LANDSCAPE CHANGE AND LANDSCAPE FRAGMENTATION ANALYSIS IN JELI, KELANTAN

by

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A final year project report submitted in fulfilment of the requirements for the degree of Bachelor of Applied Science (Sustainable Science) with Honours

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THESIS DECLARATION

I hereby declare that the work embodied in this Report is the result of the original research and has not been submitted for a higher degree to any universities or institutions.

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I certify that the Report of this final year project entitled " Landscape Change and Landscape Fragmentation Analysis in Jeli, Kelantan" by Latipah binti Muhammad Shah, matric number E15A0366 has been examined and all correction recommended by examiners have been done for the degree of Bachelor of Applied Science (Sustainable) with Honours Faculty of Earth Science, University Malaysia Kelantan.

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ABSTRACT

Landscape changes have many positive and negative impacts, it is all depends on rates of changes, planning policies and others factors that contribute in landscape changes and fragmentation. This paper main intends to quantify the landscape change in Jeli in 1994, 2004, and 2014 also to determine the degree of landscape fragmentation in Jeli in that three particular years. The landscape changes were based on the LULC. The spatial and transition changes of each LULC were analysed by using the landscape change analysis and landscape structure analysis for each landscape metric in 1994, 2004 and 2014. From the analysis it shows that the landscape change happened in Jeli for the three years periods. Jeli experienced the fragmentation of forest vegetation due to built-up. In 1994 and 2004 there was 57.34% forest loss meanwhile in 2004 and 2014 the forest vegetation loss due to built-up was 8.87%. The landscape structure that shows the Jeli area was fragmented during that period of time was from the value of the landscape structure analysis PD, LPI, MPA, LSI, ENN, and PAREA. In conclusions forest vegetation in Jeli had been experiencing landscape changes due to the increased of the anthropogenic activities.

ABSTRAK

Perubahan landskap mempunyai banyak kesan negative dan jugak positif, tetapi semuanya bergantung terhadap kadar perubahan,, dasar perancangan dan lain-lain factor yang menyumbang terhadap perubahan landskap dan fragmentasi. Objektif utama kajian ini adalah untuk mengukur perubahan landskap di Jeli pada tahun 1994, 2004, dan 2014 dan juga untuk menentukan darjah fargmentasi landsckap Jeli pada tiga tahun yang tersebut. Perubahan landskap adalah berdasarkan LULC. Perubahan spatial dan perubahan peralihan setiap LULC di analisis bagi setiap matrik landskap pada 1994, 2004, dan 2014. Analisis menunjukkan perubahan landskap berlaku di Jeli untuk ketiga-tiga tahun tersebut. Jeli mengalami fragmentasi hutan disebabkan oleh pembangunan. Pada tahun 1994 dan 2004 terdapat sebanyak 57.34% kehilangan hutan manakala pada tahun 2004 dan 2014 kehilangan hutan disebabkan pembangunan adalah 8.87%. Struktur landskap yang menunjukkan berlakunya fragmentasi di Jeli dalam tempoh masa tersebut adalah berdasarkan nilai yang diperolehi daripada analisis struktur landskap iaitu PD, LPI, MPA, LSI, ENN dan PAREA, Natijahnya, kawasan hutan dia Jeli mengalami perubahan landskap disebabkan oleh aktiviti antropogenik

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LIST OF ABBREVIATIONS

GIS	Geographic Information System
RS	Remote Sensing
ISODATA	Iterative Self-Organizing Data Analysis
LFT	Landscape Fragmentation Tool
DTM	Digital Terrain Model
UAV	Unmanned Aerial Vehicle
DEM	Digital Elevation Model
TM	Thematic Mapper
SPOT	Satellite Probatoire d’Observation de la Terre
AVHRR	Advanced Very High Resolution Radiometer
LULC	Land Use/ Land Cover
NOAA	National Oceanic and Atmospheric Administration
NDVI	Normalized Difference Vegetation Index
USGS	U.S. Geological Survey
GPS	Global Positioning System
PD	Patch density
MPA	Mean Patch Area
LPI	Largest Patch Index
LSI	Landscape Shape Index

MNN	Euclidean Nearest neighbor
PAREA	Percentage of Area
ANOVA	Analysis of Variance

LIST OF SYMBOLS

%	Percentage
m	Metre
ha	Hectare

CHAPTER 1

INTRODUCTION

Nearly 230 million hectare of forest area were lost because of global disruptions with the greatest loss occur in the tropic globally in the period of 2000 and 2012 based on the observance of the data that retrieved from satellite in recent study (Cushman, Macdonald, Landguth, Malhi, & Macdonald, 2017). Rates of the deforestation were eminent and elevated in South east of Asia. Forest loss in relation with the land area, Malaysia have highest level compared with Indonesia (Cushman et al., 2017)

For a sustainable management of forest ecosystems, the monitoring in the changes of the forest covers and also the understanding of the forest dynamics was important (Amarnath, Babar, & Murthy, 2017). A serious issue that leads to forest covers disturbances was logging activities and forest fires. The landscape fragmentation and the changes of forests configuration were also increased resulted from deforestation activity despite of the shrinking of forests area (Dalloza, Crouzeilles, Almeida-Gomes, Papi, & Prevedello, 2017).

The landscape fragmentation was defined as the green space or the forest vegetation was break into subordinate unconnected section that occur due to consequences of land usage such as agricultural activities, construction of roads and development of housing area (Beaudry, 2017). Moreover, the forest fragmentation reduced the availability amount of habitat which was also a suite issues followed when the sections of the habitat are not connected anymore (Beaudry, 2017).

1.1 Background of Study

The environmental issues like the deforestation, land and water pollution, landscape fragmentation, degradation of soil and soil erosion is at an alarming rate in Peninsular Malaysia. All of these issues were related with the unsustainable practice deforestation and land use patterns.

Deforestation in Malaysia was about at rate of 63.6%, which was about 20 890 000 hectares was cleared, this statistics was based on Butler (2006). Next, of from that 63.6% about 18.3% or roughly about 3 820 000 hectares was under the main forest classification, the most bio divergent forest form. In 1990 and 2000, there was standard amount forest loss by Malaysia per year which is 78 500 ha. About yearly medium rate of deforestation was 0.35% while there was 6.6% of forest cover had lost in 1990 and 2005.

Kelantan is one of the states in Malaysia which was located in the north-east of Peninsula and Kota Bharu as its main city. Ten districts were comprised in this state which is name as Kota Bharu, Pasir Mas, Tumpat, Pasir Puteh, Tanah Merah, Kuala Krai, Gua Musang, Machang, Bachok and Jeli.

1.2 Problem Statement

Many positive and negative impacts would arise from the landscape changes. It is all depends on it rates of changes, planning policies and many other factors that will also contribute in landscape changes. Next, there will be lots of negative effect of landscape changes which is the habitats of flora and fauna will be destructed, loss of our timber products, deforestation, human wildlife conflicts will occur and more. In order to measure the landscape changes and identify the landscape fragmentation on green space, the analysis of the landscape fragmentation and its modeling by using the remotely sense technique will be use. Moreover, this technique is still new in Malaysia and not widely exposed yet.

Main purpose of this study is intends to analyze the landscape change and landscape fragmentation in Jeli, Kelantan. Despite of that, this study also helps in filling the gaps in the knowledge which is lack in the using of Geographic Information System and remote sensing in Malaysia in process of quantifying landscape changes and landscape fragmentation analysis in Jeli area compared with the previous research.

1.3 Objectives

1. To quantify the landscape change in Jeli in 1994, 2004, and 2014.
2. To determine the degree of landscape fragmentation in Jeli in 1994, 2004, and 2014.

1.4 Scope of Study

This study is focus to determine the landscape changes and its impacts on forest vegetation in Jeli, Kelantan. The main issue in Jeli area is deforestation that will lead to the landscape fragmentation besides other factors like the development and facilities construction. In order to identify the landscape changes in Jeli and to determine its landscape fragmentation, the remote sensing and GIS technique was used in this study.

By using remote sensing and GIS technique the landscape changes and the landscape fragmentation in Jeli can be detected. Below is the research framework:-

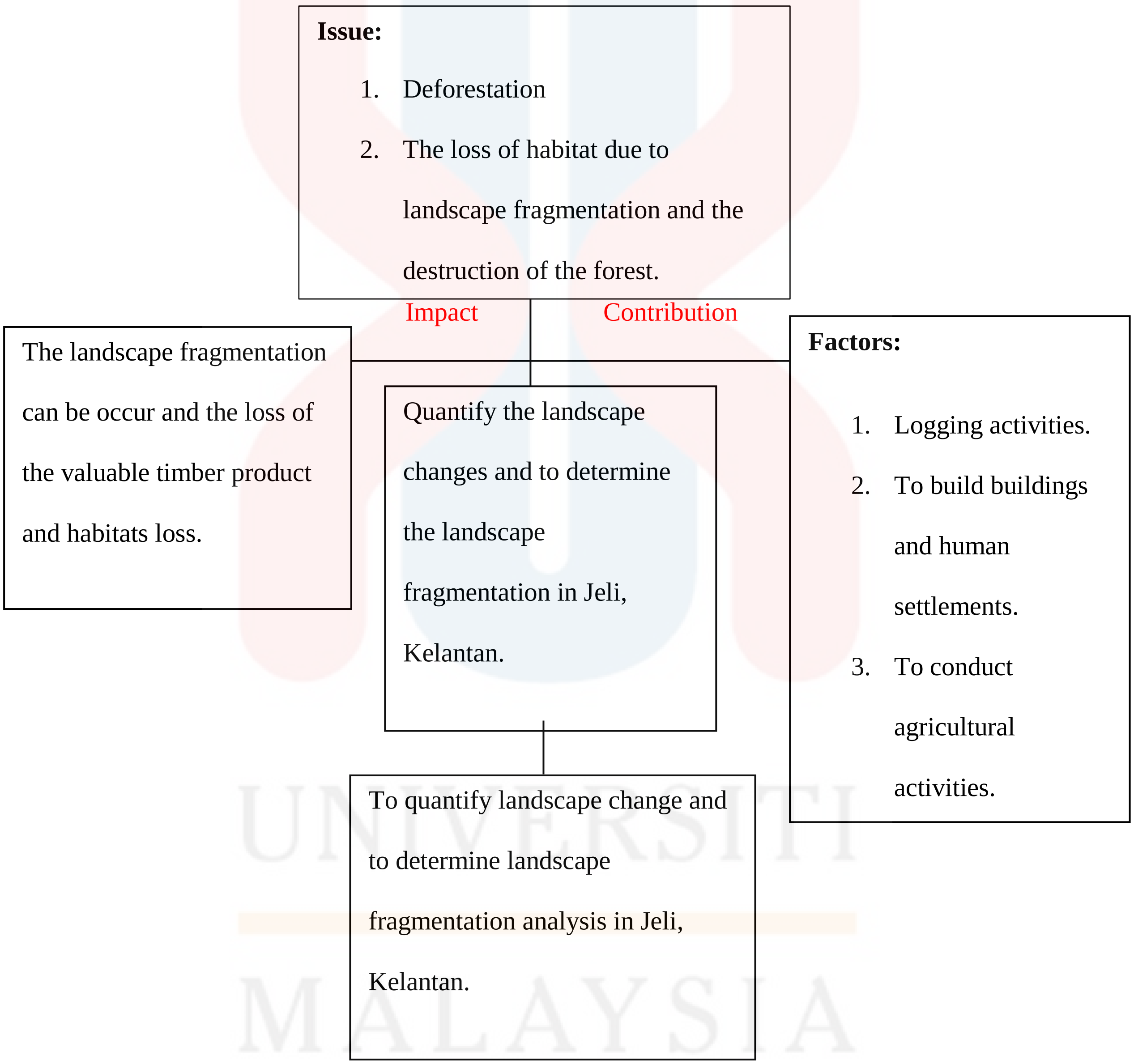


Figure 1.1 Research Framework

1.5 Significant of Study

The main purpose of this study to be carried in Jeli, Kelantan is to quantify the landscape change and to determine the landscape fragmentation analysis. In the current situations, Jeli area is prone the deforestation activity because of Jeli area is in developing phase. Thus, the forests area is cleared to develop the facilities such as the road, school, university, road and many more. Besides, logging occurs due to the lots of valuable timber products in Jeli area.

