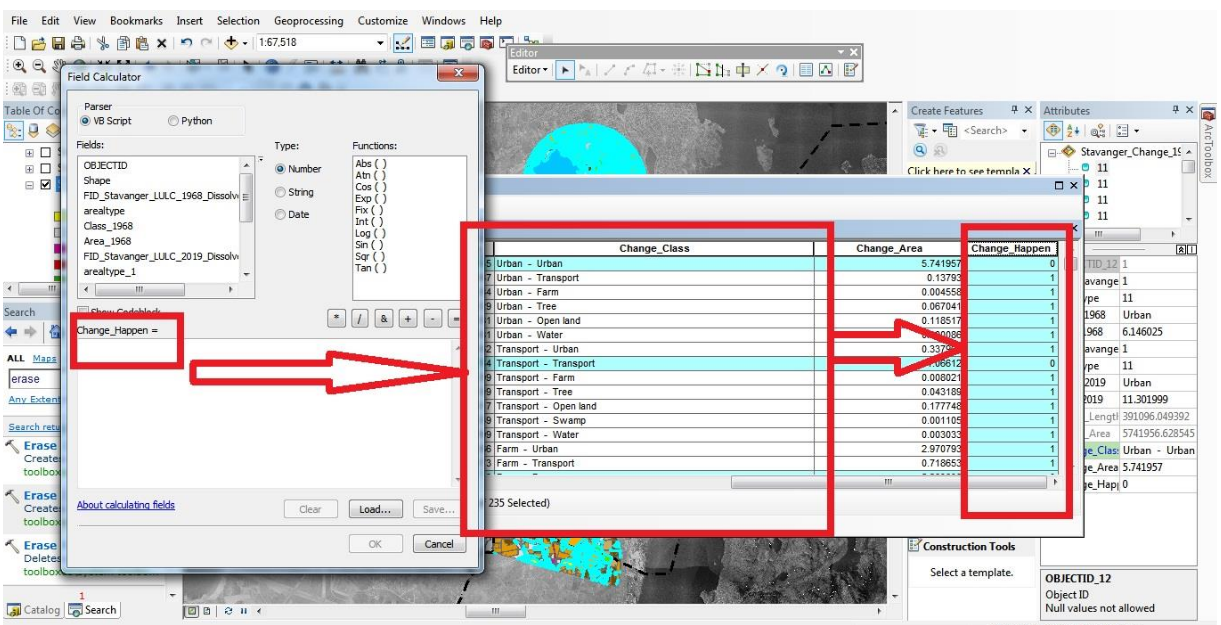

Figure.4. 17.The assignment of the records with happened from-to change

A binary field was created showing Changed and Not-changed classes and in turn, a symbology map was formed based on this field.

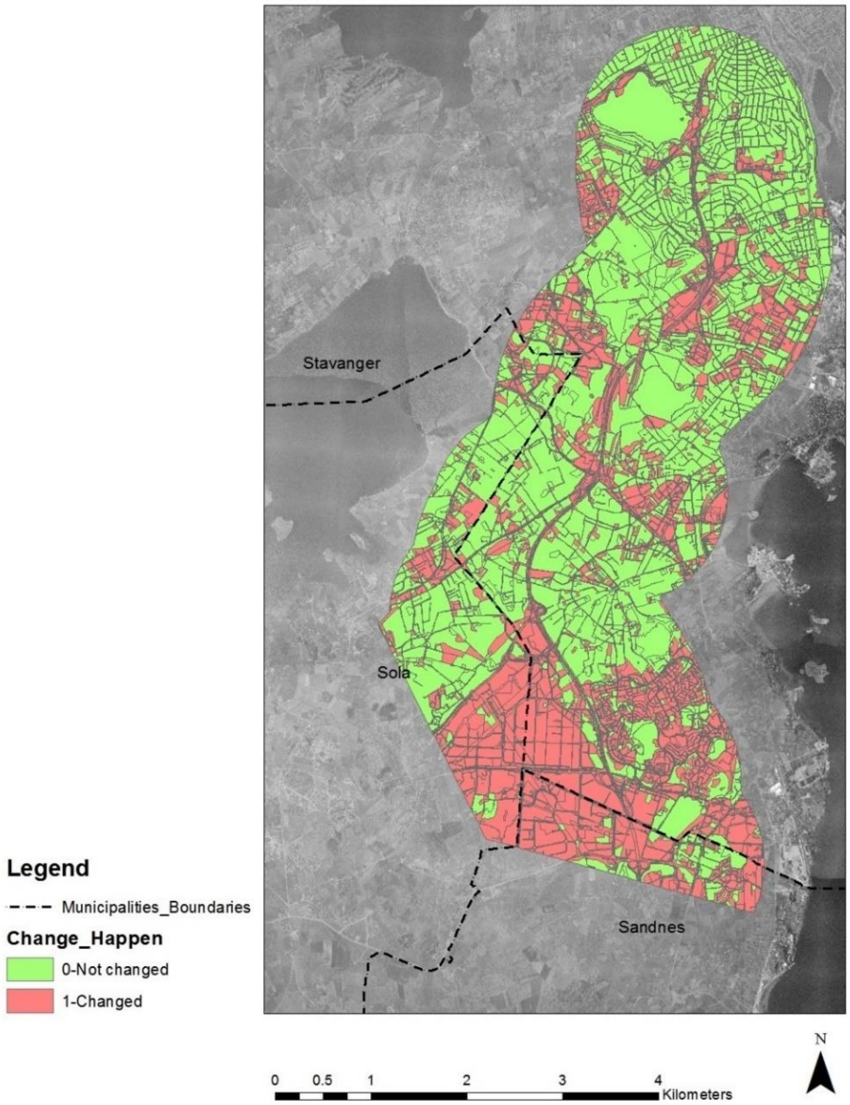

Figure.4. 18.The binary change detection map for the buffer zone 1200m in Stavanger (1968-2019)

Obviously, most of the class changes happened to the south of the buffer zone 1200m where were mostly farms in 1968 compared to the north, whose pattern was mostly urban and stayed more unchanged.

The changes between the LULC classes could be depicted in a way that showed both changes among the different classes as well as unchanged classes by choosing the color black for all the changes with the same origins and destinations in the previous from-to LULC change map for the buffer zone 1200m.

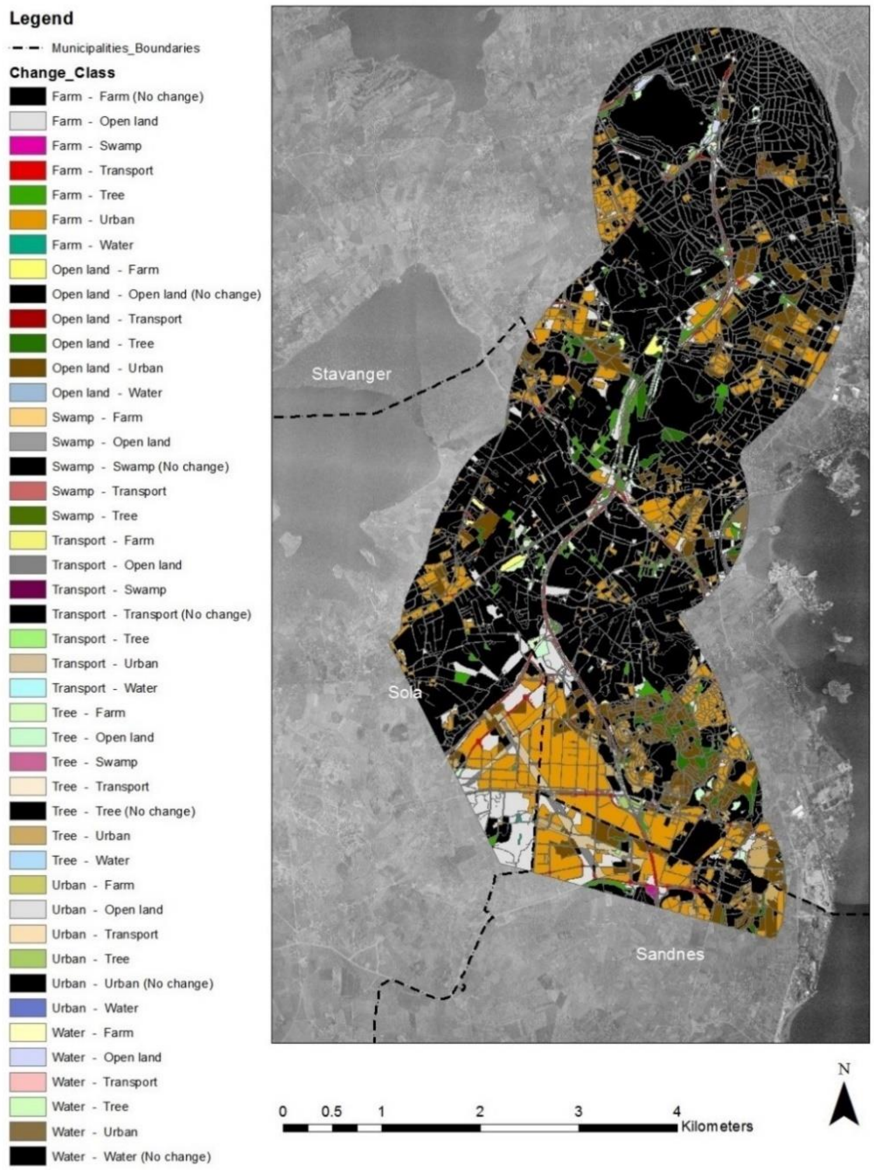

Figure.4. 19.The second Stavanger from-to map of LULC change for the buffer zone 1200m (1968-2019)

This map also confirmed that changes in the south part of the buffer zone was considerably more than the north part and all the black parcels showed no class change.

The similar procedure was used for the buffer zones 800 and 400 meters to acquire the LULC change maps and data layers from 1968 to 2019.

