



**ASSESSING RIVER ECOSYSTEM HEALTH
USING REMOTE SENSING AND GEOGRAPHIC
INFORMATION SYSTEM (GIS) TECHNIQUES: A
CASE STUDY IN JELI, KELANTAN**

by

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DECLARATION

I declare that this thesis entitled “Assessing River Ecosystem Health Using Remote Sensing and Geographic Information System (GIS) Techniques: A Case Study in Jeli, Kelantan” is the result of my own research as cited in the references. The thesis has not been accepted for any degree and concurrently submitted in candidature of any other degree.

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Assessing River Ecosystem Health Using Remote Sensing and Geographic Information System (GIS) Techniques: A Case Study in Jeli, Kelantan

ABSTRACT

This study assesses the health of the river ecosystem in Jeli, Kelantan, which has been increasingly affected by land use change and anthropogenic pressures. The objectives are to evaluate the river ecosystem health and to produce a thematic map of water quality indicating ecosystem health using remote sensing and Geographic Information System (GIS) techniques. Landsat 8 imagery was processed to generate the Normalized Difference Water Index (NDWI), Normalized Difference Turbidity Index (NDTI) and Normalized Difference Chlorophyll Index (NDCI), which were then analyzed and stacked to classify river health. Ground truth data for turbidity and dissolved oxygen (DO) were collected and used for accuracy assessment through confusion matrices and able to get overall accuracy over 70%. The findings indicate that most river sections exhibit good ecosystem health, particularly in upstream areas, while moderate degradation was detected in zones near recreational or agricultural activity. The study recommends the integration of high-resolution data, seasonal monitoring and additional water quality parameters in future research to support more comprehensive and precise river management strategies.

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Menilai Kesihatan Ekosistem Sungai Menggunakan Teknik Penderiaan Jauh dan Sistem Maklumat Geografi (SMG): Kes Kajian di Jeli, Kelantan

ABSTRAK

Kajian ini menilai tahap kesihatan ekosistem sungai di Jeli, Kelantan yang semakin terjejas akibat perubahan guna tanah dan tekanan aktiviti manusia. Objektif kajian adalah untuk menilai kesihatan ekosistem sungai dan menghasilkan peta tematik kualiti air sungai yang menunjukkan tahap kesihatan ekosistem dengan menggunakan teknik penderiaan jauh dan Sistem Maklumat Geografi (SMG). Imej satelit Landsat 8 telah diproses bagi menghasilkan indeks *Normalized Difference Water Index* (NDWI), *Normalized Difference Turbidity Index* (NDTI), dan *Normalized Difference Chlorophyll Index* (NDCI) yang kemudiannya dianalisis dan digabungkan untuk mengelaskan tahap kesihatan sungai. Data lapangan bagi parameter kekeruhan dan oksigen terlarut (DO) dikumpulkan dan digunakan untuk penilaian ketepatan melalui matriks kekeliruan dengan ketepatan keseluruhan melebihi 70%. Hasil kajian menunjukkan kebanyakan kawasan sungai berada dalam tahap kesihatan yang baik, terutamanya di kawasan hulu, manakala kemerosotan sederhana dikesan di kawasan berhampiran aktiviti rekreasi dan pertanian. Kajian ini mencadangkan penggunaan data resolusi tinggi, pemantauan bermusim dan penambahan parameter kualiti air dalam kajian akan datang bagi menyokong pengurusan sungai yang lebih menyeluruh dan tepat.

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LIST OF ABBREVIATIONS

DO	Dissolved Oxygen
ENVI	Environment for Visualizing Images
GEE	Google Earth Engine
GIS	Geographic Information System
NDCI	Normalized Difference Chlorophyll Index
NDTI	Normalized Difference Turbidity Index
NDWI	Normalized Difference Water Index
RS	Remote Sensing
USGS	United States Geological Survey
WQI	Water Quality Index

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LIST OF SYMBOLS

%	Percentage
NTU	Nephelometric Turbidity Unit



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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Rivers are very familiar within human life, since our ancestors chose to start the community or the urbanization near the water area. The relationship between rivers and surrounding biotic and abiotic are what is called river ecosystems. These water body areas like river ecosystems are chosen because of the services that could be provided by it. Due to these services, it became important to this place directly or indirectly. Water supply, transportation, seafood and energy generator are the ones that have always been emphasized in life as it gives faster benefits. Economic impact on society could also be influenced by its river condition especially if the country depends on ecotourism as its main revenue. This area could also be used as an aquaculture farm. Unconsciously, it serves as an essential ecosystem service. It is the place for a variety of ecological habitats of species that we eat and benefit from it. Small fish, mollusk and crustacean are easily found in this type of ecosystem. Having them as well as other biotics such as zooplankton, phytoplankton and aquatic plants help regulate the biogeochemical cycle within that area. This will balance the habitat according to their food web without interference with invasive species. Other than that, it also shapes urbanization development in one area as it needs to follow the river body (Levin, 2000).