The importance of this study is to quantify the landscape change and to analyse landscape fragmentation in Jeli, Kelantan. This study will provide the valuable data and information for quantifying the landscape change and for the analysis of landscape fragmentation in Jeli for the management and planning ultimately to protect the habitat area and also promotes in future sustainable land use planning.

CHAPTER 2

LITERATURE REVIEW

2.1 Deforestation

According to Food and Agriculture Organization of the United Nation (2000) under forest resources assessment, the forest conversion to another land use or the long – term decrement of tree canopy cover below the 10% threshold is defined as deforestation. In order to ensure the elimination of trees from an area, is a deforestation or not it is important for the prediction of the development area in future the land is classified as forest, if there is new forest trees are establish in near area throughout the regeneration period, and this regrowth is known as reforestation.

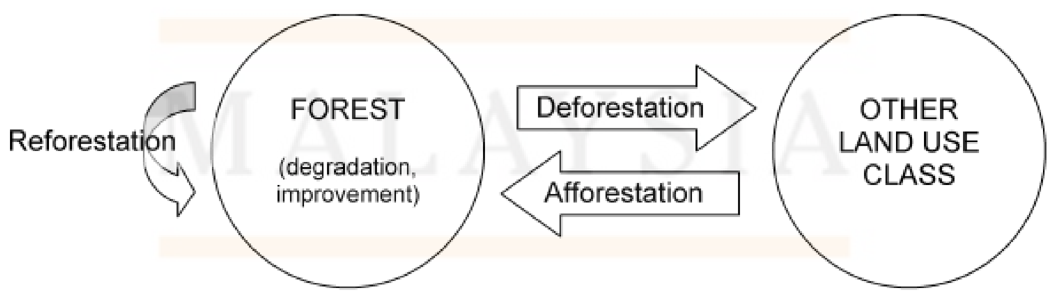


Figure2.1 Relationship between forest change terms. (Source: Food and Agriculture Organization of the United Nations, 2000)

The everlasting destruction of forest cover is the effect of deforestation. When the land is converted into agriculture, water reservoirs, grassland and urban areas are among the factors that contribute to deforestation. In a long term period the forest area was predicted to be regenerate with the aid of silvicultural or in the natural measures in the areas where the trees have been removed due to harvesting. The overutilization or changing of environmental condition influence the forest to an extent that it cannot sustain a tree cover above 10% thresholds is also included in deforestation for example burnt-over areas where severe ground conditions or recurring fires for the long-term prevents the return of forest formations, or areas that after clear cutting cannot regenerate because of forest, competing vegetation, or other natural conditions.

Next is the afforestation, refer to alteration of the land that had been used as other purposes into forests or the increase of the canopy cover above the 10% threshold. In the other words, afforestation is the reversed of deforestation which areas that actives converted from the other land use into forest through the silvicultural measure and also include natural transitions into forests. Moreover the terms that usually being used in deforestation contact is reforestation which understood as the restoration formation of forests after a impermanent condition less than 10% canopy cover due to anthropogenic activities or natural agitation (Food and Agriculture Organization of the United Nations, 2000).

15.17 million hectares of forests and thousands of species, and most modern deforestation is happening in tropical areas every year and the major factors that contribute to the deforestation are the human activities that exploit forests in unsustainable ways for the human benefits (Siregar, n.d). Besides oil and gas, forest products is recognized as the biggest source of government income but it is considered to exceed the benefits the cost to society and from deforestation and forest degradation (Siregar, n.d).

People who reside in and surrounding the forests area are really need the forests for their vital livelihoods because many of humans on this earth are rely on natural forests to supply a significant portion of foods, fuel, medicine and many other sources that valuable for humans, people also obtain the cash from timber harvesting and from the employment with logging, plantation and wood processing companies.

It is important to differentiate between the key drivers of deforestation and forest degradation. In order to deal with the growing tropical countries about the deforestation, by means of clearing the different forms of agricultural herding, of cash cropping or ranching are all the evident factors. There were two types of factors that leads to deforestation which are direct factors or indirect factors. For an example of the direct factors is the forest area was replaced by a field of coffee trees that occur because of cash cropping while the indirect factors is like the opening of a road in a forest area which next will attracts farmers in search of land for cultivation.

2.2 Remote Sensing and GIS

A geographic information system (GIS) is a computer-based tool for mapping and analyzing feature events on earth. GIS technology integrates common database operations, such as query and statistical analysis, with maps. GIS manages location-based information and provides tools for display and analysis of various statistics, including population characteristics, economic development opportunities, and vegetation types.

GIS allows the linking of the databases and maps in order to create dynamic displays. Additionally, it provides tools to visualize, query, and overlay those databases in ways not possible with traditional spreadsheets. These abilities distinguish GIS from other information systems, and make it valuable to a wide range of public and private enterprises for explaining events, predicting outcomes, and planning strategies (Kaur, 2018)

Remote sensing is the art and science of making measurements of the earth using sensors on airplanes or satellites. These sensors collect data in the form of images and provide specialized capabilities for manipulating, analyzing, and visualizing those images. Remote sensed imagery is integrated within a GIS (Kaur, 2018).

Remote sensing can be explicit as the operation of measuring the physical properties of distant objects using reflected or emitted energy. RS refers to the science of recognition of earth surface features and estimation of their geo-biophysical properties using electromagnetic radiation as a medium of interaction. Spectral, spatial, temporal and polarization signatures are major characteristics of the sensor/target, which facilitate target discrimination. Earth superficial data as seen by the sensors in different wavelengths (reflected, scattered and/or emitted) is radio-metrically and geometrically corrected before extraction of spectral data (Roy, Behera, & S.K.Srivastav, 2017).

Remote Sensing information, with its capability for a synoptic view, repetitive coverage with calibrated sensors to detect alterations, observations at different resolutions, provides a better alternative for natural resources management as compared to traditional methods. (Roy et al., 2017).

The field of satellite remote sensing has seen many interesting new evolutions such as new higher spatial resolution optical and radar systems, hyperspectral sensors, crucial by-products such as digital elevation model (DEM), the progress of new processing capabilities using machine learning (Ali, Greifeneder, Stamenkovic, Neumann, & Notarnicola, 2015).

Remote sensing information is also assists to construct a better geographical information system (GIS) which in turn can be used for learning progress at learning institutions, land management, natural resources management, and environmental (Roy et al., 2017).

Remote sensing technology offers high spatial resolution and is a useful tool for the monitoring, diagnosis, identification and zoning of natural element, especially in land-use mapping (Tan, Liu, Zhou, Jiao, & Tang, 2015). For a better understanding relationships and interactions between human and natural phenomena, timely and precise change detection of Earth's surface feature is really crucial in order to promote better decision making. Essential sources for the detection of the landscape changes are by using remote sensing data, process of identifying differences in the state of an object or phenomenon by noticing it at different times is also known as change detection (P.Mausel, E.Brondizio, & E.Moran, 2004).

Generally, the detection of the landscape changes need the involvement of the perseverance of multi-temporal datasets to quantifiably analyze the temporal effects of the phenomena and the major data sources for different change detection applications since the past decades because of the benefit of their repetitive data acquisition, its synoptic view, and digital format suitable for computer processing, remotely sensed data, such as Thematic Mapper (TM), Satellite Probatoire d'Observation de la Terre (SPOT), radar and Advanced Very High Resolution Radiometer (AVHRR) (P. Mausel et al., 2004).

The usage of remote sensing as a surveillance techniques is very advantageous in order to get all the required data for the landscape alterations, urban planning, urban sprawl, deforestation, and the other environmental issues that leads to the importance of monitoring by updating the evidence to support decision making process (Basheer Abuelaish & Olmedo, 2016).

Two parameters are required to support the monitoring of land use change and land cover which are spatial resolution and temporal frequencies that provided from the satellite imagery for performing landscape structural studies (Basheer et al., 2016).

A major advance in the application of remote sensing technologies for change detection studies has been the development of consistent imagery databases and the implementation of Land Cover (LC) mapping efforts at global, continental, and national scales. Global LC mapping efforts have been accomplished using National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) biweekly Normalized Difference Vegetation Index (NDVI) composites developed and compiled by the U.S. Geological Survey's (USGS) EROS Data Center (Lunetta, Ediriwickrema, Johnson, Lyon, & McKerrow, 2002).

Remote sensing change detection techniques can be broadly classified into as either post-classification change methods or pre-classification spectral change detection. The post-classification approach involves the analysis of differences between two independent categorization products using GIS-based analytical tools (Lunetta, 1998).

Since 1972 when the first Landsat programme was launched, satellite data have been used in forest monitoring, evaluation and resources conservation. Satellite and remote sensing images combined with forest classification maps, aid in the efficient management of forest resources (T.M.Basuki, Laake, Skidmore, & Hussin, 2009). It is observed that Landsat data aids in determining which anthropogenic activities are happening in different parts of the landscape, even when land cover seems to be the same (Angelsen & Kaimowitz, 2001).

Therefore scientific knowledge of land use and land cover change is fundamental to improving our understanding of change mechanism. It is also necessary in modeling the percussion of change on the environment and related ecosystems. New and standardized continent spanning field networks are addressing many ecological issues, from forest succession to vegetation-atmosphere interactions (Saatchi et al., 2011).

Assessing, monitoring and evaluating land cover changes, requires two most obvious variables for correlation (previous and actual size) and which can be determined by remote sensing, GIS and field work (Saatchi et al., 2011). Moreover, remote sensing is used to highlight the importance of digital change detection in apprehending the environmental situation in the forested southern part of Yunan Province, China (Diallo, Hu, & Wen, 2009).

2.3 Landscape Ecological Approach

Ecology is the research of the interrelationships between creatures and their environment (Ricklefs, 1979). Landscape ecology, as the name implies, is the study of landscapes; specifically, the combination, framework and function of landscapes**.** Landscape ecology is also known as the science and art of evaluating and influencing the relationship between spatial pattern and ecological technique on multiple scales (Wu & Hobbs, 2002).

Landscape ecology involves the study of the landscape models, the correlation among the elements of this pattern, and how these patterns and interactions change over time. In addition, landscape ecology involves the application of these principles in the formulation and solving of real-world problems (McGarigal, 2001). Specifically, landscape ecology considers the development and progress of spatial heterogeneity, spatial and temporal associations and exchanges across heterogeneous landscapes, influences of spatial heterogeneity on biotic and abiotic processes, and management of spatial heterogeneity (Wu, 2013).