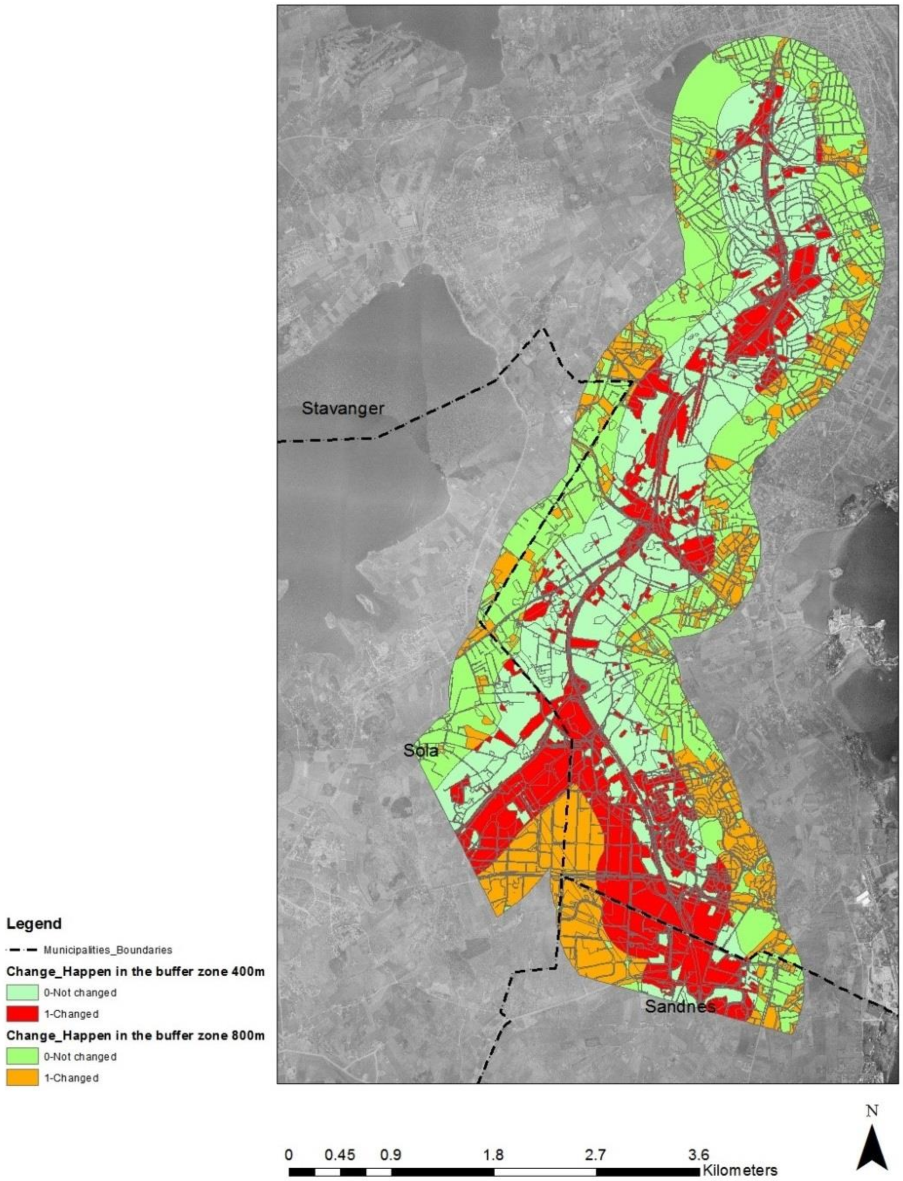

Figure.4. 20.The binary change detection layers of Stavanger for the buffer zones 800m and 400m (1968-2019)

The map focuses only on the binary condition of Changed or Not-changed among different LULC classes for the buffer zones 400 and 800 meters. For example, where the value is 0 means the origin and destination class were the same and there was no from-to change happened.

4-1-4-Statistical Analysis

After the change analysis, it was time to go further through the statistical details of the analysis. To start with this step, the attribute table of the LULC change map for the buffer zone 1200 meters was transferred from Arc GIS into Microsoft Excel.

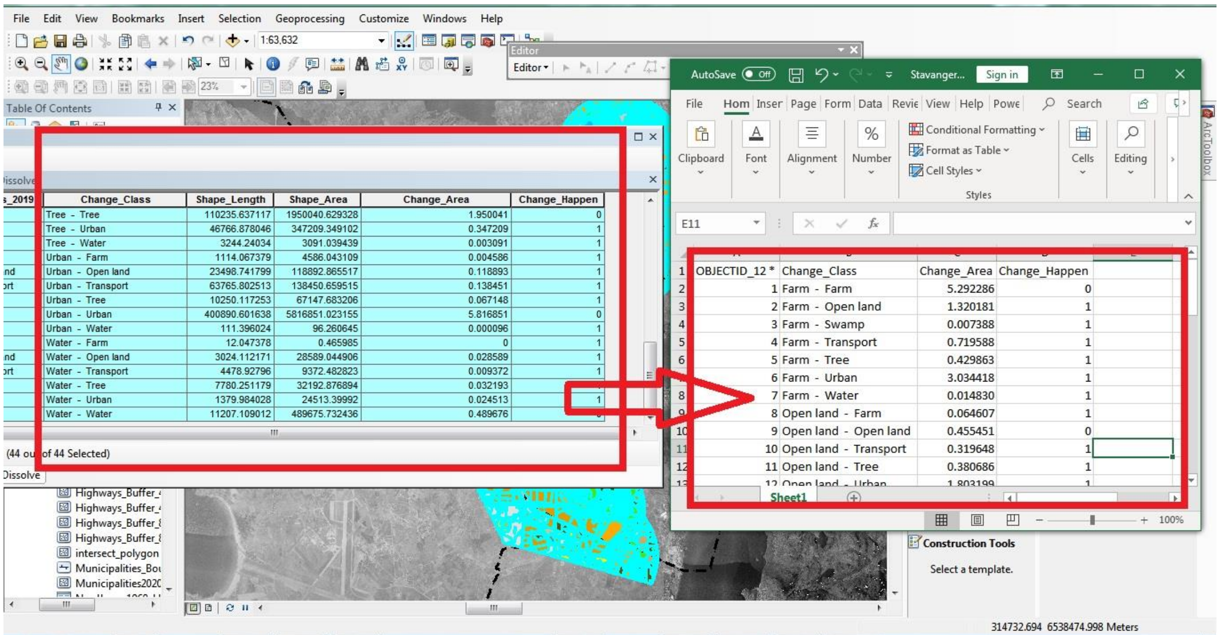

Figure.4. 21.Transfer of the from-to change records of LULC from Arc GIS into Microsoft Excel

It should be taken into account that the number of records were 44 which means there were no changes in the five from-to conditions of change as: open land to swamp, swamp to urban, swamp to water, urban to swamp and water to swamp so it was better to consider them in the analysis but assigning the value 0 for their records. Additionally, since square kilometer was chosen as the areal change unit for the analysis with 6-digit decimals, the class change for water-to-farm in this buffer zone with the value of 0.465985 square meters was estimated as 0 in the scale of square kilometer. To sum up, no change class was considered for these six from-to conditions in the buffer zone 1200 meters.

In Microsoft Excel, pivot table and bar chart for this buffer zone was created as below:

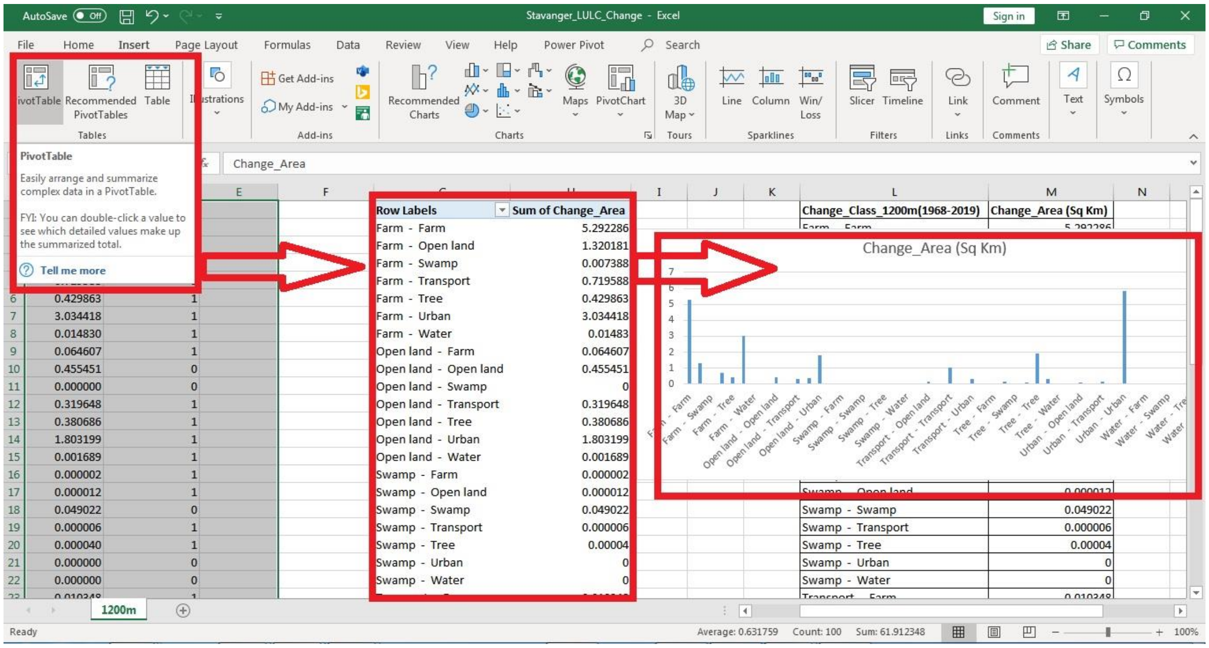

Figure.4. 22.Creation of the pivot table and bar chart of the from-to change records for the buffer zone 1200m

To create more flexible and editable charts, the data from Microsoft Excel was transferred to the software Tableau, specialized for this purpose. In Tableau, change classes with the same origins and destinations were excluded to represent just changes among the different classes of LULC.