Along with these benefits, it is never apart from the issue it is facing. Dams that are knowingly built to control flood and sustain water supply while producing hydroelectricity tend to be a great barrier for migrating fishes. The construction of dams in rivers will intrude into the habitat of current ecosystems in the river because it will smaller the population as it cannot migrate.

Besides, adding fertilizer to increase respiration could be seen as a good solution but it has severe impact on the river ecosystem. Nutrient loading will change the species inside the ecosystem as the species have different tolerances and adaptability to nutrients and importantly the oxygen level. Hence, this part is important as it will lead to a decrease in the availability of oxygen supply in the river and determine the health of the ecosystem. River eutrophication is serious issue in developing countries such as India, Southeast Asia, and Africa, as well as near major urban centres globally.

With these current issues, the urge to monitor river health is compulsory. Pollution made will disturb the ecosystem of the river and damage the habitat of biotics within the area. The hassle of monitoring the condition of the river in the rural area makes the data collected less up-to-updated. Methods that are often utilized for determining the river ecosystem health used scoring based on the identification of present taxa up to family level. It then shows the ecological water quality index or class based on the calculated data. However, some evaluations of biomonitoring programs use species-level taxonomy. Compared to species identification, family level identification has the drawback of limiting the amount of information that can be

gathered from the macroinvertebrate community data. While there is a significantly greater variety of tolerances at the family level, each species has an ecological range of environmental tolerances (Ko et al., 2020). This method seems to be less effective because of time consuming and not relevant to some places.

Hence, remote sensing and GIS will be used to gather larger scale of information as it uses satellite to gather data. The utilization of satellite data holds significant possibilities for expanding the frequency and geographic coverage of river and riparian monitoring. For instance, invasive species were distinguished from nearby native riparian vegetation using multispectral WorldView-2 satellite pictures with a 2 m resolution (Pace et al., 2022). It is more convenient and easier as it can provide real-time data. By using satellite, it is able to access remote areas without needing humans to observe it. This will help to reduce time and cost-effective compared to going to the field and running few parameters.

As for this study, it is held in Jeli, Kelantan. River in this area serve the community by the services provided by it. Located in Sungai Pergau, it is one of the river-tourism potential (Nasarudin & Bahar, 2013). Not only river-tourism, Jeli also suitable for geotourism in Sungai Renyok (Achmad Bahar et al., 2020). Local community near the area often spend time within this stream as it has beautiful scenery and refreshing place for some recreation. In Lata Keding which is one of the hotspot places for recreational activities also has diverse population and species habitat live in the river ecosystem (Amaludin et al., 2022). It also able to serve as water supply at certain area like Sungai Pergau (Samsudin et al., 2020). The services prepared by river

ecosystem could be disturb by the rapid urban growth. With an expansion in other land uses, mostly agriculture, Jeli's virgin or primary forest has severely diminished over time. Plantations of very cost-effective commodities, like rubber and oil palm, have been steadily expanding throughout time. This shift in the land use pattern demonstrated that agriculture is the main source of socioeconomic activity in Jeli (Karim et al., 2021).

In river ecosystems health study, remote sensing and GIS techniques had been used worldwide lately as it offers better benefits. Remote sensing improves river system research by enabling broad geographic coverage and rapid, frequent data collection. Satellites acquire data from remote and inaccessible areas, resulting in a full understanding of river structure. This spatial technique identifies management actions and changes in regional river systems. Integrating sensor and platform data is beneficial for river system study. Remote sensing data is used in hydrological and climate models to improve monitoring and forecasting of rivers. This connection enhances model predictions, river parameters, and management (Ko et al., 2020).

1.2 Problem Statement

Jeli is a place that is rich in natural resources and biodiversity. However, further research about home or habitat for aquatic species which in river ecosystem is still lacking. Most of the research discussed terrestrial ecosystems and species in this place. Along with development in Jeli, not only the terrestrial habitat is threatened and leads to the water quality decreasing. This could be a problem within the ecosystem and affecting the diversity in it. This research is proposed because there is no baseline data established for ecosystem health in Jeli, Kelantan especially related to river ecosystem and surrounding habitat.

1.3 Objectives

- To evaluate the current health status of the river ecosystem in Jeli, Kelantan.
- To develop a thematic map of water quality for the rivers in Jeli, Kelantan utilizing remote sensing and GIS techniques.

1.4 Scope of Study

Since the study of river ecosystems health is a broad aspect, this study will only focus on water quality indicator which is dissolved oxygen (DO). Remote sensing images in Landsat 8 will be used and methods will be employed the water body index of NDWI. DO is required for organisms to remain alive in a stream. It is a positive sign when oxygen is present and a sign of severe pollution when it is not. It is believed that stable aquatic settings with consistently high dissolved oxygen levels can support a diverse range of aquatic species (Abu Shmeis, 2018). It also conducted in Jeli, Kelantan area as there is not much research about ecosystem health in this area.