2.4 Landscape

Landscape is a term that has a broad meaning in everyday language and in terms of academic, different understanding from different stage of development starting from a term that referred to an areal category or human traces in the environment to a purely mental image of one's environment. According to Germanic and Romanic languages, landscape is "inhabitant of restricted area" or a "land as a particular area of political unity" and "aesthetically pleasing land within one's field of vision". While, from the view of academic research, landscape was understand as ranging from visual or cultural image to a physical phenomenon (McGarigal, 2001).

A heterogeneous ecological system (landscape) is made up from a set of interactive ecosystems, which impact the local components of each ecosystem and the global features of the heterogeneous ecological system that made up from the interactions among ecosystems (McGarigal, 2001).

2.4.1 Landscape transformation process

a) Landscape Fragmentation

Landscape or habitat fragmentation is the breaking up of a habitat or vegetation type into smaller, disconnected sections. It is generally a consequence of land use: agricultural activities, road building, and housing development all break up existing habitat. The effects of this fragmentation go beyond a simple reduction of the amount of habitat available.

Landscape fragmentation was happened by a lot of ways, which usually the step is the same. The building of road through the relative intact habitat and the dissection of the landscape is the first step of fragmentation of forest can be occurred. The second step usually is the landscape perforation which means the clearance of a small area of the forests to create the small opening in the forests while the other buildings and houses are being built along the roadways (Beaudry, 2017).

b) Shrinkage

Shrinkage of patches can follow fragmentation. Shrinkage is when existing patches of undeveloped habitat become smaller in area (McGee, Johnson, & Campbell, n.d.).

c) Perforation

Perforation (which means to put holes into something) is usually one of the first types of landscape alteration that happens as an area is developed. Small, unconnected patches of development cause small breaks in the undeveloped area. The majority of the landscape is still undeveloped (McGee et al., n.d).

d) Loss

Our forests are in crisis. The world has lost half its natural forests and only a tenth of what's left is protected. Every year we lose another 130,000 sq km which is an area the size of England (World Wildlife Fund, n.d).

2.4.2 Landscape Metrics

The diversity of landscape is reflected by composition and pattern, not a capability of a single metrics. For describing landscape configuration and composition many indices are available yet the majority of these indices are highly correlated with the landscape metrics (Betts, Franklin, & Taylor, 2003).Total proportion of suitable habitat, edge effects, and patch size are some of the most frequently cited as ecologically important landscape metrics.

Metrics configuration such as the connectivity, isolation, and contagion are also important to be used in analyzing the factor of 26 metrics computed on 86 land cover maps and found that 87% of the metric variation which can be understand by these factors, interpret as composites landscape area, patch shape and distribution, and map class complexity (Betts et al., 2003)

CHAPTER 3

METHODOLOGY

In Malaysia, Kelantan is one of the states that located in the north-east of Peninsular Malaysia. Kota Bharu is the capital of Kelantan. The coordinate of Kelantan is 5°15′N 102°0′E. Total area of Kelantan is 1509900 Ha. In Kelantan state there is Jeli district which is constituent in western Kelantan, Malaysia.

Jeli is located at 5°42′N 101°50′E . The total area of Jeli is 143242. 62343 Ha. To enter the Jeli district, there are have three entrances which is via Grik which is from the west, via Tanah Merah from east and via Mempelam, jelawang in Kuala Krai from the south. According to the Jeli Official Website of the Jeli Land and District Office (2014), the total population of Jeli was estimated at 36.512 people which is 2.78% of the total population of the State.

Jeli district consists of high forest coverage area, thus it is choose as the study area to achieve the objectives of this study which are to quantify the landscape change and to determine landscape fragmentation analysis in 1994, 2004, and 2014.

3.1 Study Area

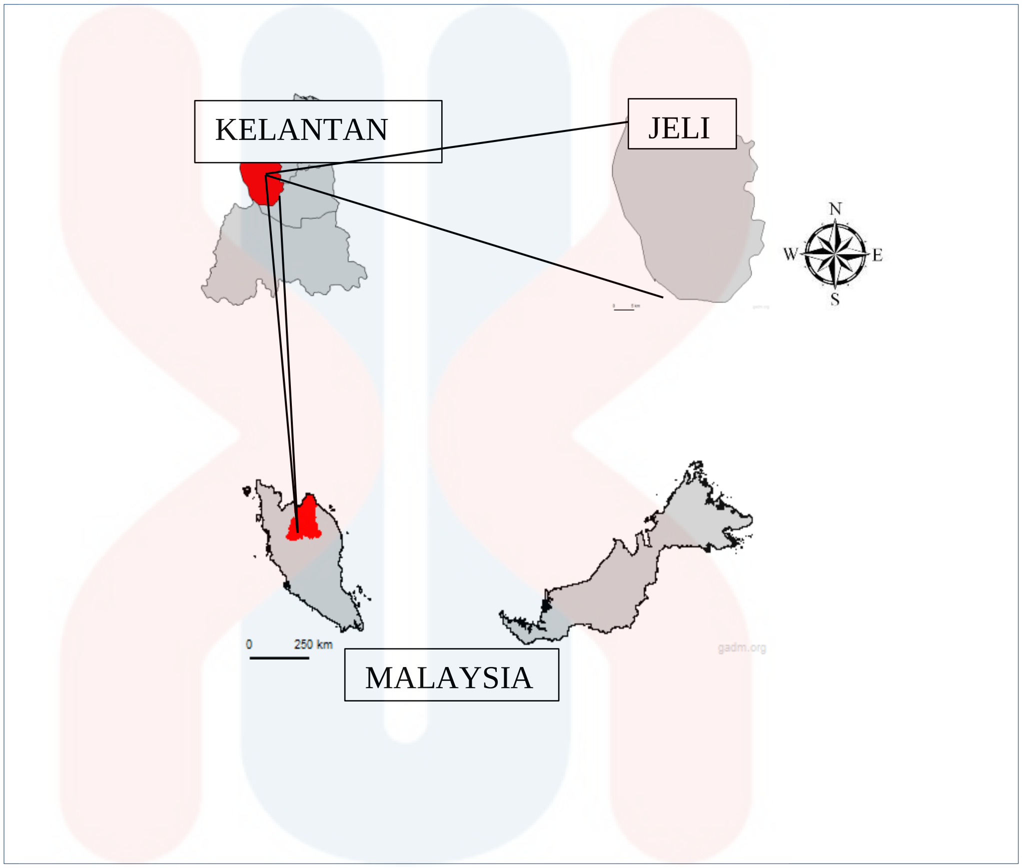


Figure 3.1 The study area of Jeli, Kelantan (Source: gadm.org)

In this proposal it will consists of three main steps which are the preprocessing of image, processing of image, and post processing of image processing the data and lastly the analysis of data.

3.2 Data Preprocessing

3.2.1 Data Collection

Landsat satellite imagery was used to obtain information about the landscape changes for the study area. Three images of Jeli district were downloaded from United States Geological Survey (USGS) (n.d.) for three respective years which are 1994, 2004 and 2014. The image of 1994, 2004, and 2014 was obtained from the Landsat-4Thematic Mapper 30 meter image. There were ten years gap between all those three images in 1994, 2004, and 2014.

3.3 Data Processing

There were three geocoded satellite images were processed by using ERDAS Imagine 2014(Intergraph Corporation) and also ArcGIS 10.3 in order to produce LULC maps for Jeli in 1994, 2004, and 2014. The boundaries of the three images that used in this study were obtained from Global Administrative Areas (2018) to extract the area of interest (AOI) from the images. However the images that selected from the satellite of year 1994, 2004, and 2014 were chosen based on the quality of the images according the coverage of the cloud. The less coverage of the cloud will contribute in the high resolution imagery which will produce more accurate results when conducting the landscape fragmentation analysis (Amal Najihah, Harris, Perotto-Baldivieso, & Corstanje, 2017).

Landsat satellite image was used because the spatial and spectral resolution was adequate for the classification of shrub types and a single scene covered a large area. (Homeier et al.,2015). Satellite images and DTM data were processed to derive vegetation and terrain information for the study area respectively. Spatial and spectral resolution is found to be enough for the classification of single scene covered a large enough area and shrub types for this study by using the Landsat data (Viedma & Melia, 1999).

There were five classes of LULC which were forest, cleared land, agriculture, built up and water body for each year were classified by using supervised classification in ERDAS software. Only land use/land cover types are able to be identified by the ERDAS software because, this classification system is designed to rely mainly on remote sensing. (Amal Najihah et al., 2017).

Google Earth was used for reference in the classification process. In order to ensure the validity of the result a field visit was done. This process of field visit to verify the data is known as the ground truthing. Next, in order to check the quality of the classification results, the accuracy assessment was performed in the ERDAS software. This is because the accuracy assesment generated the statistical outputs based on error matrix that compared class-by-class. The samples for each class was validated by using stratified random sampling technique in which 40 samples were assigned for each LULC in steps to avoid uneven distribution. (Amal Najihah et al., 2017). Lastly, the raster data that obtained in the ERDAS software were converted to vector format by using ArcGIS. Finally, the landuse maps of Jeli in 1994, 2004, and 2014 were analysed to study the changes of the landscape and analyse the landscape fragmentation.

3.4 Data Post-Processing (Analysis)

3.4.1 Landscape Change Analysis

The amount of forest converted to built-up areas and other land uses between 1994, 2004, and 2014 was determined by using the change detection analysis. Which were consists of two steps, the first one was the spatial changes that used to determine the percentage of area for each LULC class for each year. The second step was the transition change which was used to detect the changes of the percentage area between the different class and the same class for that particular year. In order to do the transition changes, the maps from two different years were overlaid in the ArcGIS software and the table containing the conversion of LULC was produced. The overlay was done for 1994 with 2004 and 2004 with 2014. Then, the percentage area in spatial changes and transition changes was calculated manually. The percentages that have been obtained were transformed into graph of transition matric and spatial changes graph.

3.4.2 Landscape Structure Analysis

The landscape structure of Jeli in 1994, 2004, and 2014 were analyzed at landscape, class and patch levels in order to compute the changes in the spatial structures of green space (Amal Najihah et al., 2017). The entire landscapes were effective to be quantified by the landscape level metrics while the landscape patterns of each LULC were analysed through the class level metrics individually (Su, Xiao, Jiang, & Zhang, 2012). More specific information about landscape spatial patterns, variations can be provided by the class level metrics at the local level and the distribution of LULC (Abdullah & Nakagoshi, 2008). In understanding the mechanisms of landscape change, patch level metrics are crucial. It was also important in determining significant changes between patches in Land Use/Land Cover class (Baldivieso et al., 2011).

There were six parameters for landscape structure analysis were choose which were patch density (PD; no. of patches/100 ha), mean patch area (MPA/ha), largest patch index (LPI/%), landscape shape index (LSI;m/ha), Euclidean nearest neighbor distance (MNN/m) and percentage of area (PAREA/%) (Table 3.1). The FRAGSTATS software. All of these landscape metrics were used to characterised the changes in green space landscape criteria such as isolation of patches, shape and size.

Next, the statistical analysis was carried out in the SPSS software which was the Analysis of Variance (ANOVA) test was performed. This test was performed in order to compare the significance of the two landscape metric in analyzing the landscape metric at patch level. Two landscape metric were chosen, AREA and ENN.

The AREA and ENN were the landscpae metrics that had been chosen to evaluate all the five LULC class in all the three respective years at the patch level which were in 1994, 2004 and 2014. Before the ANOVA test being performed, the normality test was conducted to determine the data distribution was normal or not-normal. Lastly, the landscape transformation proces were done. The image from the landscape transformation were retreived from the three LULC maps that have been produced in the three years, which were 1994,2004 and 2014 in order to shows the landscape tranformation process that occurred in Jeli area in those three respective years.