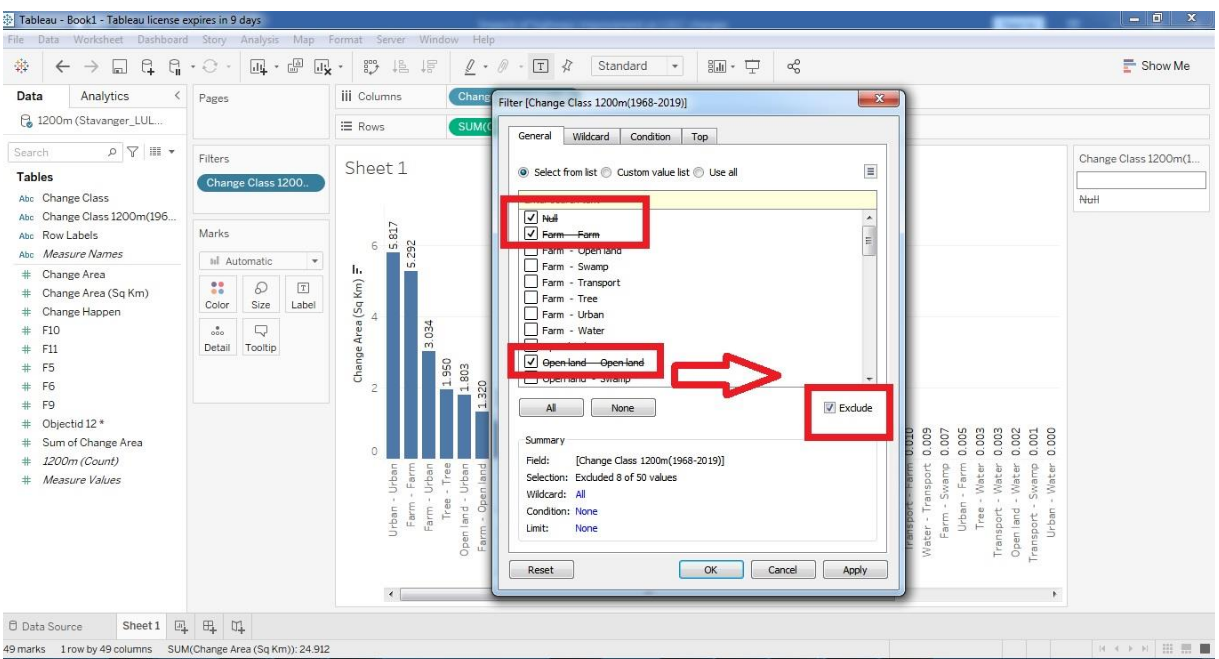

Figure.4. 23.Creation of the descending bar chart of the from-to change classes in Tableau

The records were sorted out descending to represent from the biggest from-to change to the smallest one and the result became as below:

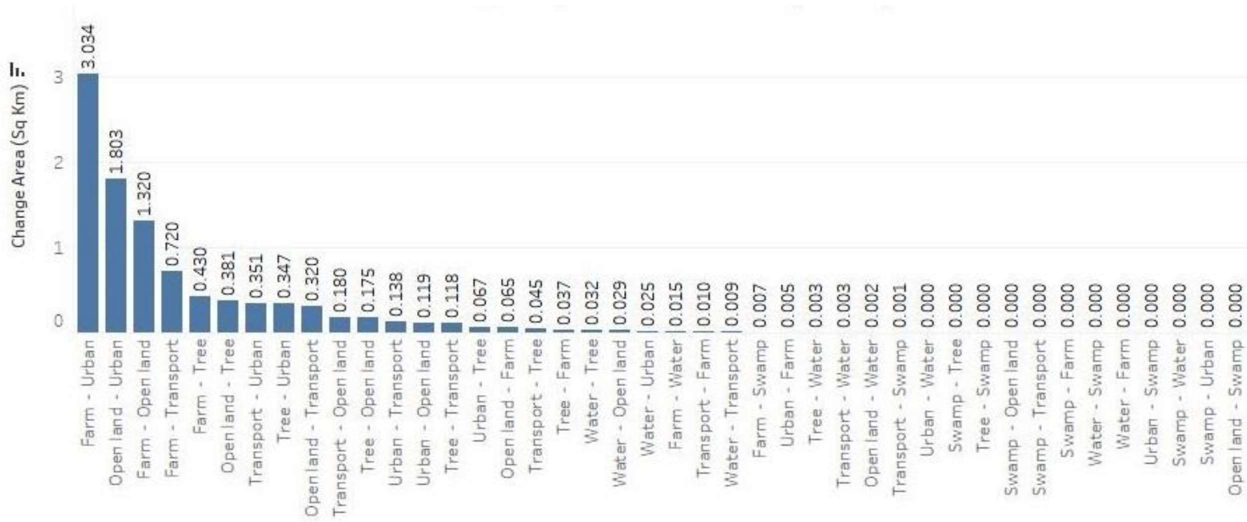

Figure.4. 24.The Stavanger bar chart of the from-to change in the buffer zone 1200m (1968-2019)

Obviously, the biggest from-to change in the buffer zone 1200 m was for the farm-urban class the same as the other two buffer zones and following that, the open land-urban, farm-open land, farm-transport classes and so on. The same procedure was passed to get similar bar charts for the buffer zones 800 and 400 meters.

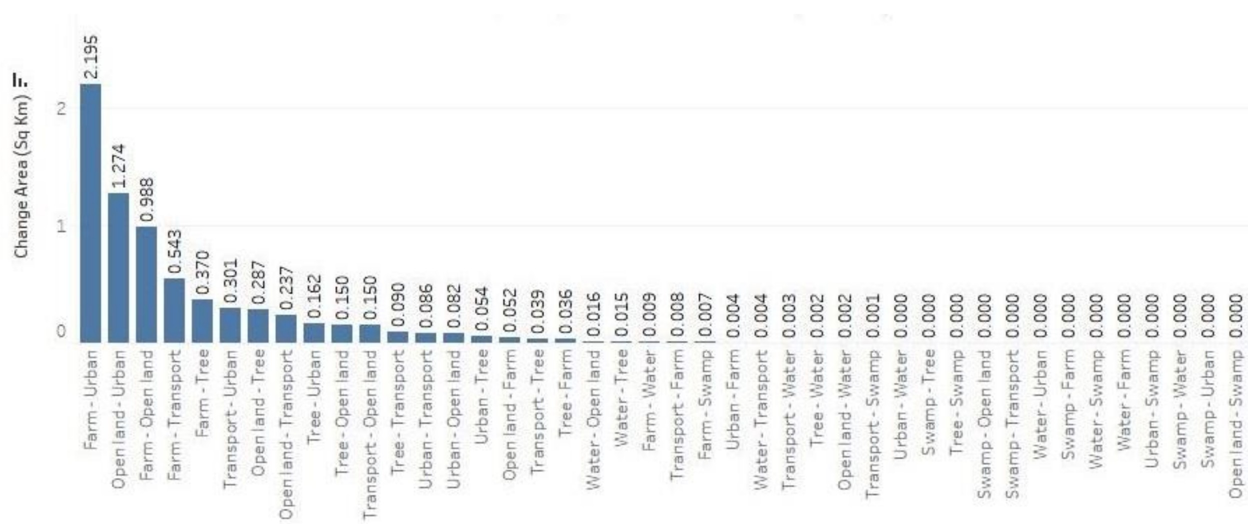

Figure.4. 25.The Stavanger bar chart of the from-to change in the buffer zone 800m (1968-2019)

The same trend was observed in the buffer zone 800 m from the first rank to the fifth and the sixth rank was from the transport to the urban despite the sixth rank in the buffer zone 1200 m, which was open land to tree.

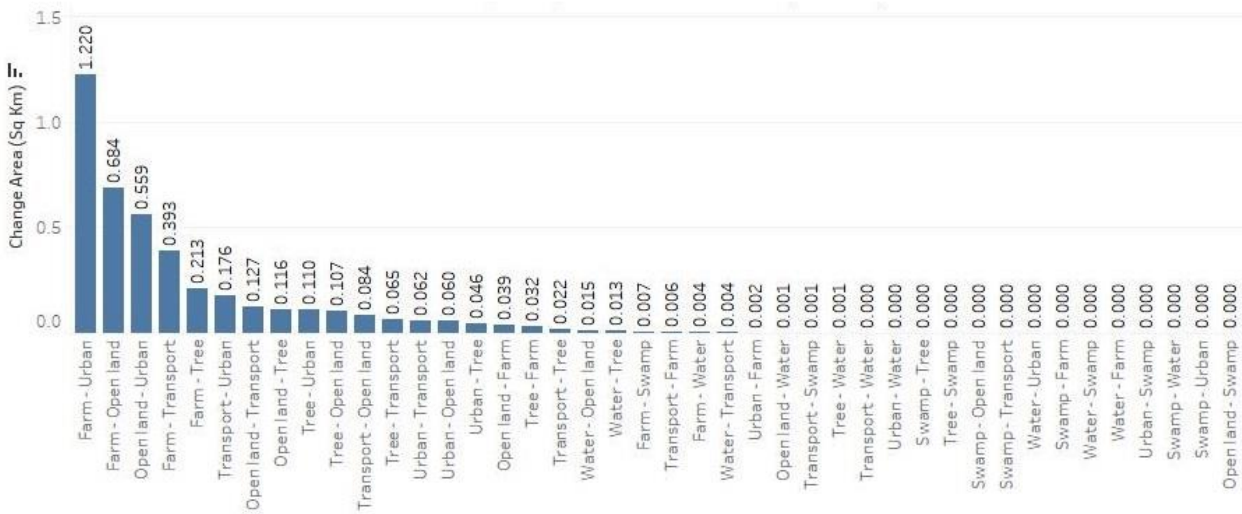

Figure.4. 26.The Stavanger bar chart of the from-to change in the buffer zone 400m (1968-2019)

For the buffer zone 400 m, the first rank was the same as the other two buffer zones, but the second rank was the farm-open land class while for the other two buffer zones the open land-urban class was the second. The third place was for the open land-urban class while for the other two buffer zones, the farm-open land class was the third place. However, the fourth and fifth ranks were common among all the buffer zones.