1.5 Significant of Study

The significance of this study is to provide local authorization data of stream's ecosystem health. A map of NDWI and spatial analysis could be used to track unhealthy areas. This can be used as a precaution to the ecosystem. By this, it will make it easier for decision making and urban development in the future. As the stream gives serenity and acts as cultural services, more developers surely will be attracted to these places.

CHAPTER 2

LITERATURE REVIEW

2.1 River Ecosystem Health

The idea of assessing the health of rivers was first clearly introduced in Europe, America, and Australia. Historically speaking, the Clean Water Act (CWA) of the United States most likely established the idea of river health for the first time in 1972. Nowadays, most nations in the world have a management strategy to protect their most valuable natural resources, such as rivers and streams. In certain nations, evaluating the health of rivers is a standard part of river management (Copeland, 2016).

Ecosystem health concept has long been discussed since the 1980s. Rapport et al., (1999) states that ecosystem health is the capability of one area that integrates between biotic and abiotic to quickly recover after disturbance and sustain itself for long time use and give their services to others. As this definition marks the introduction of this concept for the first time, several indicators or factors affecting ecosystems health have been assessed to determine the ecosystem health. However, there is still uncertainty to define this term as it consists of several aspects that indicate 'health'. Physical, chemical and biological characteristics are things to be considered in evaluating river ecosystems area (Norris & Thoms, 1999). The ecosystems are considered healthy when it has this ability: it is able to back to its condition, the problem or threat are taken into consideration and fulfill the quantifiable indicators.

Based on research conducted by Xu et al., (2022), the assessment for the river ecosystem was conducted by evaluating index of water quality, index of water regime, index of aquatic organisms, index of riparian environment and index of physical morphology. The study was to measure ecosystem health for restored urban rivers in North China resulting to significant differences number of changes in water quality index and index of aquatic organisms in a good way. Hence, it shows that index of water quality is the obvious indicator and influential thing to evaluate. Increasing in number of benthic macro and index of fish diversity could also depend on water quality as the habitat is suitable for the aquatic organisms to live.

In the Jeli area, there is no holistic research conducted about river ecosystems' health. The study was focused on indicators or smaller scopes that will help to measure the river ecosystem's health. Kelantan River water quality has been assessed using water quality index (WQI) back in 2021 and it only focuses on Kota Bharu, Kuala Krai and Tanah Merah. It shows that Total Suspended Solid (TSS) is the main thing affecting WQI values in its parameters and usually relates with the water turbidity (Radin Nizar et al., 2021). There is also study in Lata Janggut using bacterial morphological to determine its river water health. *Aeromonas spp.* was found in the river water and was recommended to manage the proper river water properly (Vivian et al., 2019). This species is known as a pathogen and able to tolerate low pH values (D'Agostino & Cook, 2016). The presence of this species will bring sickness to the aquatic animal and indirectly affect humans (Martino et al., 2016). Similarly to these past studies, the study will be conducted focusing on assessing water quality and will be related to its ecological factors that affected by it.

2.1.1 Indicators of River Health

Ensuring the health of rivers requires effective management. The accomplishing of river health objectives is aided by the river management criterion. The four basic components of the river health evaluation indicator system are morphological structure, biological integrity, social service functions, and hydrology and water quality. The state of the human-water interaction can be fully reflected by using indicators like shoreline ecology, water quality status, control capacity adaptability, monitoring system completeness, and management measure progress in study. Criteria related to hydrology and water quality might show the river's water quality and abundance, reflecting the state of the river's natural environment now. However, the physical and chemical characteristics of river water are reflected in the water quality status, which may be evaluated to determine the level of pollution and to support the health of the river (Huang et al., 2024).

The amount of free, noncompound oxygen (O_2) dissolved in water or other liquids is known as dissolved oxygen (DO). Water's (H_2O) bound oxygen is a compound and does not contribute to the amount of dissolved oxygen. Because DO affects the creatures that live in a body of water, it is a crucial metric for evaluating the quality of the water. Through aeration, photosynthetic waste products, or diffusion from the surrounding air, oxygen enters water. For organisms to survive in a stream, DO is necessary. When oxygen is present, it is a good thing; when it is not, it indicates serious pollution. Consistently high dissolved oxygen levels are thought to be stable aquatic environments that may sustain a wide variety of aquatic life (Abu Shmeis, 2018).

2.1.2 Threats to River Health

In Malaysia, water pollution is a major issue that negatively affects the sustainability of water resources. In addition, it has an impact on the economy, population health, and living things like plants and animals. The overall amount of water supplied is greatly decreased since treating contaminated water is very expensive and sometimes the water is not fit for human use. Water eutrophication is the biggest problem and becoming a threat to rivers usually comes from human behavior (Afroz & Rahman, 2017).