Table 3.1 Landscape metrics used for landscape structure analysis (modified from McGarigal et al., 2002).

Metrics	Abbreviation	Description of Metric Level (Units)		
		Landscape Level Metrics (The landscape as a whole)	**Class Level Metrics (Each patch type (class) in the landscape)**	**Patch Level Metrics (Individual patch in the given class, where applicable)**
Percentage of area	PAREA (%)	N/A	The percentage of each patches type in the landscape. Proportional abundance of class types in the landscape	n/a
Patch density	PD	Number of patches per 100 ha.	Number of patches per 100 ha in that class.	n/a
Mean patch area	MPA (Ha)	The area occupied by a particular patch type divided by the number of patches of that type. A function of the number of patches in the total area.	A function of the number of patches in the class and total class area.	A function of the difference in patch sizes among patches.
Largest patch index	LPI (%)	Area (m^2) the	An indication of the dominance of the different	n/a

		largest patch of that type divided by total landscape area (m^2), multiplied by 100.	land cover classes	
Landscape shape index	LSI (m/ha)	SHAPE equals patch perimeter (m) divided by the minimum perimeter of the corresponding patch area in a landscape. A measure of the overall geometric complexity of the landscape.	A measure of the overall geometric complexity of a focal class. It can also be interpreted as a measure of landscape disaggregation. The greater the value of LSI, the more dispersed the patch types.	LSI is one patch and any patch edges (or class edges) measured by the perimeter
Euclidean Nearest-Neighbor Distance	MNN (m)	Distance (m) from a patch to nearest neighboring patch in a landscape.	The distance between a patch and its nearest neighbor of the same class, based on the distance between cell centers of the two closest cells from the respective patches.	MNN deals explicitly with the degree to which patches are spatially isolated from each other. The context of a patch is defined by the proximity and area of neighboring habitat patches

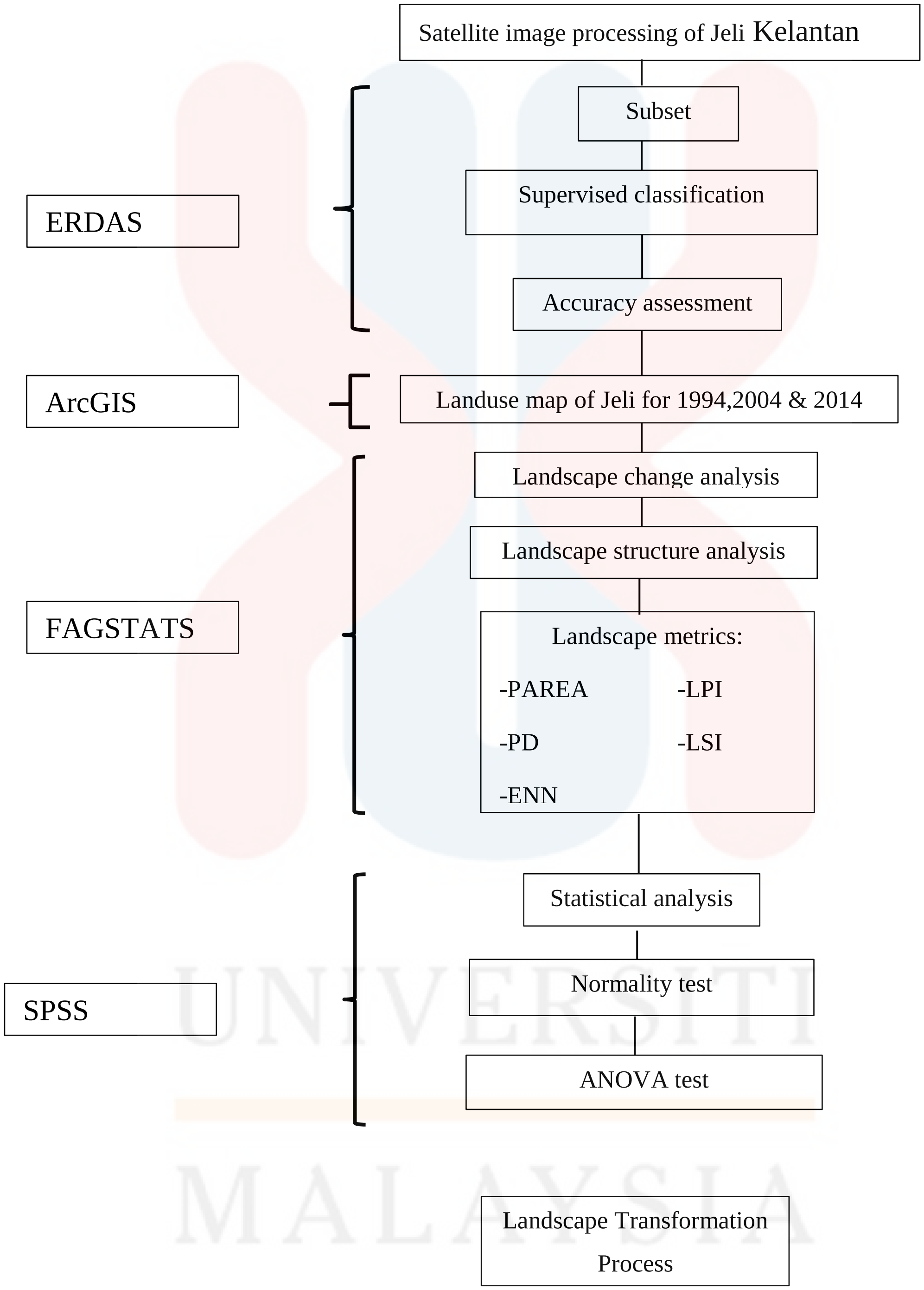


Figure 3.2 Methodological framework

CHAPTER 4

RESULTS AND DISCUSSION

Throughout this study, there are significant results through image preprocessing, processing and post processing.

4.1 Landscape Change Analysis

4.1.1 Spatial Changes Analysis

Spatial change analysis were also known as the area change analysis which were function to detect the area changes in landscape in among all the five LULC in those three selected years (Yuan, Sawaya, Loeffelholz, & Bauser, 2005).

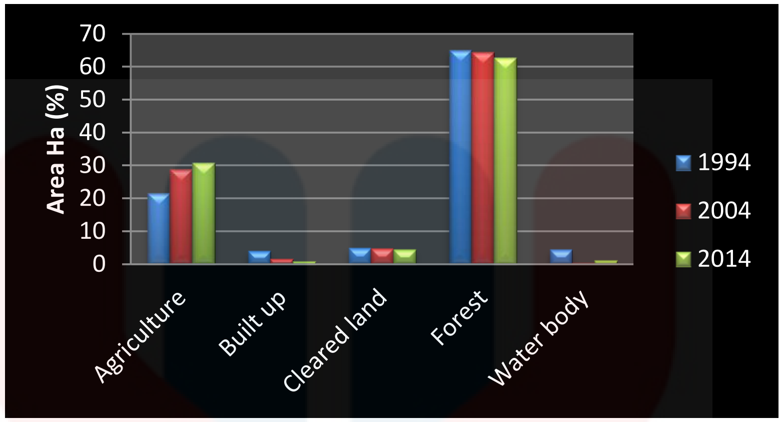


Figure 4.1 Percentage of area of LULC of Jeli in 1994,2004, and 2014

In 1994, the highest percentage of forest area was (65.04%) followed by 2004 (64.47%) and 2014 (62.74%). (Figure 4.1). The percentage area of built up was smaller compared with the percentage of forest which were in 1994 (4.01%), 2004(1.60%) and in 2014 was (0.91%). The total percentage of agriculture also increased in 1994, 2004, and 2014 (21.52%, 28.79%, and 30.74% respectively). The total percentage area of cleared land in 1994 and 2004 was nearly same which have the percentage 4.97% and 4.78% respectively. Lastly, the water body have the lowest percentage area in 2004 which was only (0.36%), followed by 2014 (1.17%) and the highest was in 1994 (4.45%). Based on the graph it shows that the built up area was not really cause the impacts towards the decreasing of the forest coverage area but the agricultural areas shows quite high effects towards the forest area decrease. About 32% Ha area in Jeli were represented as the agricultural area (Global Forest Watch, 2010). This it still can be said that the anthropogenic activities still give the impacts on landscape fragmentation in Jeli area in 1994, 2004 and 2014.

4.1.2 Transition Changes Analysis

The transition change analysis was carried out in ERDAS software. The transition analysis functioned to detect how much each of the LULC class area was transformed into another LULC class. Such that, how much the area of forest area changes into built up areas, agricultural areas, cleared land areas, water body and vice versa. Based on the Table 4.1 and Table 4.2, the transition changes area was done by overlaying the attribute table of the LULC map of 1994 and 2004, 2004 and 2014 in ArcGIS software. Table 4.1 shows the transition changes in area of each LULC class for 1994 and 2004 while Table 4.2 shows the transition change in areas for 2004 and 2014. The transition changes helps in supporting the Land use map of Jeli in 1994, 2004, and 2014 because from the three maps it shown the area changes of the LULC class.

Table 4.1 Area Ha and percentage area **(%)** of transition metric 1994 and 2004

2004 \ 1994	Forest	Water body	Cleared land	Built up	Agriculture
Forest	77722.58 **(84.17)**	3663.10**(3.97)**	1262.16 **(1.37)**	1321.58 **(1.43)**	8373.96**(9.07)**
Water body	33.78**(6.48)**	202.55 **(38.85)**	23.68**(4.54)**	223.37**(42.85)**	37.95**(7.28)**
Cleared land	1698.83**(24.83)**	1134.76 **(16.58)**	1218.88 **(17.81)**	1133.49**(16.56)**	1657.25**(24.22)**
Built up	1317.67 **(57.34)**	104.97**(4.57)**	139.98 **(6.09)**	615.09**(26.77)**	120.19 **(5.23)**
Agriculture	12393.10 **(30.05)**	1267.22**(3.07)**	4477.48 **(10.86)**	2455.47**(5.95)**	20643.53**(50.06)**

Table 4.2 Area Ha and percentage area **(%)** of transition matric 2004 and 2014

2014 \ 2004	Forest	Water body	Cleared land	Built up	Agriculture
Forest	74681.35 **(83.10)**	16.14**(0.02)**	1596.19**(1.78)**	1333.18 **(1.48)**	12241.44**(13.62)**
Water body	392.39**(23.36)**	483.80 **(28.81)**	603.98 **(35.96)**	43.25 **(2.58)**	156.02 **(9.29)**
Cleared land	2864.91**(45.09)**	1.51**(0.02)**	611.34**(9.62)**	109.06 **(1.72)**	2766.38 **(43.54)**
Built up	115.61**(8.87)**	4.59**(0.35)**	422.69 **(32.43)**	487.79**(37.42)**	272.71 **(20.92)**
Agriculture	14289.12 **(32.45)**	15.29**(0.03)**	3609.02 **(8.20)**	324.62**(0.74)**	25800.24**(58.59)**

The figure below shows the transition changes in area of 1994 and 2004, 2004 and 2014. The graphs were constructed in order to provide clearer view on the transition changes of LULC class in between the two intersect years. The Figure 4.2 shows transition change between 1994 and 2004 while Figure 4.3 was the transition change between 2004 and 2014.