Regarding the percentage of each class of LULC in 1968 and 2019, following pie charts were created in Microsoft Excel.

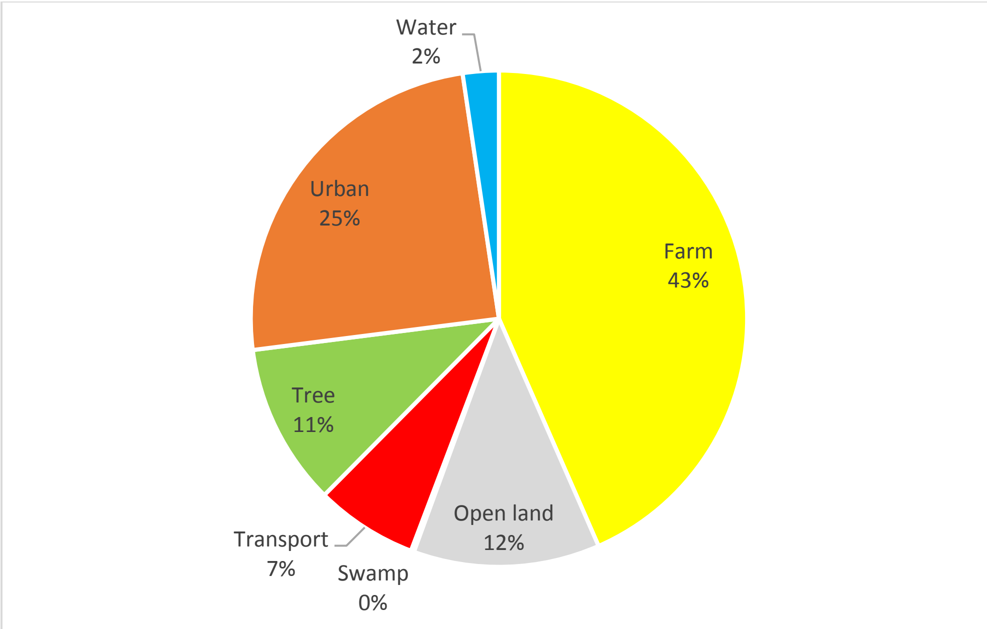

Figure.4. 27.The Stavanger LULC percentage for the buffer zone 1200m in 1968

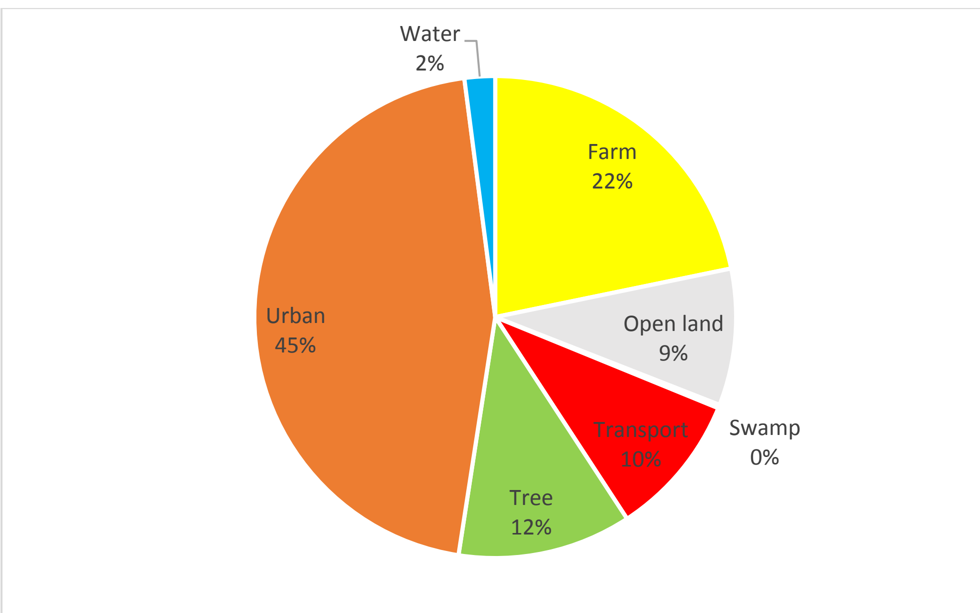

Figure.4. 28.The Stavanger LULC percentage for the buffer zone 1200m in 2019

As the pie charts show, the dominent class in 1968 was farm with 43 percentage of the whole area in the buffer zone 1200 meters while in 2019 the biggest precentage was for the urban class with the percentage of 45. Conversely, the second biggest classes in 1968 and 2019 were urban and farm respectively. The third place in 1968 was for the open land class with 12 percent closely more than the tree class with 11 percent while the open land's rank fell into the fifth rank with 9 percent in 2019 and the tree class increased to the third rank with 12 precent. The transport class also experienced an increase from fifth rank in 1968 to the fourth rank in 2019. The classes water and swamp formed a trifle proportion of the buffer zone with about 2 and 0 percent of the area in 1200 m buffer distance.

The same change was observed in the buffer zone 800 meters between the urban and farm class as they were replaced by each other from the first rank to the second between 1968 and 2019. As the urban class doubled in size, the farm class became half through the time. The open land and tree classes were also replaced by each other between the ranks third and fourth as the tree class grew two precent to stand in the third rank while open land class fell from 13 to 10 percent to stand in the fourth in 2019. The transport class kept the fifth place despite its growth and water class met a decrease from 3 to 1 percent of the whole buffer zone 800 meters between 1968 and 2019.

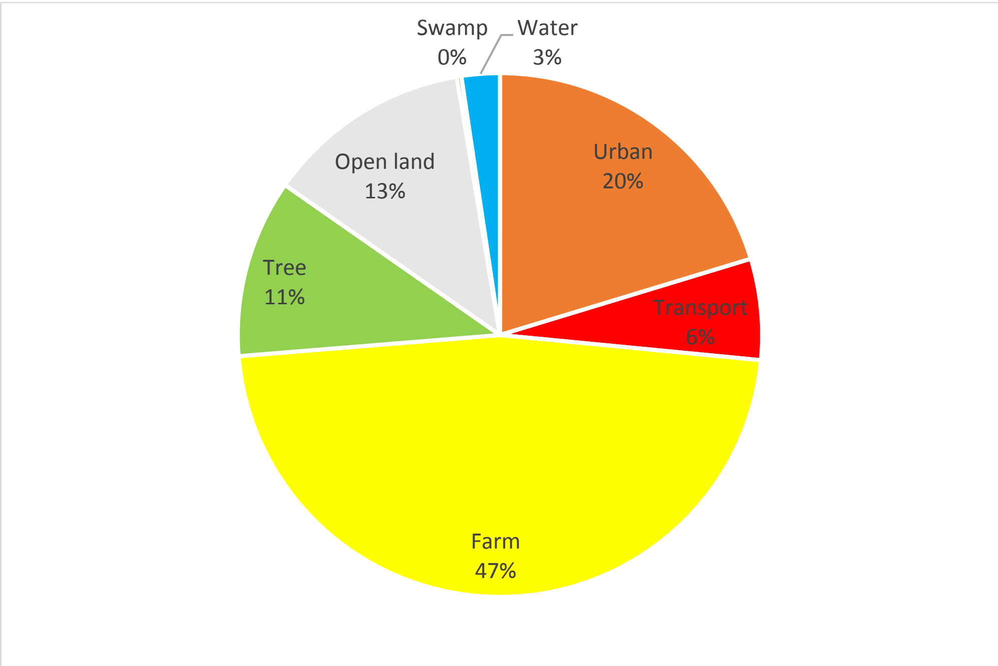

Figure.4. 29.The Stavanger LULC Proportions for the buffer zone 800m in 1968

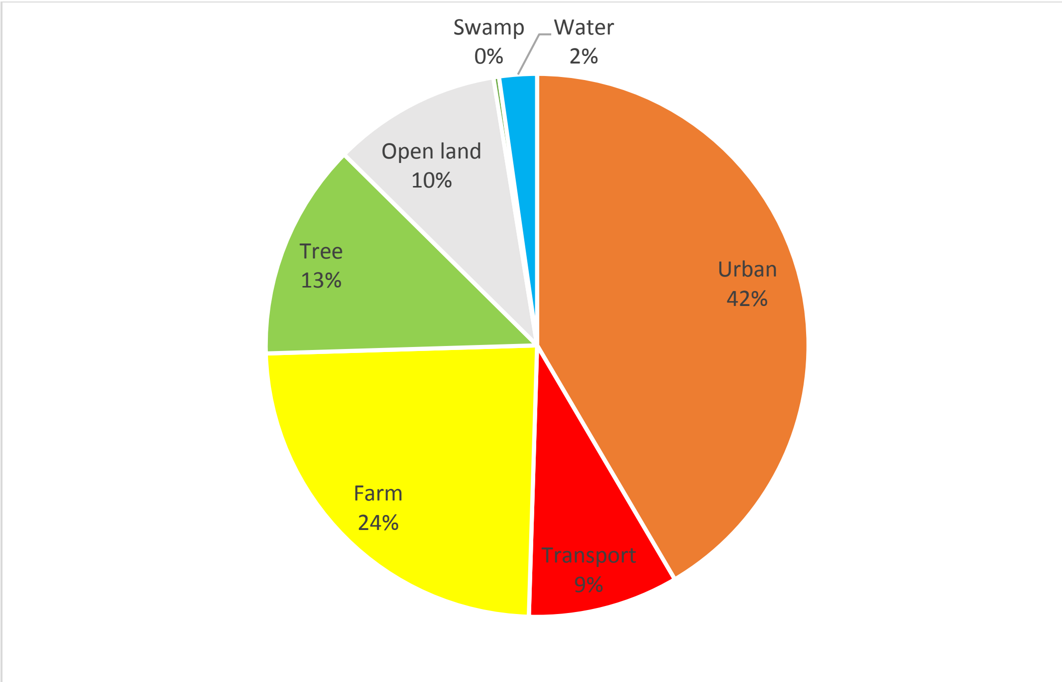

Figure.4. 30.The Stavanger LULC Proportions for the buffer zone 800m in 2019

Regarding the buffer zone 400 meters, the same subsititute between urban and farm class was observed as they changed from the first and second place to the second and first vise versa again with the same change percentage, double in the urban class and being half in the farm class. In this buffer zone, the open land and tree classes share the third place together in the both time slots while both of them increased in size from 12 percent to 13. The water class met again a decrease in this buffer zone as the same change size for the buffer zone 800 meters while an increase was observed in the class swamp from 0 to 1 percent of the whole buffer zone 400 m.