In daily life, a considerable amount of wastewater is produced by the market's operations, which include food preparation, cleaning, and washing. The wastewater can harm the ecosystem and is frequently disposed of illegally. Unpleasant smells, contaminated water sources, and the occurrence of illnesses caused by water are all possible outcomes of the pollution that this waste causes. Organic loads from food sources and slaughtering, as well as trace amounts of detergent from washing, often account for the majority of the wastewater load from wet markets (Azha et al., 2023). Other than this, industrial production released pollutants into river ecosystems without proper management is current and have been long term issue. Along with it, aquaculture and agriculture also contributor to the water contamination. Uses of nitrogen and pesticides excessively bring major harm the quality of water and the ecosystem surrounding. The issues related to the discharge of some compounds may worsen if specific regulations are not in place to control their release (Lin et al., 2022).

The primary negative impact of water eutrophication is its ability to disrupt the natural balance of the aquatic environment, causing harm and a slow decline in its functions. Consequently, it may have an impact on water quality and worsen water transparency. As a result, sunlight cannot reach a large body of water, and underwater plant photosynthesis will be reduced or even interrupted. Additionally, excessive amounts or a lack of dissolved oxygen in the water can result from water eutrophication, endangering aquatic life and possibly killing it (Yang et al., 2008).

2.2 Remote Sensing in River Monitoring

The measurement of the physical characteristics of objects located far away and their environments using reflected and emitted radiation is known as remote sensing. Remote sensing is therefore a science, a tool, and a source of fundamental data. The measurements are the data, regardless of whether they were captured on film, magnetic tape, or a strip chart. The process involves taking relative or absolute measurements, processing the data manually or mechanically, analysing the findings, and deriving significant conclusions, hence the remote sensing is a science (Moore, 1979). It is a tool since the findings may be applied to resource inventories and ecological problem-solving. In addition to more recent methods that employ different regions of the electromagnetic spectrum, remote sensing covers all of the traditional sciences of photography, photogrammetry, and aerial geophysical surveys. Numerous remote sensing sensors and methods can be applied to hydrological issues and research.

Based on histories, the first discoveries of remote sensing were found by Gaspard Felix Tournachon in Paris back in 1859. Utilizing balloons to capture photograph 'remotely' made him the first person to find it. This method also used in American Civil War for air observation. It then developed by 1909, when it started to use airplane to take photographs for information gathering. Modern small satellites, a new satellite model had emerged in the late 1980s and created a new class of space applications. Even if small satellites might be a disruptive or enabling technology, their purpose is always what counts. The utility of a tiny space mission, regardless of its intended use, is the standard by which small satellites will eventually be evaluated and, consequently, become more widely accepted (Xue et al., 2008).

2.2.1 Application of Remote Sensing in River Monitoring

The material composed of a body of water and the state of its components determine its spectral properties. The following is the basic idea underlying remote sensing for water quality monitoring: Some of the energy from sunlight that strikes the water is absorbed by the atmosphere, while some of it reaches the water's surface and interacts with its molecules. Light changes direction due to the reflective qualities of the water, allowing light that has been backscattered and light that has been reflected from the bottom of the water to return to the surface. Remote sensors placed at the air-water contact eventually record these rays. To make water quality monitoring easier, these gathered data are then integrated with the water body's spectral properties (Yang et al., 2022). This will help in applying remote sensing in river monitoring.

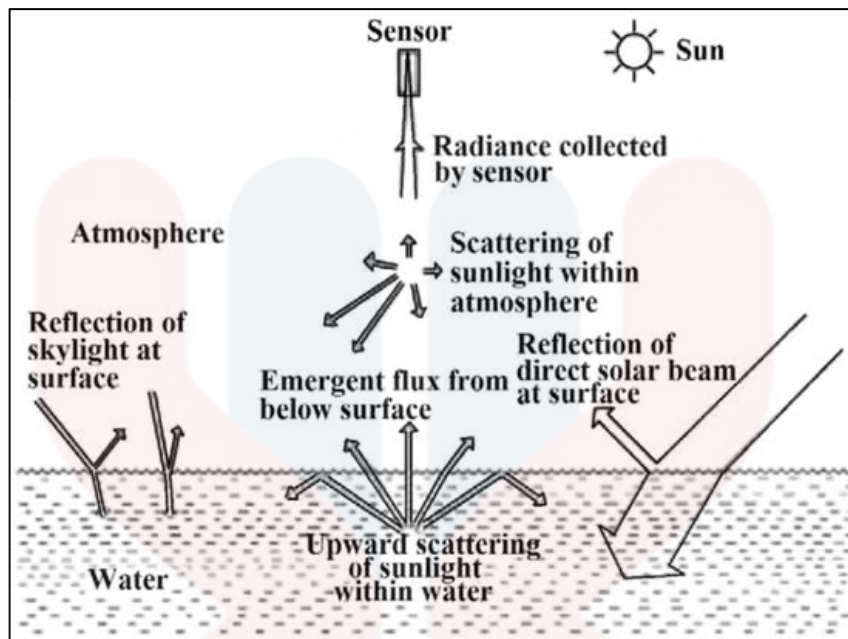


Figure 2.1: Water Quality Monitoring using Remote Sensing (Yang et al, 2022)