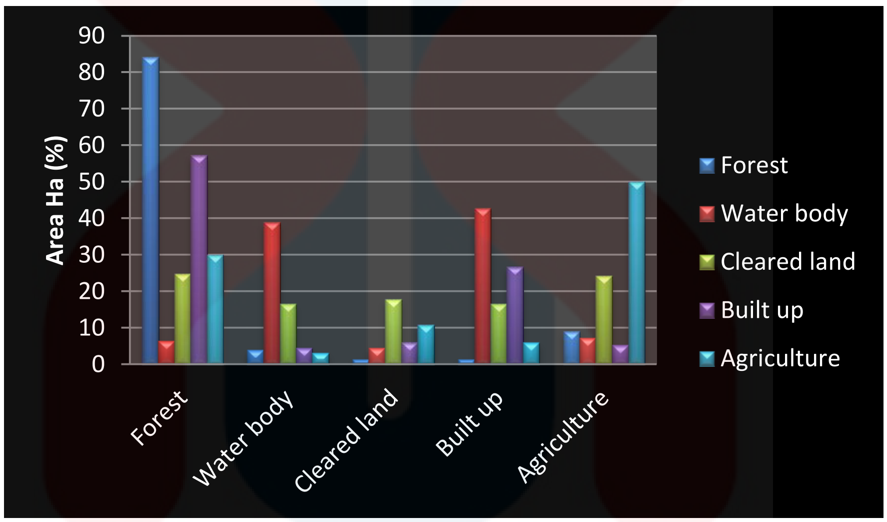


Figure 4.2 Transition metric 1994 and 2004

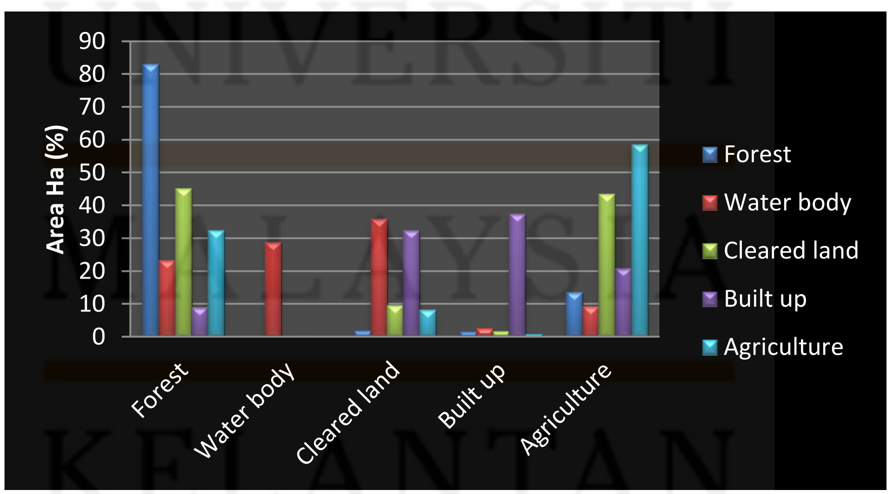


Figure 4.3 Transition metric 2004 and 2014

The transition result show five types of land use namely forest, water body, cleared land, built up, and agriculture for Jeli area in 1994, 2004, and 2014 which have been summarized in table 4.1 and table 4.2. The results of transition matric from table 4.1 and table 4.2 were transformed into graph in order to observe the percentage of the transition clearer (Figure 4.2 and Figure 4.3). Forest class was the highest contributor of land use in Jeli for both of the transition. In the year 1994 and 2004 the transition of forest with built up was 57.34% (Table 4.1). Meanwhile the transition of forest with built up in 2004 and 2014 was 8.87% (Table 4.2). Table 4.1 shows the transition of built up with forest in 1994 and 2004 was 1.43% while in 2004 and 2014 was 1.48% (Table 4.2). The results shows that there was decreasing in transition of the forest with built up in 1994 and 2004 while slightly increasing in the transition of built up with forest in 2004 and 2014.

The transition in 1994 and 2004, for the forest with cleared land shows the percentage increasing in the transition of forest with cleared land in 2004 and 2014 which were from 24.83% to 45.09%. The transition percentage of cleared land was increase due to anthropogenic activities such as deforestation, urbanization, and agriculture. Deforestation was one of the major factors that contribute to landscape fragmentation because it was the major form of habitat destruction (Scanes, 2018).

Next, in 1994 and 2004, the percentage of area transition for the forest with agriculture also shows slightly increased in percentage about 2.4% in the percentage of transition in 2004 and 2014 (Table 4.1 & Table 4.2).In Table 4.1 the percentage area of cleared land with forest was 1.37% while in Table 4.2 was 1.78%. There was slightly increased in the percentage of the transition area which was 0.41%. Next, Figure 4.4, Figure 4.5, and Figure 4.6 w the land use map in Jeli for 1994, 2004 and 2014.

The LULC maps of the Jeli area in 1994, 2004 and 2014 were produced by using ArcGIS software. In this software all the three maps were produced. From the maps, it can be clearly shown the LULC classes that have been increasing or decreasing in the period of the three years with the ten years gap. The map shows that the forest vegetation area has the highest coverage in Jeli. The transition changes results were for supported the maps. It shows the transition areas in 1994 with 2004 and 2004 with 2014.

In those three land use maps, the legends and the north arrow acted as the indicator for the future researcher that wanted to refer the land use maps of Jeli in 1994, 2004 and 2014. The dark green color indicate the forest area, red color indicate the built up area, pink color indicate the cleared land areas, dark blue indicate the area of the water body and the light green color shows that the area was covered by the agriculture or crops.

From the maps it shows that the forest vegetation area in Jeli was decreasing in that ten years period of gap, and it was due to the anthropogenic activities. The main activity that shows high impacts to the decreasing of forest coverage was the agricultural activities. According to the Global Forest Watch, (2018), the agricultural activities have the highest percentage of the land use in Jeli area which was 32% of