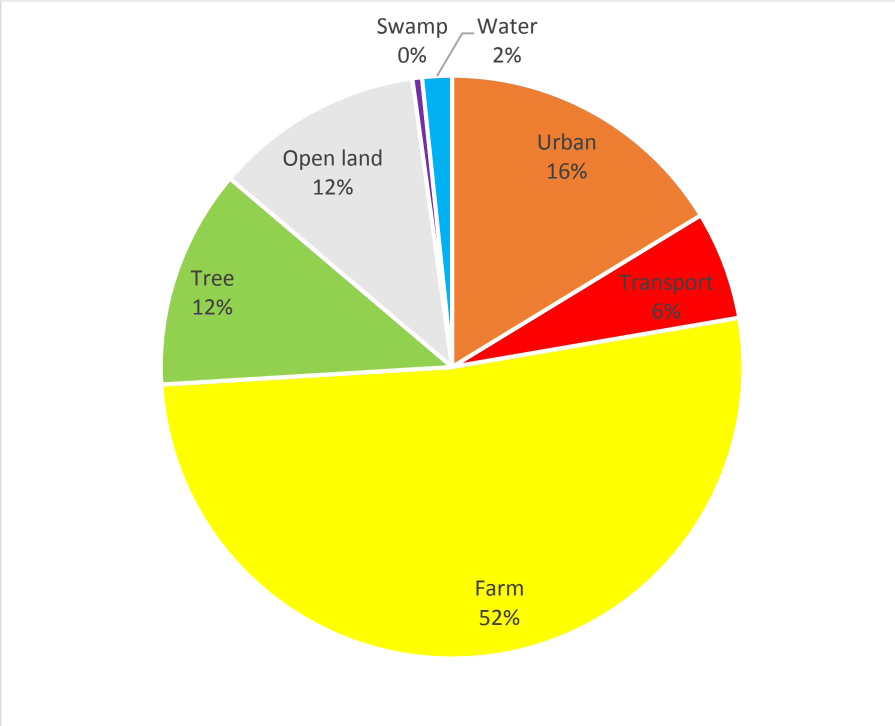

Figure.4. 31.The Stavanger LULC Proportions for the buffer zone 400m in 1968

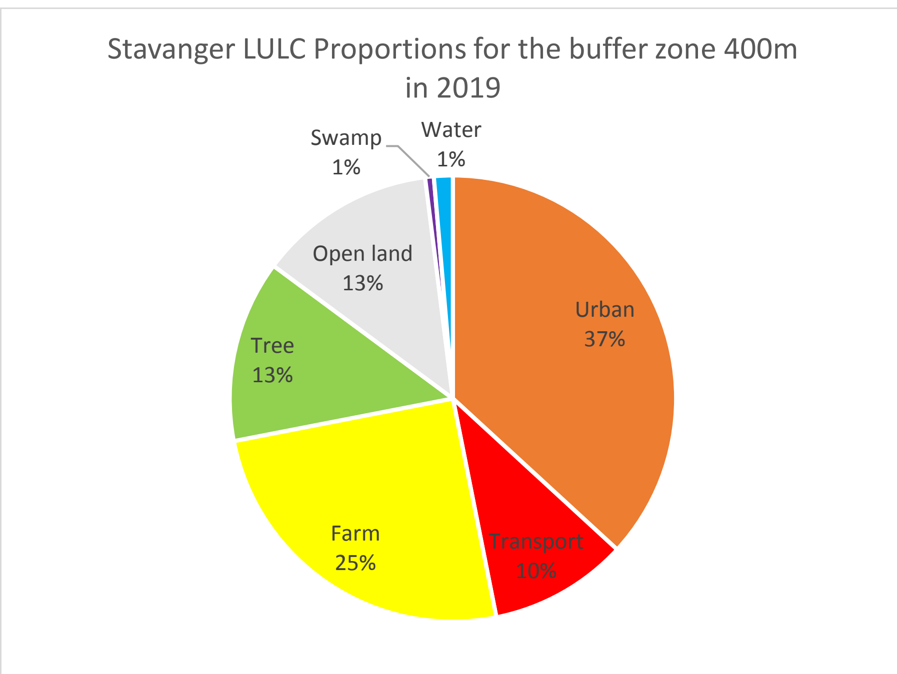

Figure.4. 32.The Stavanger LULC Proportions for the buffer zone 400m in 2019

Another approach about change detection can be investigation of how much each class has been maintained, increased or decreased in each buffer zone through the time period. In this case, the attribute table from LULC map layer in Arc GIS was transferred into Microsoft Excel and the area in 2019 was reduced from the area in 1968 to show the change inside each class through the time period.

Figure.4. 33.The Stavanger growth of LULC classes for the buffer zone 1200m (1968-2019)

As the diagram shows, the four classes of urban, transport, tree and swamp had positive trend and conversely, open land, farm and water had negative trends in the buffer zone 1200 m. The biggest changes happened in the classes urban and farm but opposite direction of each other.

The same statistical analysis went through the buffer zones 800 and 400 m and reuslts were as follows:

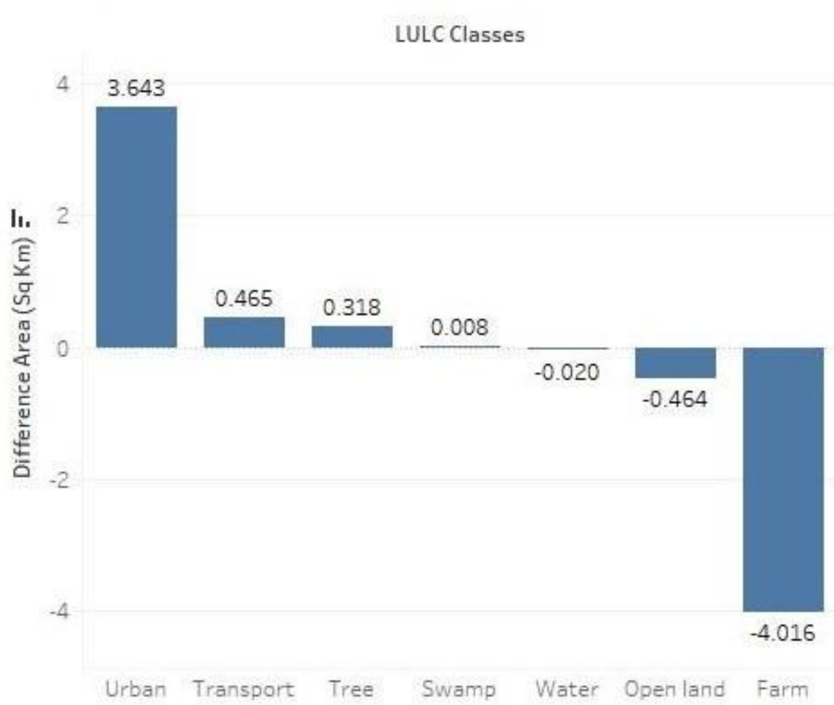

Figure.4. 34.The Stavanger growth of LULC classes for the buffer zone 800m (1968-2019)

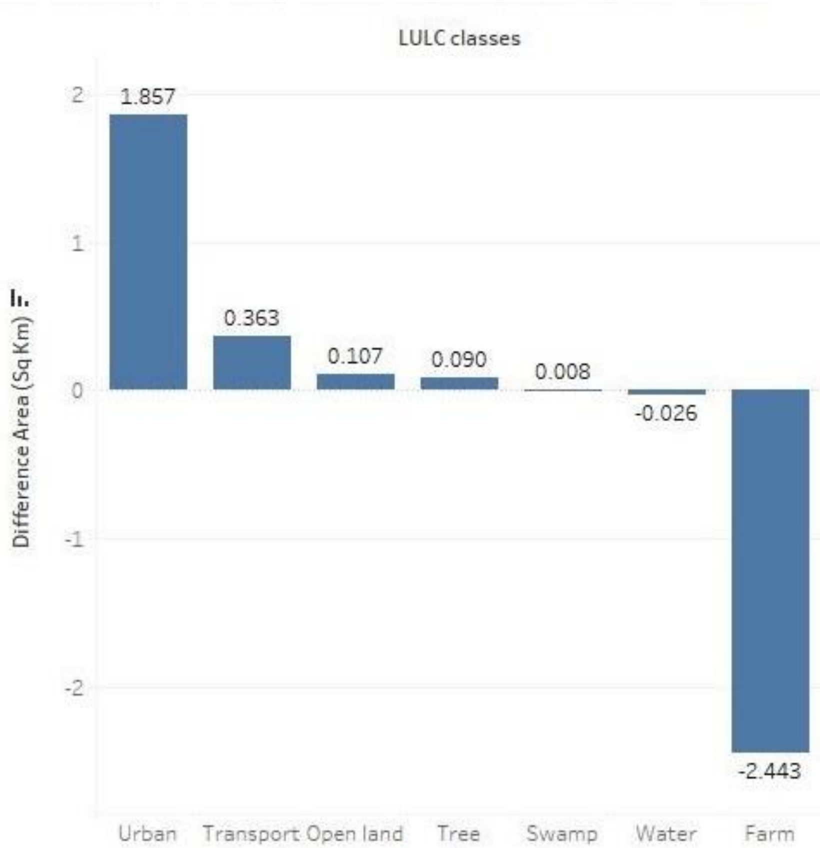

Figure.4. 35.The Stavanger growth of LULC classes for the buffer zone 400m (1968-2019)

The growth trend in the buffer distance 800 m, was exactly the same as the buffer zone 1200 m, the biggest increase and decrease were observed in the urban and farm classes respectively. The trend for the transport, tree and swamp was increasing while the open land and water met a decreasing trend in the buffer zone 800 m between 1968 and 2019.