When compared to clean water bodies, water bodies that are polluted or contain compounds frequently exhibit different spectral properties. By utilizing these spectral characteristics, remote sensing is a useful technique for tracking water quality indicators. The concentration of chlorophyll, suspended matter, water transparency, and coloured soluble organic matter are only a few of the water quality indices that may currently be efficiently monitored using remote sensing. Light reflection is greatly influenced by suspended particulates, dissolved organic matter, and phytoplankton algae during the remote sensing monitoring procedure for lake water quality. When algae build up in the water, the spectral curve of the observed water undergoes noticeable changes, especially in the blue or 676 nm region (Lin et al., 2024). As a result, there is a noticeable peak in this band, which makes it possible to determine the pollution levels in water bodies. In order to monitor water bodies using remote sensing technology, changes in the spectral fingerprints of water quality must be recorded and correlated with water quality indicators. Remote sensing monitoring of water quality

indicators can be divided into photosensitive and non-photosensitive metrics based on the different light absorption and scattering properties displayed by different compounds inside water bodies.

A study was conducted by Batina & Krtalić (2024) about integrating several methods in remote sensing for monitor and assessing water quality. The methods used is empirical, semi-empirical, semi-analytical, analytical and machine learning. There are several ways to use remote sensing for gathering water quality parameters. The analytical method, sometimes referred to as the physical method, is one often employed technique that is distinguished by its theoretical examinations of spectrum data. Empirical and semi-empirical approaches, which are favoured because of their complexities, frequently employ statistical analysis. This study helps in improving water quality parameters for problem solving of different scenarios in the future.

2.2.2 Limitations of Remote Sensing in River Monitoring

Remote sensing typically uses small amounts of input data and has a low geographical or temporal resolution, local interpretations are unreliable and often inaccurate. The resolution of thermal infrared imagery is still relatively coarse (≥ 100 -m pixel size), so it can currently only be used to estimate temperature for very large rivers, even though satellite-based remote sensing of suspended sediments is already well-developed and will continue to advance due to the increasing resolution of satellite-based optical imagery (Kuehne et al., 2023). However, it is anticipated that the upcoming introduction of new sensors would provide greater resolution data,

allowing thermal remote sensing to be extended to smaller rivers and significantly increasing the precision of global water temperature models.

2.3 GIS in River Health Assessment

The term geographic information systems (GIS) have no universally accepted definition. "Geographical information" might mean a variety of things, such as the position of a certain entity or a hint as to what might be found at a specific spot. A key indicator of the system's numerous components is the phrase "system," which can refer to any combination of "computer hardware, software, geospatial data, and other information." Data containing a place that can be geocoded, mapped, and examined as a collection of digital layers using GIS software is known as geospatial data. By using a fundamental GIS method known as "overlay," which allows users to superimpose data sets and rearrange them to study or portray geographical relationships, the layers usually represent certain themes. All kinds of data can be created, managed, analysed, and mapped using GIS technology. Through the integration of location data and various forms of descriptive information, GIS links data to a map (Ali, 2020). This gives research and practically every sector a basis for mapping and analysis.

The Canada Geographic Information System (CGIS), created by an IBM team led by Roger Tomlinson, is arguably the most well-known and significant project in the history of GIS as a computer application back in 1960s. This event marks as the first time GIS was properly introduced. Other attempts at the time included the UK's Experimental Cartography Unit's work and Duane Marble's at Northwestern University, which supported transportation research in the Chicago area (Goodchild,

2018). All of these and other recent advancements occurred in what is now considered to be a very limited and basic computing environment.

2.3.1 Mapping and Analysis

In Denwa River, a study to assess physical habitat using GIS has been conducted. When evaluating ecological conditions, the bioassessment process is a key factor in determining the potential for living things of a given environment. Prior to evaluating a habitat, this potential must be understood in relation to the composition and structure of the biota. It is also consisting of measurement for water quality indicators. A map created using GIS techniques might be the most effective way to illustrate the spatial and longitudinal variation in habitat conditions. Each parameter was assigned a score based on visual observation of the conditions, and it was then categorized into different groups ranging from suboptimal to ideal (Vyas et al., 2013).

Study conducted by Oseke et al. (2021) emphasizes the uses of GIS by creating spatial maps based on the water quality parameters. It is easier to analyze as it gives range from the lowest to healthiest parameter. The result of this study will be helpful as it urge to monitor the quality of the water continuously.