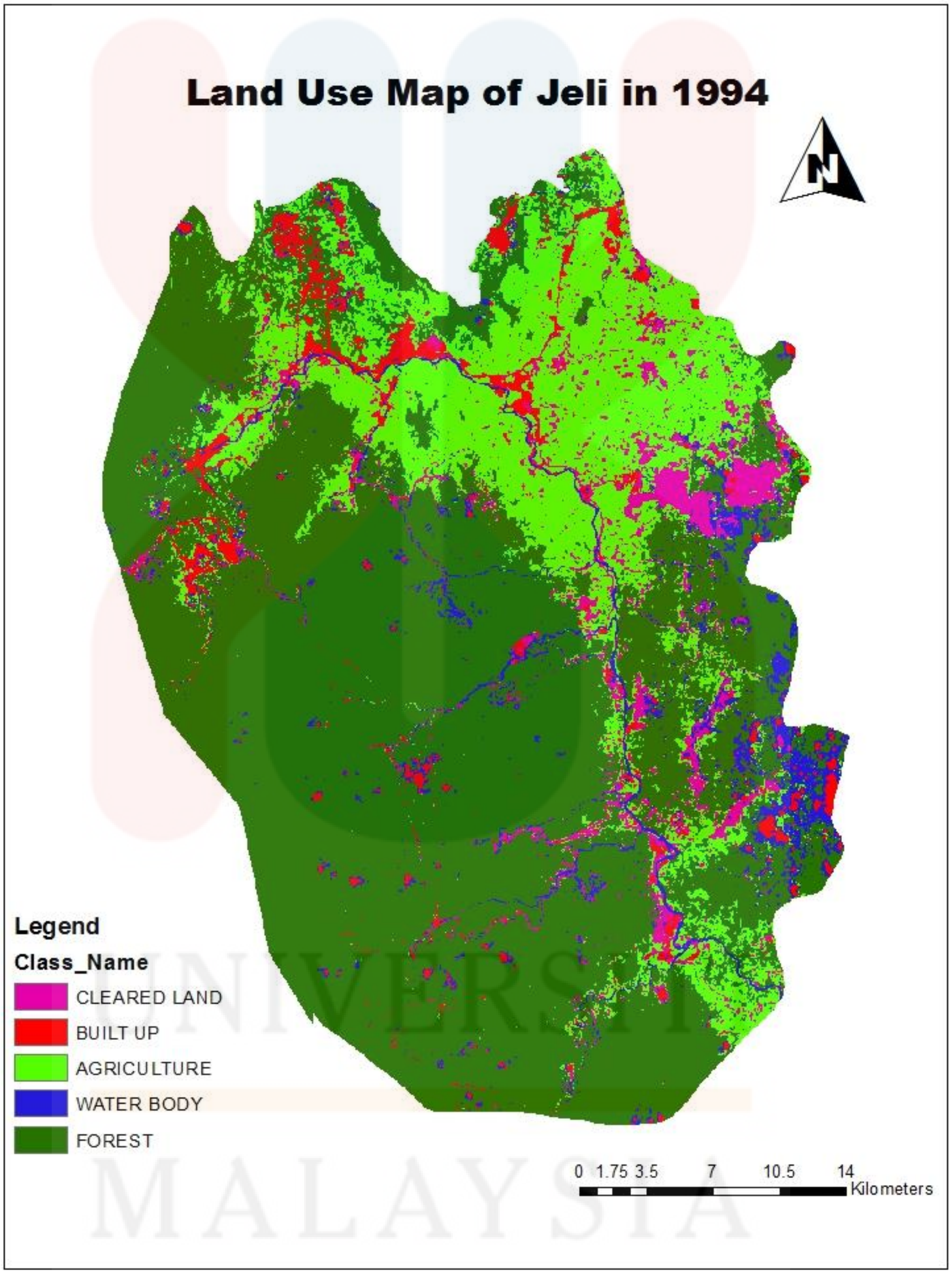


Figure 4.4 Land use map of Jeli in 1994

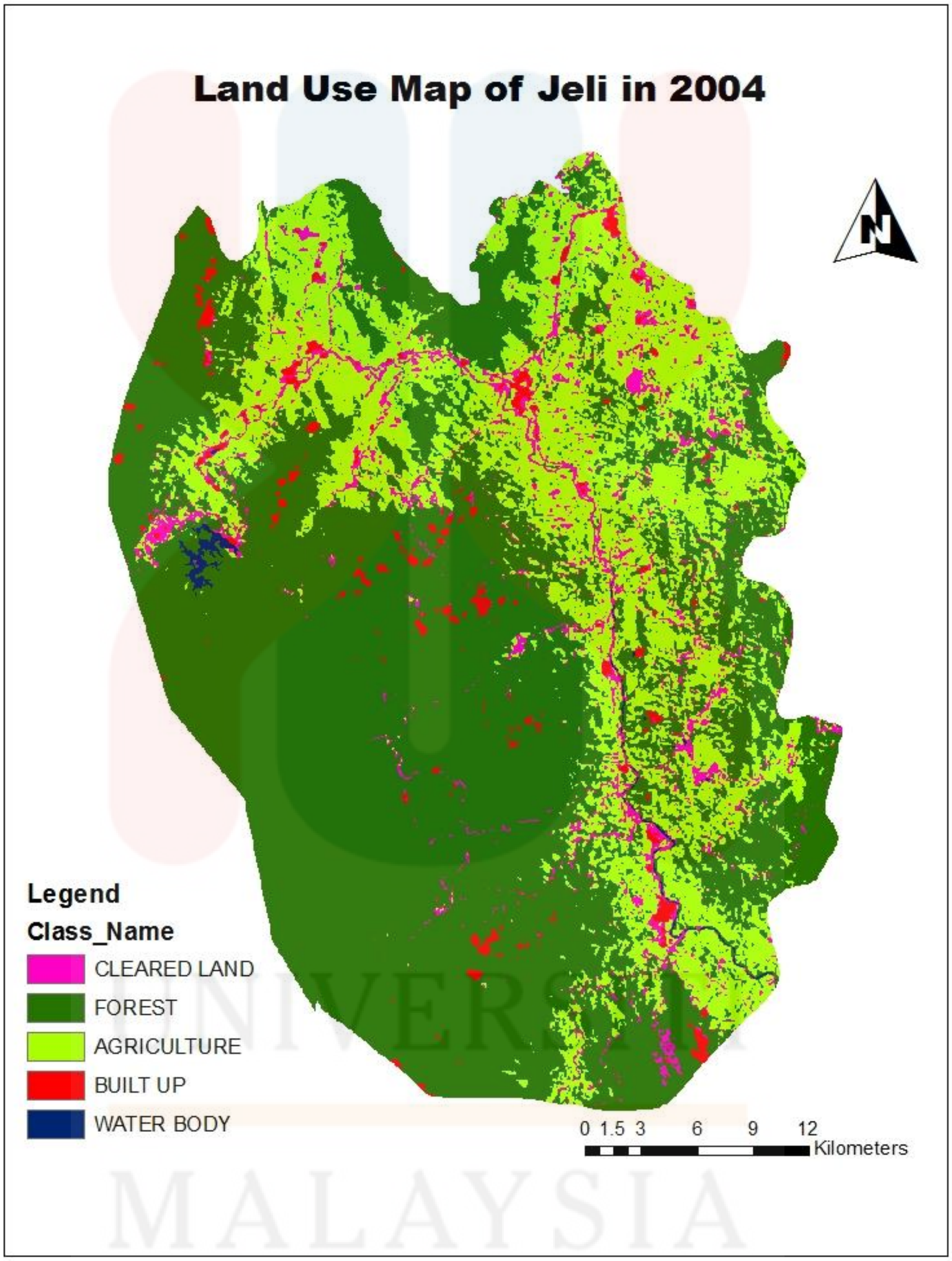


Figure 4.5 Land use map of Jeli in 2004

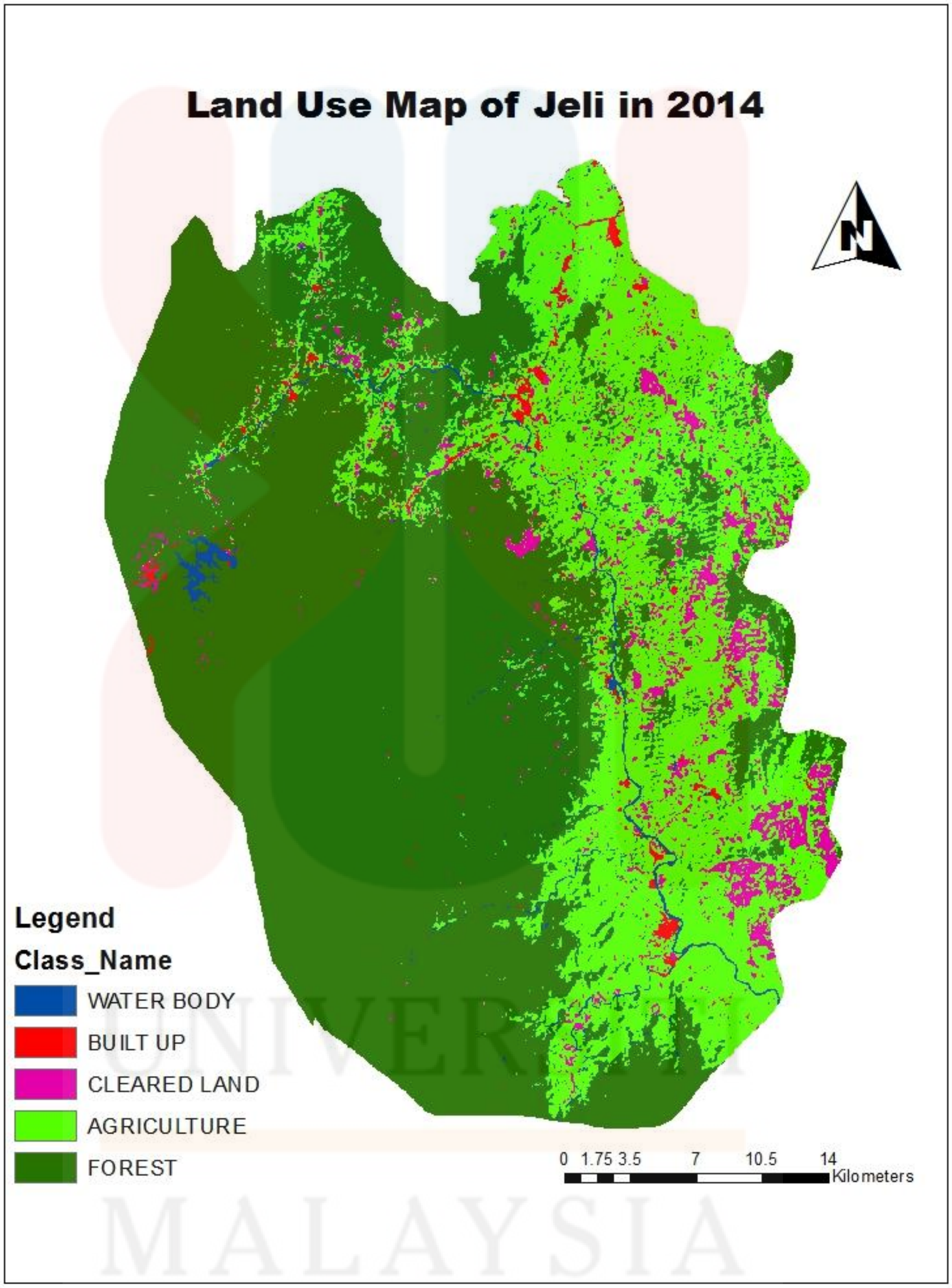


Figure 4.6 Land use map of Jeli in 2014

4.2 Landscape Structure Analysis

4.2.1 Comparison of Landscape Metric at Class Level

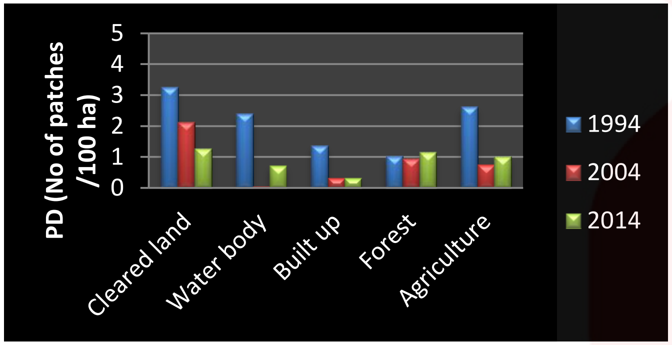


Figure 4.7 PD (No. of patches/100 ha)

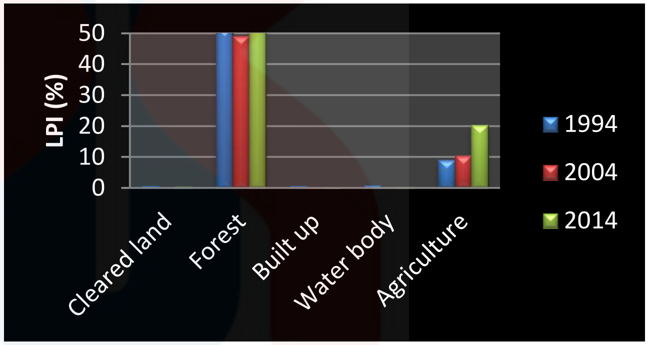


Figure 4.9 LPI (%)

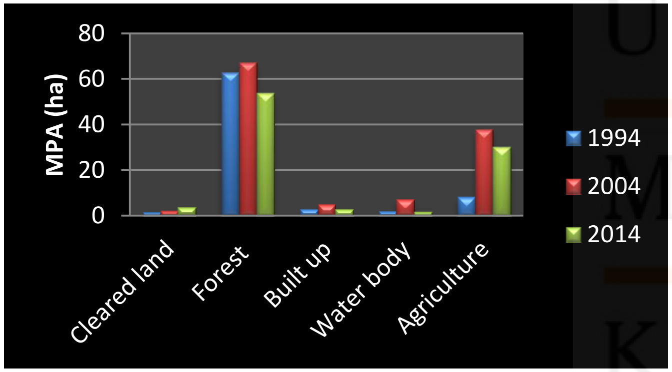


Figure 4.8 MPA (ha)

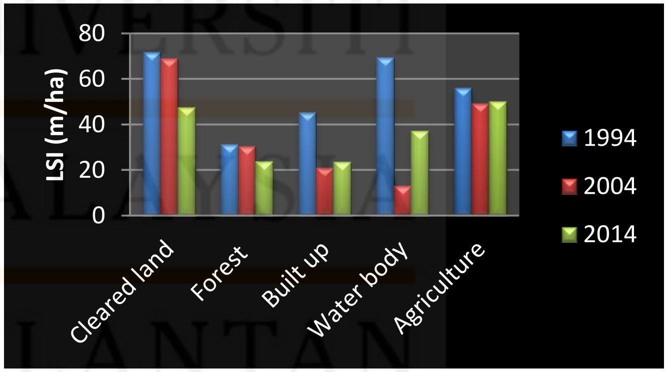
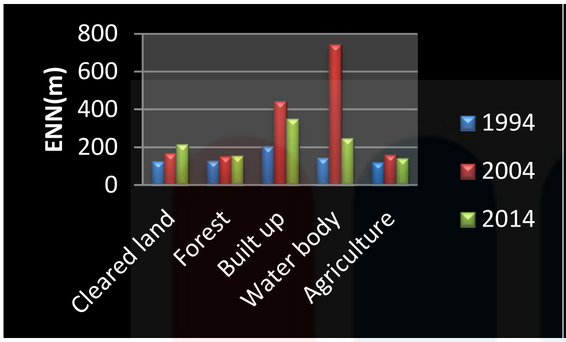


Figure 4.10 LSI (m/ha)



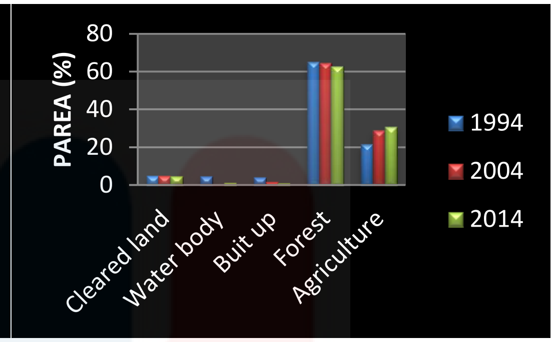


Figure 4.11 ENN (m)

Figure 4.12 PAREA(%)

In landscape structure analysis there were three types of metrics that have been analyzed at class level, which were class, landscape, and patch. There were all six metrics that have been chosen in the comparison of metric at class level which were patch density (PD), Largest Patch Index (LPI), Mean Patch Area (MPA), Landscape Shape Index (LSI), and Euclidean Nearest- Neighbor (MNN). Generally, PD indicates the number of patches per 100 ha. At each class level metric it shows the number of patches per 100 ha in that particular class while Mean Patch Area or MPA is a function of the number of patches in the class and total class area. According to Figure 4.7 the PD values for forest decreased from 1.03 to 0.95 patches/ 100 ha in 1994 and 2004. In 2004 and 2014 the PD values of forest was increased from 0.95 to 1.16 patches/ 100 ha. Meanwhile in Figure 4.8 the MPA values for forest shows the increment in year 1994 and 2004 which was from 62.92 increased to 67.25 ha. However the MPA values then decreased to 54.00 ha in 2014. From all of the three years, it shows that the value of PD was lower than the values of MPA .According to Amal Najihah et al., (2017) when the PD values was low compared with the high values of MPA, the aggregation of patches was occurred. Aggregation of patches means the degree of clumping of patch types. The dispersion and interspersion of each LULC class also deals with the aggregation metrics (McGarigal, 2014)

The PD values for built-up in 1994 was decreased from 1.37 to 0.33 and 0.32 patches/ 100 ha in 2004 and 2014. There was an increment in the values of MPA for built up in1994 and 2004 from 2.94 to 4.93 ha. However the value then decreased into 2.84 ha in 2014.