The growth trend for the buffer zone 400 m were not the same as 1200 and 800 m buffer zones. The urban and farm classes still had the biggest increase and decrease. The transport and tree had also increasing trend but with less intensity compared to the buffer zones 1200 and 800 m. The class open land had a positive trend in this buffer zone despite the other two buffer zones. The water class experienced a subtle decrease and the swamp class had a small increase the same as in the other two buffer zones.

The last statistical illustration in this thesis is comparison of the intensity of changes happened in each class through the three buffer zones between 1968 and 2019.

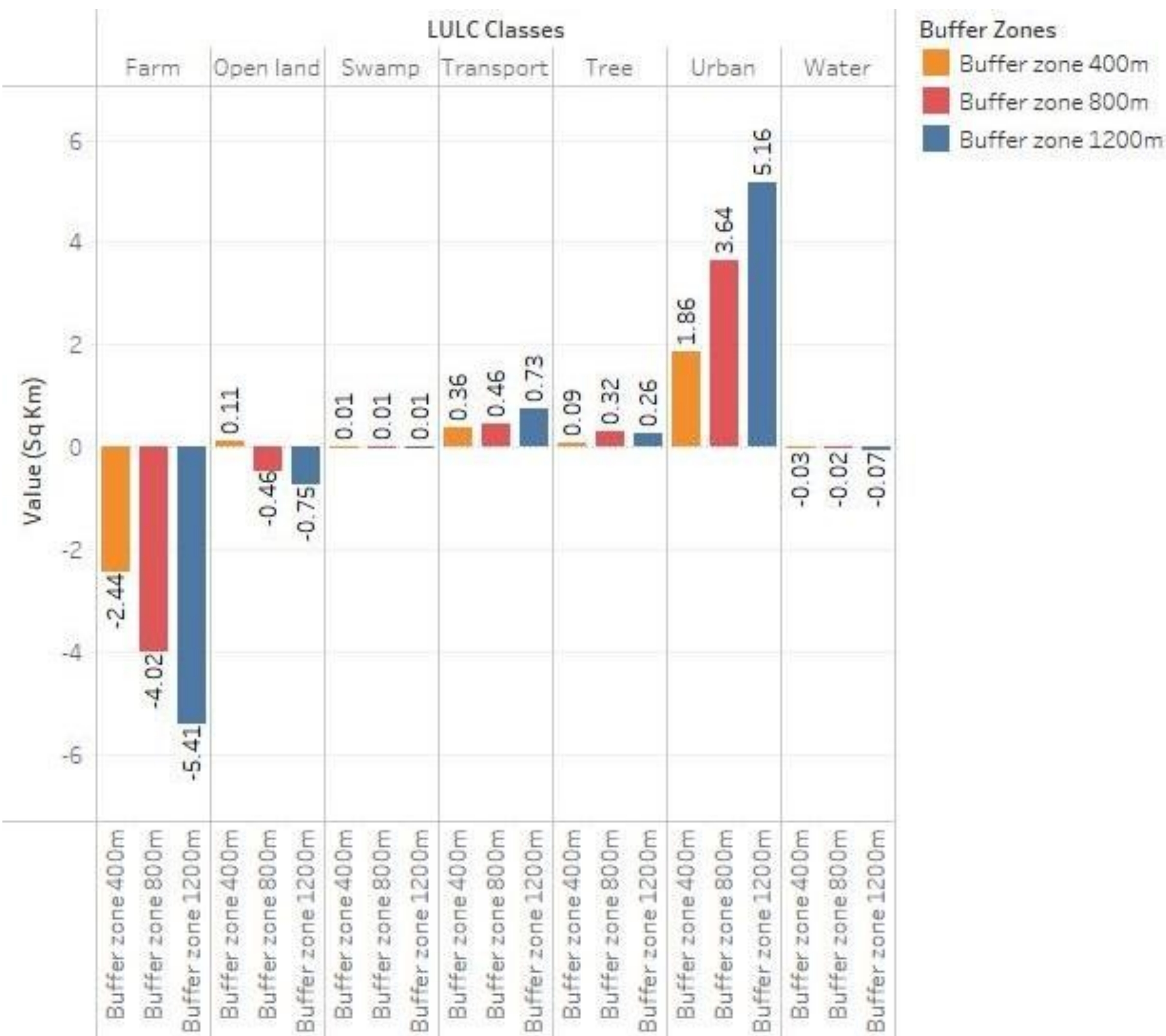

Figure.4. 36.The change intensity of the Stavanger LULC classes between 1968 and 2019

The most intense difference between adjacent intervals was for the open land class between 400 and 800 m buffer zones as it first had an increase of 0.11 Sq Km while it turned to a decrease of -0.5 Sq Km ,which was negatively five times bigger change, and it still followed decreasing in the buffer zone 1200 m.

The second most intense difference was for the water class between the buffer zone 800 and 1200 m as it had a decrease of -0.02 Sq Km while the decrease followed more intense with about -0.07 Sq Km which was more than three times more intense. Although the size of water class in the buffer zones was not considerable compared to the size of the other classes except swamp, which was the smallest class in this research.

The third most intense difference was almost commonly for the farm and urban classes between the buffer zones 400 and 800 m as the first one experienced two times negative growth while the second one had two times positive growth and both of them continued with their previous direction of change in the buffer zone 1200 m as well.

The trend of change for the transport class through the three buffer zones has a mild positive slope starting with an increase of 0.36 Sq Km in the 400 m buffer zone and finishing with 0.73 Sq Km still increase in the 1200 m buffer zone. The class of tree had an increasing change in the all three buffer zones but the size of change in the 800 m buffer zone was the biggest compared with the other two buffer zones. Finally, the swamp class experienced the same amount of change between each buffer zone with about a positive increase of 0.1 Sq Km.

5-Discussions

In this chapter, the analysis results of the research have been discussed in terms of socio-economic impacts and reasons of the LULC changes in the area through the time period.

To start with the changes, the biggest from-to change discovered in the analysis was from the farm to the urban class for the all three buffer zones around the highways (see the Figures Figure.4. 24,Figure.4. 25 Figure.4. 26). The location of these changes was mostly to the south of the area (Figure.4. 15) near Forus district and this might have been related to oil discovery in 1969 in the North Sea. Stavanger was chosen as the onshore center of oil industry on the Norwegian side of the North Sea after the debates. In particular, Forus now is the biggest and most important business area for the whole Norway ("Forus - About Forus - Norway's Most Important Business Area," n.d.) while it was mostly farm lands before as it was evident in the aerial photos of 1968 (see the Figure.4. 12 and Figure.4. 27). Apart from oil discovery, Stavanger municipality was merged with two adjacent municipalities Hetland and Madla in 1965 and these two were primarily agricultural communities, So this combination provided access to new, substantial housing construction zones for Stavanger (byhistorisk forening stavanger, 2016). Building a new highway like E39 going through Forus district was a necessity for this tremendous transition from a mostly agricultural land to the most important business area in the country.

The second rank of from-to changes was the open land-urban class for the buffer zones 1200 m and 800 m and the farm-open land class for the buffer zone 400m (see the Figures Figure.4. 24, Figure.4. 25 and Figure.4. 26). The change from the open land to the urban class made sense according to the fast urbanization pace of Stavanger through the time but the second rank for the buffer zone 400 m was from the farm to open land class. Additionally, the open land class itself has had descending trend in the buffer zones 1200m and 800m but ascending in the buffer zone 400m (Figure.4. 36) which means in the closer proximity of the highways, there were some areas not built up and considered as public spaces like vegetation and so-called right of way, for example figure below shows some of this areas in the close proximity of the highway E39.

Figure.5. 1.An example of the open land class created close to the highways in Stavanger between 1968 and 2019

The fourth and fifth ranks in from-to change classes were the same for the all three buffer zones which were the farm-transport and farm-tree classes respectively. Apart from this, an increasing growth can be seen in the class of tree in the all buffer zones through the time (Figure.4. 36). Considering all of these together is in line with current management plan for urban trees in Stavanger municipality whose vision is making the city a green city with a diverse and species-rich population of city trees, which has intrinsic value both in terms of climate and living circumstances.

As a result of this plan, investing in urban trees should be viewed as part of the municipality's efforts on improving living circumstances. Through the city's green infrastructure, trees should be seen as equally vital as other infrastructures (Stavanger kommune, 2020). Regarding the evident growth in urban and transport classes beside the farm-transport and farm-tree change classes, which were the fourth and fifth ranks in the from-to change classes in the all buffer zones, it is possible to speculate that authorities in Stavanger have efforted to keep or add the number of the trees against the increase of the urban and transportation classes to make a balance between them.