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2.4 Remote Sensing and GIS for River Ecosystem

To evaluate and track the water quality in river ecosystems, remote sensing and Geographic Information System (GIS) approaches have become necessary tools. By addressing the limitations of typical, point-based sample techniques, these technologies provide spatial and temporal insights that are essential for sustainable river management (Usali & Ismail, 2010). With the use of remote sensing methods, water bodies can be continuously observed on a broad scale, gathering vital data on factors like as suspended solids, turbidity, and chlorophyll levels that might reveal information about the health of the ecosystem and water quality (Zaidi, 2012). By combining different data layers, such as topography, land use, and water quality characteristics, into a single framework, the integration of GIS and RS technologies improves the predictive modelling of water quality. By locating the sources of pollution and modelling possible remediation situations, this method aids in the creation of management plans. Remote sensing imaging and GIS-based pollution level mapping have effectively located areas with greater pollutant concentrations, enabling specific responses.

The potential of remote sensing to offer spatially extensive and repeated data makes it extremely helpful for evaluating water quality since it allows for the detection of pollution sources and changes over time (Chatrabhuj et al., 2024). This approach is especially beneficial for developing areas, where financial limitations may prevent conventional monitoring. Satellite data's spectral reflectance values have been found to correlate with water quality indicators including turbidity and chlorophyll,

providing dependable and affordable monitoring alternatives for suspended sediments and other contaminants.

Based on research conducted in Tigris River, water quality parameters were assessed using satellite imagery with the on-site sample to validate the data. This study helps in identifying places with low levels of water quality. It contributes to standardize the law and act to reduce pollution happening in the area (Ahmed et al., 2023).

2.4.1 Conservation and Restoration

Nizamani et al., (2023) had stated the usage of remote sensing and GIS in conservation efforts. These techniques' ability to detail the spatial analysis helps in identifying habitat suitability and relationship between environmental and its residents whether it is animal or plant. It could promote better decisions because of the monitoring system by satellite imagery to conserve the ecosystems. It also helps categorize the conservation priority zone based on the map created (Sudhakar et al., 2006).

By examining the connections between land cover, land use, and water quality metrics like nutrient concentrations and sediment loads, GIS may also be used to simulate the effects of land-use changes on water quality. This data can be used to guide the creation of water quality management plans, evaluate the efficacy of conservation efforts, and locate possible sources of contamination.

CHAPTER 3

MATERIAL AND METHOD

3.1 Study Area

This study was conducted within a river in Jeli, Kelantan. Jeli is one of the districts in Kelantan state. Located in 5.7007° N, 101.8432° E which near to Perak and Thailand (Google Maps, 2024). This region, which is 90–500 meters above river level and has several streams and rivers, is located between Sungai Pergau, Sungai Renyut, Sungai Suda, and Sungai Balah. 82% of the terrain is hilly and covered in forests (Pejabat Tanah dan Jajahan Jeli, 2024). It is consisting with two main river which is Sungai Pergau and Sungai Golok. Famous for its local attractions, which consist of Lata Kashmir, Lata Renyok and Lata Janggut make even well-developed cities residents come here to enjoy its river ecosystem services.