The Largest Patch Index or LPI is an indicator of the dominance of different land cover classes. In 1994 the patch size of the forest was bigger compared in 2004 which was 51.79 % . The patch size of the forest decreased slightly in 2014 to 49.10% . Here the results indicated that the size of forest patch in 1994 was biggest compared with the other two years. This is because of the Jeli was one of the district in Kelantan which still have the high percentage of forest cover which was supported by Global Forest Watch (GWF) (2018). stated that until 2010, 51% of Jeli was a natural forest cover. Next, the LPI for the built- up was decreased continuously starting from 0.55 %, 0.09% and 0.07% in 1994, 2004 and 2014 respectively.

Next, Landscape Shape Index (LSI) is functioning to measure the overall geometric complexity of class. LSI also can be understand as a measure of landscape disaggregation. The patch types was more dispersed with the higher value of LSI (Mcgarigal, K. Cushman, C., & E., 2002). LSI value of forest for those three years was decreased from 31.36, 30.37 and 23.75 m/ha (Figure 4.10). However, the LSI value for built-up was decreased to 21.04 m/ha in 2004 from 45.22m/ha in 1994. In 2014 the LSI value for built-up area slightly increased into 23.61 m/ha.The value of LSI for built-up and forest was decreased which revealed the patches for both of the class was not complex (Hepcan, 2012).

According to McGarigal et al., (2002) ENN or Euclidean Nearest-Neighbor Distance measures the distance between one patch with its nearest neighbor of the same class. In all the three respective years, the distance between forest patches to the neighboring patches increased from 128.08, 152.08 and 154.18 m. From the results, it can be clearly determined the forest patches experienced the shrinkage in landscape fragmentation. Likewise, the ENN value for the buil-up patches in 1994 and 2004 was increased from 204.15 m to 441.02 m. This shows the highest increment in the distance of the built-up patches with its nearest patches. However, the the ENN values in 2004 was decreased to 351.24m in 2014. Thus the results can help in urbanization planning and also forest clearing planning in future to prevent the forest patch decreasing over a period of time.

PAREA or also known as the Percentage of area functioning to measure each of patches type in landscape in percent. Based on Figure 4.12, it was clearly shown that the PAREA of the forest patches was decreased by 1994, 2004, and 2014 which were 65.00%, 64.46% and 62.72% respectively. Likewise, the PAREA of built-up patches were also shows the decreasing trends which were 4.03% in 1994, 1.61% in 2004, and 0.91% in 2014. The decreasing of forest patches percentage may due to all the anthropogenic activities during that particular time at Jeli. While the decreasing of the built-up patches area percentage in 2014 which was only 0.91% was because the urbanization rate at Jeli may have slow down in that year. From this results it can helps a lot for the state governement in order to planning future forest clearing either for economic or for urbanization aspects.

4.2.2 Comparison of Landscape Metric at Landscape Level

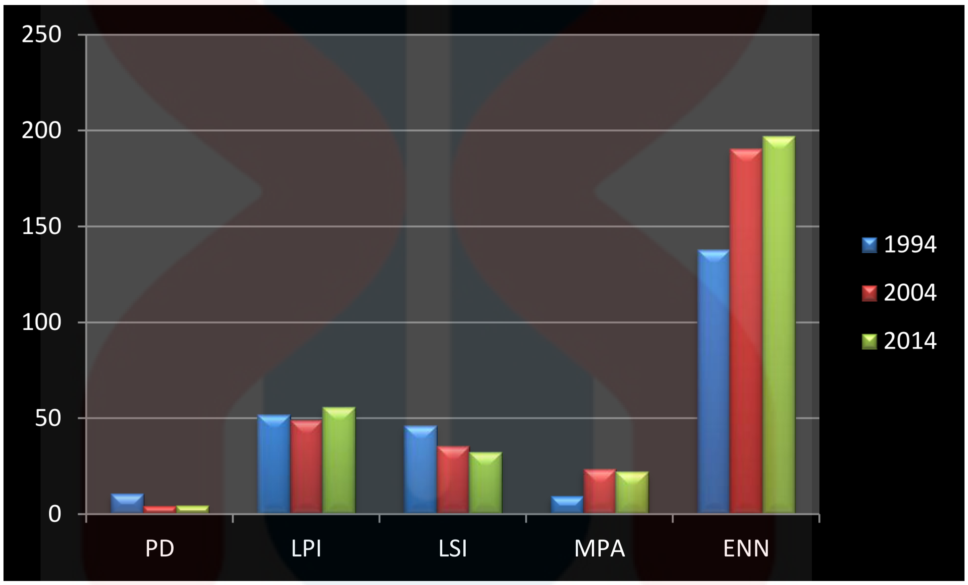


Figure 4.13 Comparison of metric at landscape level

In order to quantify the entire landscape, the landscape level metrics are effective to be used. At the landscape level, PD was decreased from 10.67, to 4.23 patches /100 ha in 1994 and 2004. However there was a slight increase in 2014 to 4. 49 patches/ 100 ha in 2004. LPI values decrease in 1994 and 2004 which was from 51.79 % to 49.10%. The LPI values then increase significantly in 2014 to 55.72%. In the study period, the LSI values were decreasing from 46.30 m/ha, 35.43 m/ha and 32.49 m/ha. There was significant increase in the value of MPA in 1994 and 2004 which from 9.37 ha increased to 23.66 ha. However the MPA values decreased in 2014 to 22.28 ha. Lastly, for the

ENN values, it shows the increasing patterns in 1994, 2004 and 2014 (Figure 4.12). The significant increase in 1994 and 2004 which was 137.96 m to 190.51 in 2004 and slightly increased in 2014 197.09 m. Thus it can be said in 1994 there was landscape fragmentation occurred. This was because of the high value of PD and low value of MPA. In 2004, there was landscape aggregation occur because the PD values was lower than MPA values. Lastly, in 2014 the results indicate the fragmentation of landscape same as in 1994 which was the value of PD was higher than MPA values.

4.3 Statistical Analysis

4.3.1 Normality test

The comparison of landscape metrics at patch level was evaluated by using the ANOVA test. The normality tests were used to determine whether a data set is a modeled for normal distribution or not normal. The type of normality test that has been used in this study was the skewness and kurtosis. The skewnesss is a measure of the asymmetry of the variable of the probability distribution of a random variable about its mean or else can be said that the skewness tells you the amount and direction of skew (departure from horizontal symmetry) (McKenzie, 2007). Meanwhile the kurtosis told the height and sharpness of the central peak, relative to that of a standard bell curve.

4.3.2 ANOVA test

In this study the comparison of landscape metric at patch level was analyzed using ANOVA. Before the ANOVA test was performed. The normality test was carried out to determine the distribution of the data either normal or not- normal distributions.

Table 4.3 Results of ANOVA

Landscape Metric	YEAR		
	1994	2004	2014
AREA	0.01	0.29	0.62
ENN	0.00	0.00	0.00

The landscape metric that have been chosen to analyze patch level were AREA and ENN. The AREA and ENN were dependent variables while the independent variable in this analysis was the LULC class. In this ANOVA test all the five LULC class which were forest, built up, cleared land, water body and agriculture.

The Table 4.3 shows the results of the AREA and ENN for all the LULC class of the year 1994, 2004 and 2014. In ANOVA if the value was less than 0.05, then the results was significant. For the AREA value of LULC class in 1994 was significant compared to 2004 and 2014 with the values of 0.01, 0.29 and 0.62 respectively. Meanwhile, for the ENN values, for all of the three years of the LULC class were significant because all of the values were below than 0.05. The values of the ENN were significant for all the three years which indicated that the distance between neighboring patches of the class in those three years was has significant changes.

4.4 Landscape Transformation Process

The landscape transformation process consists of four steps which were perforation, fragmentation, shrinkage, and attrition.

4.4.1 Perforation

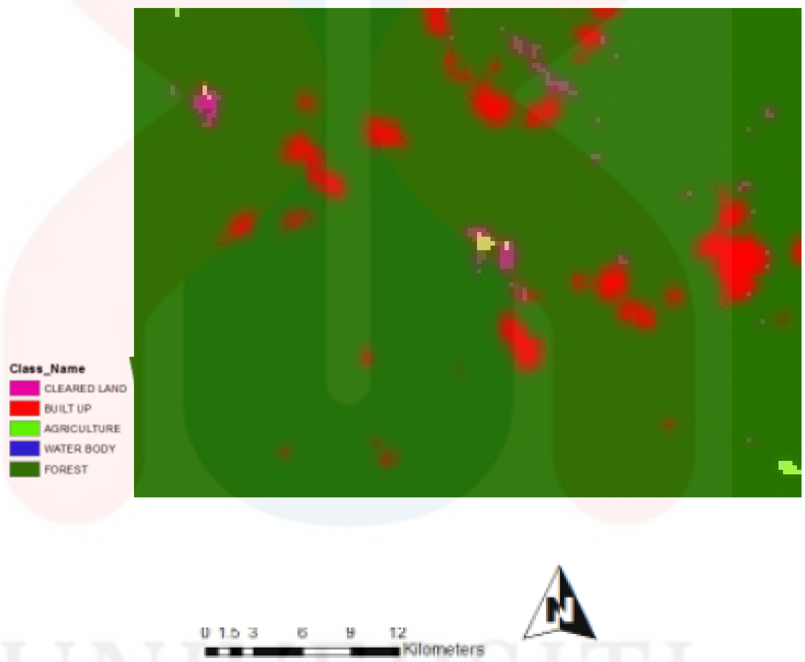


Figure 4.14 Landscape perforation

The landscape perforation in Figure 4.14 was retrieved from the Jeli land use map in 1994. The perforation occurred in that year because of the original forest vegetation was disturbed with the built-up patches that makes a hole in the forest vegetation. Dark green color indicates the forest vegetation and red color indicates the built up patches.