However, the increasing rate for the class of tree in the buffer zone 400m was less intense compared to the 800m and 1200m buffer zones (Figure.4. 36) meaning that as the distance got closer to the highways, less chance to plant new trees although the change for tree class was still positively growing in the 400 m buffer zone. This analysis just considered two time slots (1968 and 2019) and to investigate the changes in shorter periods inside this thesis's time span, more time intervals are needed to evaluate how much they succeeded since the authorities have started their programs.

The classes of water and farm were the only classes which have experienced negative rate in the all three buffer zones although their sizes were not comparable to each other (see the Figures Figure.4. 27, Figure.4. 28 and Figure.4. 36). Regarding the amount of negative change for the water class in the buffer zone 1200m (-0.07 Sq Km) was two to three times bigger than the its change in the buffer zones 800m (-0.02 Sq Km) and 400m (-0.03 Sq Km). Confirming these figures, some alterations of the water class in the aerial photos were observed between 1968 and 2019. For example, there was evident change of landscape in the east of the biggest buffer zone 1200m adjacent to the sea located in Hinna, where was close to Forus district.

Figure.5. 2.The first reduction in the water class observed in the aerial photos of Stavanger in 1968

Figure.5. 3.The first reduction in the water class observed in the aerial photos of Stavanger in 2019

The other considerable change for water class was around Mosvatnet lake, part of that was replaced by the green patch and trees and the other part was related to the direct construction of E39 next to the lake.

Figure.5. 4.The second reduction in the water class observed in the aerial photos of Stavanger in 1968

Figure.5. 5.The second reduction in the water class observed in the aerial photos of Stavanger in 2019

Another meaningful trend of change happened in the transportation class which was increasing for the all three buffer zones 0.36 Sq Km, 0.46 Sq Km and 0.73 Sq Km for the buffer zones 400m, 800m and 1200m respectively (Figure.4. 36) showing that, as the buffer zones became bigger, the bigger was the value of change. It's possible to speculate that as the distance from the highways grew longer, more demand for transportation grew, and this acted as a motivator to build new modes of transportation to meet the demand.

Spatially, highways create greater choice for industrial location. Typically, industries gather in a regional environment and decide upon the most beneficial location in that area like Forus district in common between Stavanger, Sola and Sandnes. Theoretically, "competitive regions have cities that gain competitive advantages from a highway link and experience positive economic effects" (Rephann & Isserman, 1994).

According to (G. Kraft, Valette, & Meyer, 1971), transportation performs to foster a 'spill-over' or 'growth fallout' from expanding centers to the supposedly underdeveloped areas as it was observed in the area of Stavanger, the direction of change and/or development from north of the area, which was mostly developed, to the south, which was mostly undeveloped was in 1968 (see the Figures Figure.4. 12, Figure.4. 6Figure.4. 15), and E39 as the most significant transportation tool, was placed exactly along this direction of change connecting developed areas towards undeveloped areas.

This direction of development from north to south might refer to also a planned intention of developing the linear «ribbon city» between Stavanger and Sandnes, first introduced in 1965 by Per Andersson, city planner from Stavanger (Figure.5. 6).

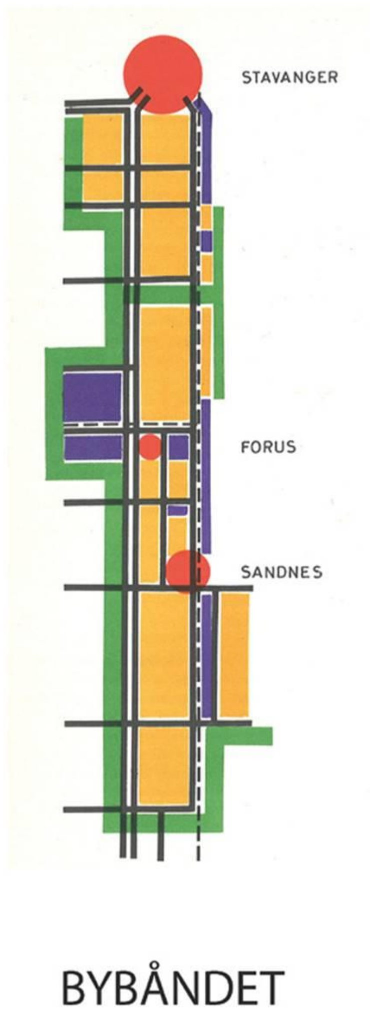

Figure.5. 6.The concept of ribbon city introduced by Per Anderson in 1965

The plan of developing the ribbon was then included as a central element in the first regional land use plan for Jæren in 1971, as well as the newer regional plans in 2000, 2013 and 2020 (Grimnes, 2020; KAP, 2019). Regarding ribbon concept, it is still very important part of the plans but the main priority in the ribbon city is currently to build a bus rapid transit system as the Rogaland County Council, the included municipalities and the national government have agreed to a goal of zero increase in personal transportation by car since 2019 (Dirdal, 2019).

The construction of a new or greatly improved highway that reduces commuting time and short-haul expenses may attract more workers and/or industry, resulting in the conversion of land from a less intensive to a more intensive usage. As a result, a cycle of forced growth begins and continues until the system's advantages outweigh the costs (Day, 2006b). However, investment in transportation infrastructure does not guarantee a boost of money and/or population. The regions must have a competitive side over other regions in order to the highway be effective. In other words, markets finally determine location.

In fact, policies determine land use, and in turn, leading to land cover change. Then again, land cover mostly forms human land uses, movements and reactions. “While landscape change is affected by human policies and plans, those plans are simultaneously formed in reaction to existing physical conditions and perceived changes and threats” (Erickson, 1995). As it comes to the area of this case study, there are now good conditions for promoting cooperation with the county municipality, the Norwegian Public Roads Administration, and the municipalities of Sandnes and Stavanger. The Partial County Plan for Land Use and Transportation, as well as the Transport Plan for the bigger area called Jæren formed in 1989, are the examples of this. However, There are significant challenges ahead in terms of mobilizing a sufficient and coordinated effort to shift land use and transportation commitments in a more ecologically friendly direction (*Cities of the Future City of Stavanger - Free Download PDF*, 2018).

Transportation and land use are two different elements of a region while their relationship is not very visible, but it is quite firm. One side of this relationship is the direct effect of progressing transport networks and following construction on direct land provision, and impact on the quality of soils because of construction and maintenance of transportation (Mothorpe, Hanson, & Schnier, 2013a). However, transportation has also effects on land use indirectly. At the same time, it is also necessary to consider the popularity of administrative or industrial locations particularly for placing centers of transport networks. As proper transport accessibility increases urban development in the proximity of a road, pressure rises on providing land for new residential and commercial interactions (Mothorpe et al., 2013a), confirming this with current case study, the largest positive growth in size was observed in the urban class in the all three buffer zones and the overall area of the urban class in the proximity of the highways became almost double between 1968 and 2019 (see the Figures Figure.4. 27,Figure.4. 28,Figure.4. 29Figure.4. 30Figure.4. 31Figure.4. 32).

However, there is a firm opposite connection as the way land is exerted and developed directly influences the need for passengers and goods mobility, so the pressure for the building new or rebuilding of existent sections of the transport network (Jedlička et al., 2019). Apart from the construction of E39, which has been the most important transportation infrastructure in the area beside Jæren Line (railroad from Stavanger to Egersund), a considerable increase was observed in the all three buffer zones for the class of transportation (Figure.4. 36) which means the demand for better accessibility and transportation was not met just by building of E39.

It is regarded that land use changes reflect different aspects of socio-economic progress and political conditions, beside environmental alterations (Łowicki, 2008). Five main types of determining forces that have made these changes include political, economic, technological, cultural and natural/spatial (Pazúr & Bolliger, 2017; Schneeberger et al., 2007; Skokanova, Falťan, & Havlíček, 2016).

Regarding this case study, the construction of highways is a technological driving force, and has been basically in the following of the urbanization that commenced in the 19th century because of economic progress and a high need for residing space. Urbanization associated with demographic growth and the developed spatial mobility of residents was particularly expressed after the Second World War (Ágnes et al., 2012; Kanianska et al., 2014). As a matter of fact, the population in

Stavanger increased from about 80000 in 1968 (Statistics Norway, 2000) to 143114 in 2019 (Statistics Norway, 2021) as it shows a significant growth of 179 percent which is completely in harmony with about 200 percent growth in urban class in the proximity of E39 as well as considerable economic growth after discovery of oil in the end of 60s in Norway.

Economic development related to post-war reconstruction and expanded industrialization facilitated the expansion of urban areas and the progress of the transportation infrastructures, which leading to more urbanization in Europe (Müller, Steinmeier, & Küchler, 2010). This was made by development in technological advances beside political drivers to subsidize transport construction, as was shown, for instance, in a study by (Schneeberger et al., 2007). Road construction can have also impact on agricultural intensification since it gives farmers to have access to inaccessible land (Biró et al., 2012; Hersperger & Bürgi, 2009). The lack of transport paths or their malfunctions might also turn to the increasing desertion of agricultural land (Haase, Walz, Neubert, & Rosenberg, 2007; Łowicki, 2008). However, in this case study, changes in the farm class parcels, which were mostly close to Forus, were significantly decreasing for all the buffer zones, because the area was relatively undeveloped in the south prior to the oil discovery in 1968, and then it became the country's most important business area afterward.

Some researchers have also focused on assessing the impact of the construction of highways and other important roads on land use in their vicinity (Müller et al., 2010) as this thesis project was focused on that. (Hrelja, 2015) investigates how driving cultures in local authorities influence execution of unified public transport and land use planning. It is now a very important matter the unifying of interrelation between transport and land use towards spatial planning (Colonna, Berloco, & Circella, 2012; Kii, Nakanishi, Nakamura, & Doi, 2016)

From an economic point of view, growth can show a successful economy. Populations need improvement in job opportunities and revenue that rely on the economic sources. So, growth meets this demand (Day, 2006b). Regarding this case study, an economic boost was obvious resulting from oil discovery, rapid industrialization and urbanization from 1968 but it was difficult to find a right economical index to evaluate how much was affected by highway improvements and LULC changes because of limited available economic data from 1968 and this arises needs for separate research concerns specifically related to economic matters. For example based on (The World Bank, 2021), Gross Domestic Product (GDP) for Norway increased from 10.16 billion USD in 1968 to 403.3 billion USD in 2019 but when it came to Stavanger scale, it was difficult to find particular economical information in 1968 so this case study is limited in terms of economic indices relevant to LULC changes and highway improvements.