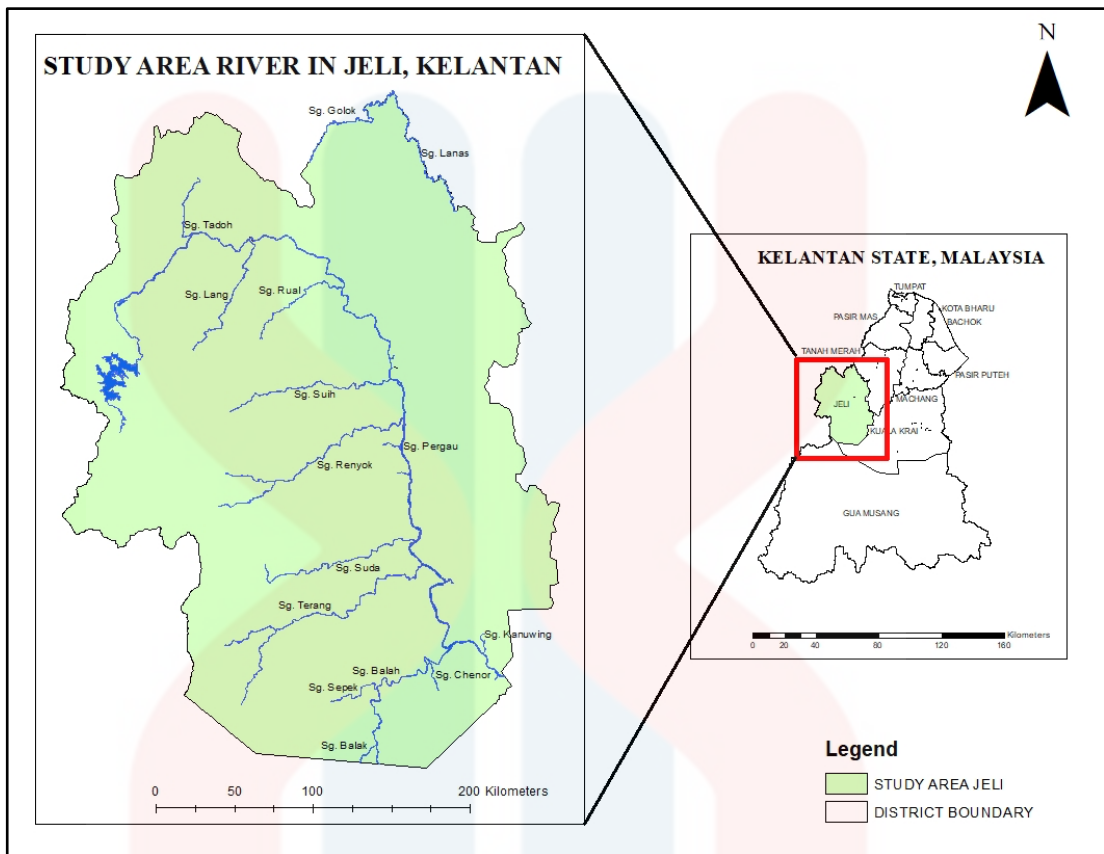


Figure 3.1 Map of study area in Kelantan state

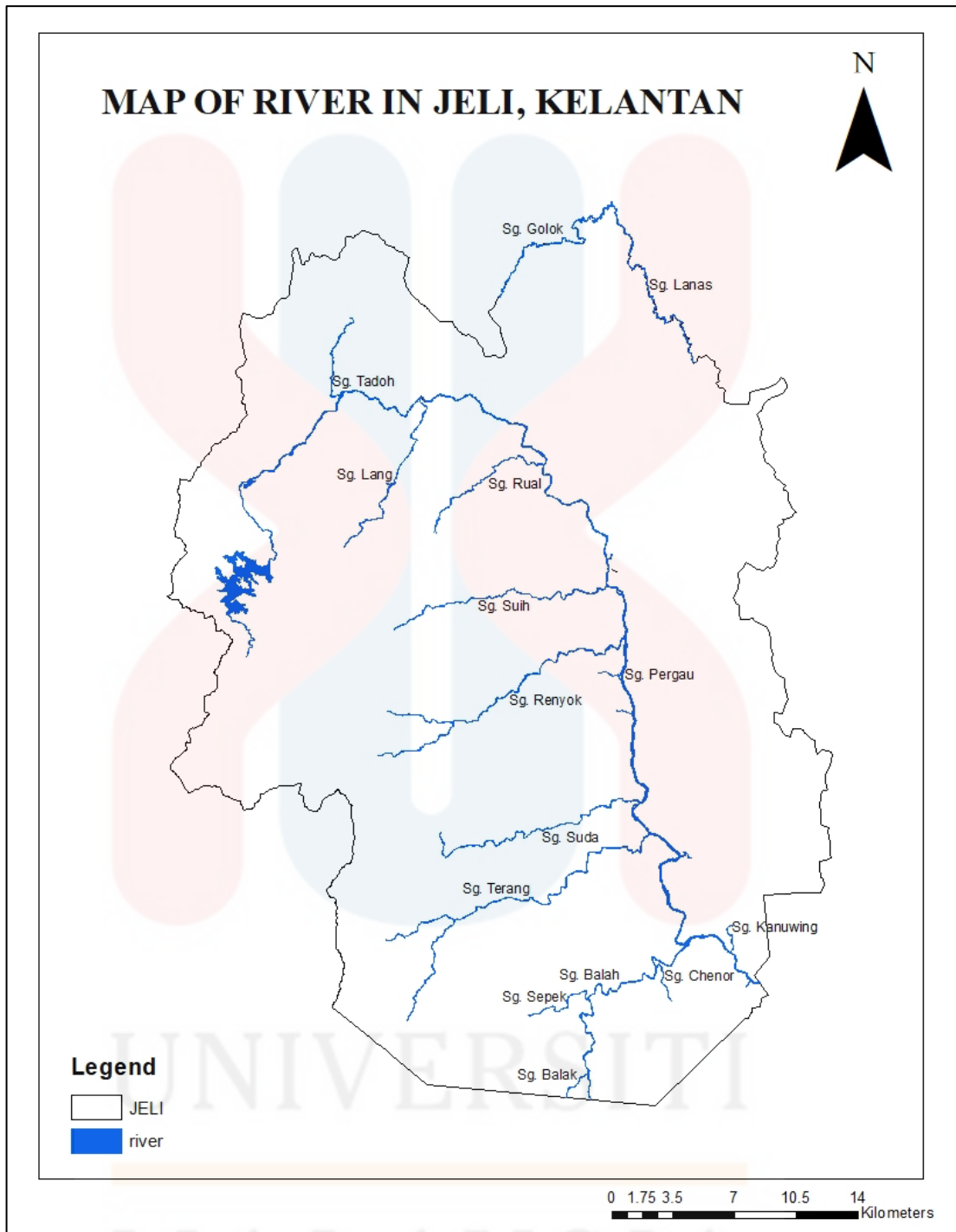


Figure 3.2 Map of River in Jeli, Kelantan

3.2 Data Collection

3.2.1 Remote Sensing

Landsat 8 was used, and the data was accessed on the 2024 data from United States Geological Survey (USGS) website. Landsat 8 was chosen because it can provide cloud-free satellite imagery, including details on the range of resolution and the breadth of bands (Aziz et al., 2021). The technique of radiometric calibration will be applied to all acquired satellite pictures in order to correct reflectance values. To do this, the Landsat satellite imagery's raw digital numbers (DN) are first converted to Top of Atmosphere (TOA) reflectance.