4.4.2 Fragmentation

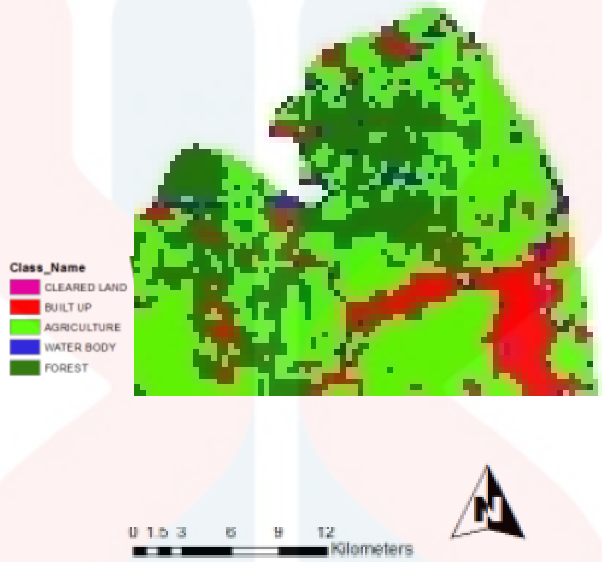


Figure 4.15 Fragmentation of Landscape

The figure above shows that the process of landscape fragmentation, retrieved from land use map of Jeli in 1994. The fragmentation occurred at the location in the figure because of due to the agricultural activities and the built-up areas that contribute to the increasing in the distance between forest vegetation patches. The fragmentation of the landscape was supported by the previous results in this study, based on the comparison of landscape metric at landscape level, the lower values of MPA and higher PD value contribute to landscape fragmentation.

4.4.3 Shrinkage

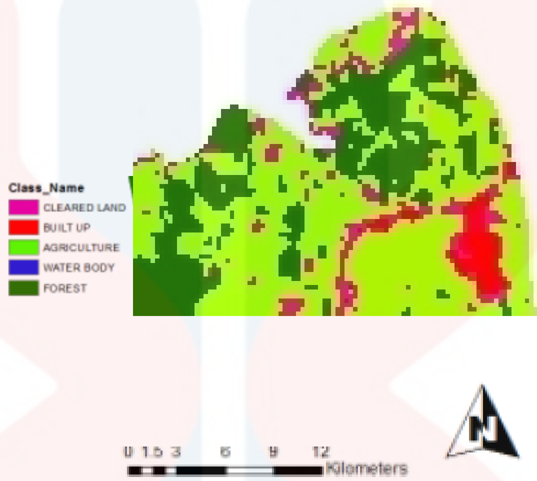


Figure 4.16 Shrinkage of landscape

The shrinking of landscape was shown in the Figure 4.16. It was retrieved from the Land use map of Jeli in 2004. The shrinking of landscape occurred because of the cleared land patches, built-up patches and agricultural patches were influencing the shrinking of the forest vegetation patches in that particular area. The size of the forest vegetation patches was gradually decreased.

4.4.4 Attrition

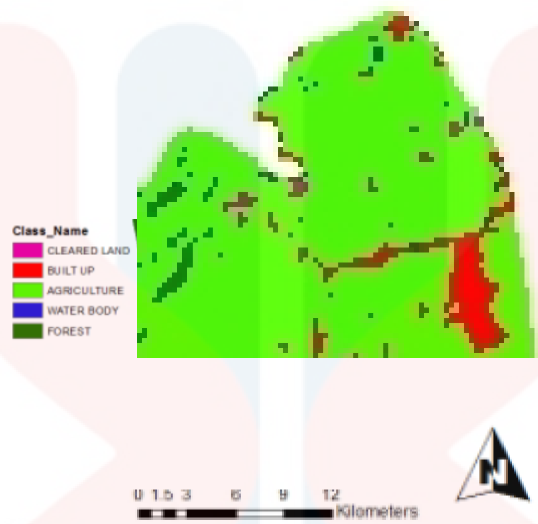


Figure 4.17 Attrition of landscape

Landscape attrition was the process of landscape fragmentation that occurred in the figure above was retrieved from the Land use map of Jeli in 2014. The attrition of landscape occurred because of the agricultural patches and the built-up patches getting bigger and makes the forest vegetation patches shrinking and lastly total loss of the forest patches occurred.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

In conclusion the objectives of this study were achieved. The first objective of this study was achieved because the landscape fragmentation was clearly shown under spatial change analysis or also known as the area change analysis. Where the forest percentage area in 1994, 2004, and 2014 were decreasing from 65.04%, 64.47% and 62.74% respectively.

Next, the second objective of this study which was to determine the degree of the landscape change. This second objective were achieved, this was clearly shown under the results of comparison of landscape metric at the class level from the forest percentage area. In all the three respective years, it shows that the degree of landscape fragmentation in Jeli were quite high. From the 1994, 2004 and 2014 it can be said that the forest vegetation area experienced the fragmentation due to anthropogenic activities. Thus, this study is important in planning forest strategy and authorities interventions in future towards sustainable forest and for healthy ecosystem.

5.2 Recommendations

In the future research, the up to date data can be applied through the ARSM and the other government department such as Jeli Land and District Office for the best reference in doing the classification of image.

Planning and managing the built up and deforestation activities properly in the future can prevent the forest vegetation area in Jeli to experienced further fragmentation. Besides, if there is a proper planning of the deforestation activities, it can balance the built up and other human interference with the forest vegetation. In the future research more comprehensive view on forest vegetation fragmentation is needed in order to manage the landscape in Jeli area.

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APPENDICES

APPENDIX A

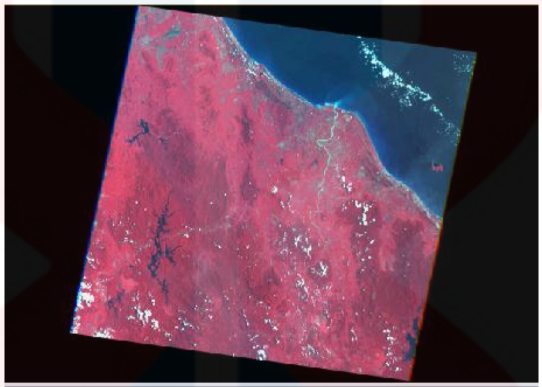

Figure 1 Raw data from Landsat

Figure 2 Addition of boundary

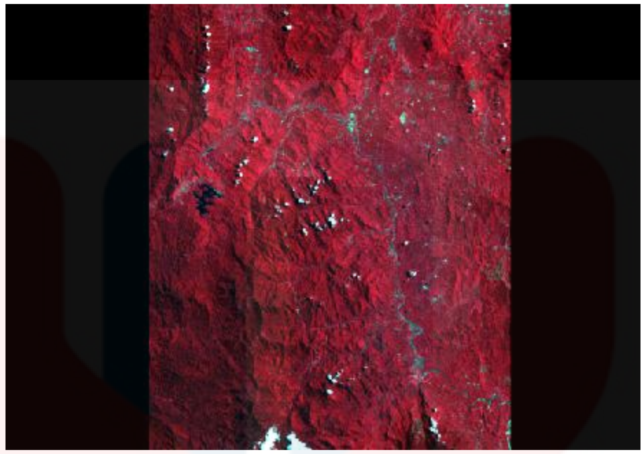

Figure 3 Subset AOI

Figure 4 Groundtruthing process

APPENDIX B

Table 1 Patch class in 1994

	CA	PLAND	PD	LPI	LSI	AREA_MN	SHAPE_MN	ENN_MN
Cleared Land	7137.54	4.98	3.25	0.56	71.73	1.53	1.24	123.49
Forest	93115.53	65.00	1.03	51.79	31.36	62.92	1.26	128.08
Built Up	5766.39	4.03	1.37	0.55	45.22	2.94	1.20	204.15
Water Body	6399.18	4.47	2.40	0.78	69.53	1.86	1.26	144.71
Agriculture	30825.18	21.52	2.62	9.08	56.00	8.22	1.29	118.99

Table 2 Patch class in 2004

	CA	PLAND	PD	LPI	LSI	AREA_MN	SHAPE_MN	ENN_MN
Cleared Land	6867.00	4.79	2.13	0.26	68.88	2.25	1.31	167.20
Forest	92340.54	64.46	0.96	49.10	30.37	67.25	1.33	152.08
Built Up	2299.95	1.61	0.33	0.09	21.04	4.93	1.23	441.02
Water Body	519.93	0.36	0.05	0.22	13.04	7.12	1.55	741.93
Agriculture	41216.40	28.77	0.76	10.37	49.29	37.99	1.39	160.16

Table 3 Patch class in 2014

	CA	PLAND	PD	LPI	LSI	AREA_MN	SHAPE_MN	ENN_MN
Cleared Land	6377.76	4.45	1.27	0.37	47.49	3.51	1.24	214.41
Forest	89847.63	62.72	1.16	55.72	23.75	54.00	1.26	154.18
Built Up	1307.16	0.91	0.32	0.07	23.61	2.84	1.23	351.24
Water Body	1689.39	1.18	0.72	0.31	37.31	1.645	1.28	245.55

Table 4 Patch land in 1994, 2004, and 2014

	1994	2004	2014
TA	143243.82	143243.82	143243.82
PD	10.67	4.23	4.49
LPI	51.79	49.10	55.72
LSI	46.30	35.43	32.19
AREA_MN	9.37	23.66	22.28
SHAPE_MN	1.25	1.33	1.28
ENN_MN	137.96	190.51	197.09

Table 5 Spatial changes for 1994, 2004 and 2014

	1994	Area Ha (%)	2004	Area Ha (%)	2014	Area Ha (%)
Agriculture	30832.881055	21.52	41236.790156	28.79	44038.301131	30.74
Built up	5749.000798	4.01	2297.906359	1.60	1303.388637	0.91
Cleared land	7122.182062	4.97	6843.216149	4.78	6353.18607	4.44
Forest	93165.958705	65.04	92343.383284	64.47	89868.302039	62.74
Water body	6372.600816	4.45	521.327488	0.36	1679.445559	1.17

Table 6 Detail of satellite imagery

Year	Satellites	Date	Resolution	Source
1994	Global Land Survey	21/6/1994	30m	United States Geological Survey (USGS)
2004	Global Land Survey	30/6/2004	30m	
2014	Landsat 8 OLI/TIRS C1	14/2/2014	30m	

Table 7 Accuracy assessment results in 1994

Types	Reference Data							
Classification	Built up area	Forest area	Cleared land	Water body	Agriculture	Classified total	Producers accuracy (%)	User accuracy (%)
Built up area	**3**	15	17	25	40	100	42.86	100.00
Forest area	10	**62**	4	23	1	100	96.88	84.93
Cleared land	50	11	**3**	28	8	100	37.50	60.00
Water body	5	35	9	**6**	45	100	60.00	100.00
Agriculture	4	18	28	39	**11**	100	100.00	84.62
Reference total	72	141	61	121	105	500		

Overall accuracy (%) = 85.00
Kappa statistics = 0.70

Table 8 Accuracy assessment results in 2004

Types	Reference Data							
Classification	Built up area	Forest area	Cleared land	Water body	Agriculture	Classified total	Producers accuracy (%)	User accuracy (%)
Built up area	**94**	1	3	1	1	100	88.68	90.38
Forest area	10	**48**	15	8	19	100	98.01	89.70
Cleared land	4	14	**50**	10	22	100	86.96	97.09
Water body	1	3	1	**94**	1	100	94.00	92.16
Agriculture	24	11	28	4	**33**	100	96.38	97.79
Reference total	133	77	97	117	76	500		

Overall accuracy (%) = 93.28
Kappa statistics = 0.92

Table 9 Accuracy assessment results for 2014

Types	Reference Data							
Classification	Built up area	Forest area	Cleared land	Water body	Agriculture	Classified total	Producers accuracy (%)	User accuracy (%)
Built up area	**54**	7	18	20	1	100	92.11	100.00
Forest area	35	**24**	14	6	21	100	96.14	97.82
Cleared land	1	4	**86**	5	4	100	95.56	80.37
Water body	4	1	2	**90**	3	100	93.40	96.12
Agriculture	8	17	6	10	**59**	100	95.21	95.78
Reference total	102	53	126	131	88	500		

Overall accuracy (%) = 94.79
Kappa statistics = 0.93