Moreover, from an environmental or planning perspective, growth indicates challenges, but is apparently not unwelcome (Straszheim, 1972). For instance, despite the fact that decentralization and urban sprawl bring more chances and development at the local scale, they also make land use planning policies complicated (Day, 2006b). LULC changes monitoring affected by highway improvements as this research study, is a solution to simplify that complexity and is a necessity for any resource management and local policy program (Michalak, 1993).

The impact of highways on natural resources must be investigated in order to ensure the long-term sustainability of local tourism and agriculture, and this includes tracking changes in land cover caused by highway improvements. Depending on the scope of the study, the links between land use change and environmental and ecosystem changes, such as climate, soil, water, and ecosystem services, vary. However, as (Geist & Lambin, 2002) point out, globalization entails functional connections between changes in land use in distant regions. Many research have shown that land use regulations in other spatially distant locations influenced LULC change in a specific geographic location (Elzbieta Bielecka, 2020) for example, local land use policies in Sandnes municipality might affect land use change in Stavanger area and vice versa.

Human-caused land use change, according to (de Groot, Alkemade, Braat, Hein, & Willemen, 2010) and (Seto, Fragkias, Güneralp, & Reilly, 2011), results into carbon sequestration and climate change on a global level through the adjustment of albedo, temperature, and rainfall patterns. Alterations in land use produce fluctuations in river and groundwater flow, soil erosion and loss, and biodiversity dispersion on a regional or continental level, while at a local level, it's water and soil contamination, as well as extreme weather events (floods, storms, and drought). Many research studies have pointed out that spatial analyses of LULC changes, and particularly their impact on future LULC patterns and hydrological processes at the watershed scale, are necessary in monitoring, planning and management of water sources. However, this case study has focused more on physical impacts of highways improvements on LULC changes than environmental impacts of highways as for example, (Mansuroglu et al., 2010) did. Even though this study's results can be used and continued in the further research studies of LULC changes and highway improvements with environmental concerns in the area of Stavanger.

6-Conclusion

One of the most pressing challenges in land use change modeling is determining the amount to which both human and climate-induced changes are caused by human activities. Since the late 1990s, data on land use has been derived from widely available satellite imagery, which has been processed using a variety of GIS-oriented software programs. Satellite data also enables ongoing monitoring of land use changes at various scales. Highways as technological drivers for these changes as well as a necessity for economic progress come to spotlight for investigation. Regarding this case study, use of remote sensing data to extract land use data was not possible due to unavailability of that for 1968 in Stavanger and instead, photogrammetric data for both 1968 and 2019 was employed. The procedure of land use classification and extraction for 1968 in the current case study's methodology was quite more time-consuming than methods used in image processing in RS like supervised and unsupervised although accuracy was enhanced compared to them.

The urban sprawl phenomenon is quite problematic, as it is both environmentally and economically costly. This concern must be considered for Stavanger area if it plans to reach carbon neutrality in the next decades since it has had an outstanding development since the end of 60s and even more and fast progress is anticipated for the close future. New and improved roads are almost certainly required. Urban sprawl, on the other hand, is neither necessary nor desired. As a result, separating urban sprawl from road improvement is a critical issue and it is needed to learn more about this phenomenon in order to avoid it in the future. Therefore, we need to learn more about how it was made in the past and at this step studies like this research can contribute to prevent or address the issues.

Although change happens by natural cycles or events, human forces also have effects on land cover face. (Loveland & DeFries, 2004) Therefore, continuous monitoring of the earth's surface might determine causes of change from their effects. Geospatial technologies can monitor land use and land cover change over time as a result of highway investments and try to bring the conflicts into vision with decision makers.

According to the bibliometric study, GIS spatial analytic modeling for land use change is an interdisciplinary field of science headed by scientists from all over the world, regardless of whether they specialize in natural, technical, or social sciences. However, collaboration in this field has so far been more national than international and more cooperation is needed in the international scale. LULC spatial analysis at the local, regional, and global levels is covered in these works. However, research at different geographical scales are typically undertaken in isolation from one another and often belong under a single science subject (e.g., environmental sciences, ecology, geography, geosciences, urban, forestry). Based on the literature review, Indirect impacts are more difficult to assess, but they are also more substantial and detrimental. They have the ability to affect larger geographic areas in the long run.

In brief, the function of photogrammetry and a GIS platform was employed to show the pattern of spatial land use/land cover change coming from development along E39 and R509 in Stavanger. This investigation has focused more on change detection and major socio-economic causes of change in the area; although population, economic or other such elements may determine the results, and further research analyses with diverse economic and demographic indices integrating together are needed with current analysis of this research to find the correlation among them and deliver more comprehensive approach of impacts and causes of change.

After the analysis part of this study, the output LULC layers and changes were produced and evaluated for 1968 and 2019. The significant monitored changes and statistical results with the relevant socio-economic impacts and causes of the area Stavanger were discussed later. The biggest change was from the farm class to urban to about being double for the urban class and half size reduction for the farm class in the all three buffer distances from the highways. This rate was interestingly similar to 179 percent increase of population in Stavanger between 1968 and 2019. The effects of oil discovery in Norway in the end of 6os and choosing Stavanger as the oil capital and later, Forus district as the most important business center in the country, were evident on the tremendous observed change in the area since the LULC change maps showed before the most intense changes happened in the south close to Forus. Considering the geographically direction of change detected from north to south, E39 has had a great impact to transfer the development from the developed north to the undeveloped south inspired from the concept city ribbon introduced by Per Anderson in Stavanger in 1965.

GIS as the main tool in this master thesis, can facilitate communication among planners and contracting parties through the depiction of geographical and temporal land characteristics like different LULC maps and change detection illustrations in this case study or in a another way, it can bring the land use conflicts into the vision for policy makers to prevent or eradicate them. More crucially, through the construction of an interface, a decision support system (DSS) may be the link between the data's potential and its usefulness (Day, 2006b).

An active location policy and focused land development implies the optimum location of functions in relation to each other (the right function in the right location) and high exploitation of existing, established centrally situated parcels of land. This also relates to land space inside the influence regions of the most centrally placed public transport axes that already exist or in expansion to these. The steps are intended to lower the number of kilometers traveled every trip (*Cities of the Future City of Stavanger - Free Download PDF*, 2018). In this scenario, having a clear picture of what has happened over time is vital to arrive at this active location policy and avoid adverse or unnecessary alterations, especially in the case of urban sprawl, which is very probable for the urban areas with rapid rate of development like Stavanger.

The flow of people and goods into and out of Stavanger has been critical to the economy of the area so the key role of E39 and R509 as the most important transportation infrastructures in the area is undeniable. Overall, determining the exact impacts and causes of happened changes in such a fast-growing area like Stavanger is complicated and dependent on diverse socio-economic factors, but this study should have enhanced understanding of E39 and R509 impacts on land use change in Stavanger.

LULC changes monitoring affected by highway improvements as this research study, is a solution to simplify that complexity and is a necessity for any resource management and local policy program (Michalak, 1993).

Finally, back to the research questions of this thesis study, the land use changes created by the highways (E39 and R509) improvement in Stavanger municipality area have been detected in the three effective buffer distances from the highways with a well accuracy. The main socio-economic drivers of these changes were explained although further research studies might be needed since this study was limited to go deeper in various demographic and economic indices due to difficult access to relevant data and restricted data. Moreover, environmental approach can be another research concept for land use change related to highways improvement which needs fully focus on environmental impacts. This research methodology can be exerted as a prototype for the other similar case studies in different musicality areas in Norway to extract and monitor LULC changes compared to any transportation infrastructure. Regarding the lessons learned from this research, the results of this thesis research can be used and continued in further research studies with environmental or more socio-economic concerns in Stavanger. The output statistical and illustrations can be beneficial for the policy makers in Stavanger municipality, Rogaland county and Norwegian governmental authorities to update the regulation plans to address today urban development issues.

7-Future studies

The following concepts can be considered : the existent processes of suburbanization (Dostál, Havlíček, & Huzlík, 2010), alterations in urban forms of postmodern cities (Krejčí, Dostál, Havlíček, & Martinat, 2016; Mulíček, Osman, & Seidenglanz, 2015), unifying towards spatial and mobility planning (Jedlička et al., 2019; Malasek, 2012) or impacts on regional progress (S. Kraft, Halas, & Vančura, 2014; Michniak, 2015).

Another approach complementary to this study might be more research on highways impact on the environment, both human and physical, as well as the human-environment interaction.

The following are some areas related to this thesis research concept, which is about land use change caused by highway improvements in Stavanger through a time period, could be improved where future research should be conducted:

- It is necessary to complete a relationship between the locations of significant change and their associated demographic parameters, such as population, migration, and employment. This path may highlight the effective external variables that influence change.
- A comparison of change between the research area Stavanger and other neighboring municipality areas could help evaluate whether the findings given in this study are typical of infrastructure-impacted areas or find any significant correlation between changes happened in this case study area and the other areas in the proximity.
- To determine better the rate of change in the research area between 1968 and 2019, several time sections should be examined. During a certain time period, the area may have undergone growth booms that provide indications as to what produced successful development or considerable change.
- Prediction should be considered in further research studies of Stavanger area. Economic activities could be boosted by forecasting where development is most likely to occur among different districts in Stavanger area. It is possible that directing finances and resources to a certain location will avoid the misappropriation of economic resources.
- Continuous monitoring is required to assess the study area's future development. Every ten to twenty years, a similar study might be conducted.

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