Figure 3.3 Landsat 8 (NASA/USGS, 2013)

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Table 3.1: Information on Landsat 8 (Anak Kemarau et al., 2024)

Landsat 8 OLI and TIRS	Wavelength detailed	Wavelength (micrometres)	Resolution (metres)
Band 1	Coastal Aerosol	0.45 – 0.52	30
Band 2	Blue	0.52 – 0.60	30
Band 3	Green	0.63 – 0.69	30
Band 4	Red	0.76 – 0.90	30
Band 5	Near-Infrared	1.55 – 1.75	30
Band 6	Shortwave infrared	10.40 – 12.50	60
Band 7	Shortwave infrared	2.08 – 2.35	30
Band 8	Panchromatic	0.50 – 0.68	15
Band 9	Cirrus	1.36 – 1.38	30
Band 10	Thermal Infrared 1	10.6 – 11.19	100
Band 11 Thermal	Thermal Infrared 2	11.50 – 12.51	100

3.2.2 Software

Software such as ArcGIS 10.8 and ENVI was used in this study for map creation and analysis. It then shows the accuracy after the map is created. Other than this, Google Earth Engine was also used in map creation.

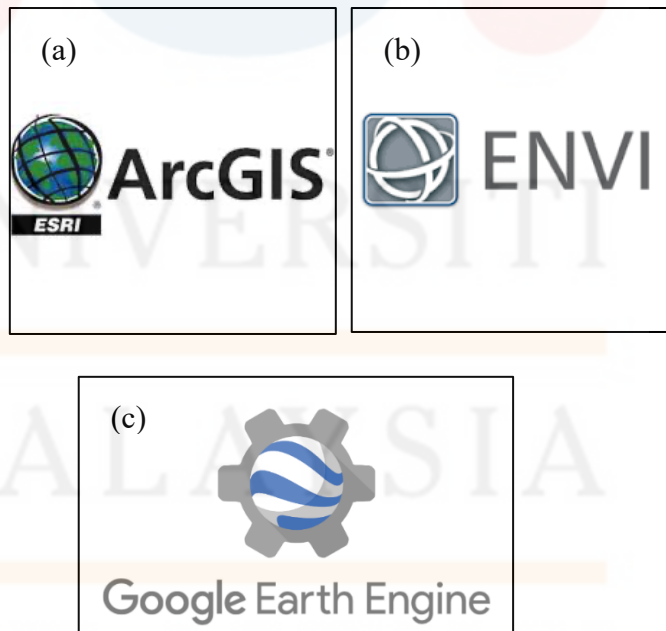


Figure 3.4: Software used are (a) ArcGIS 10.8 Software, (b) ENVI & (c) Google Earth Engine

3.3 Data Analysis

3.3.1 Remote Sensing and GIS Analysis

Map of Normalized Difference Water Index (NDWI) was created after the analysis was made. This helps in determined the water body areas. Chlorophyll-a content, which is frequently a sign of algal blooms that can deplete DO as they respire and decompose, water temperature, which influences DO solubility, and turbidity, which can obstruct sunlight and prevent photosynthesis by aquatic plants, are some examples of these markers. Generating proxy indicators to roughly represent DO levels after processed the data. For example, temperature of the surface water was estimated using thermal infrared bands because lower DO levels are frequently associated with greater temperatures. The Normalized Difference Turbidity Index (NDTI), which is based on the visible red and green bands, used to estimate turbidity. High turbidity levels frequently signify suspended particles, which can diminish DO by obstructing light penetration and photosynthesis.

Table 3.2: NDTI Value Classifications (Anak Kemarau et al., 2024)

NDTI Value	Turbidity Level
-1 until 0	Slightly turbidity
0 until 0.25	Fairly turbidity
0.25 until 1	High turbidity

Indexes such as the Normalized Difference Chlorophyll Index (NDCI), which is derived from red and red-edge bands, used to measure the amount of chlorophyll-a present. Higher values here signify higher amounts of algae, resulting in DO depletion. The distribution of DO along the river was spatially modelled using GIS analysis when these DO related indicators have been determined. Additionally, the bloom status index demonstrated sensitivity to chlorophyll-a (chl-a) concentration in murky, challenging waters, indicating that NDCI has the ability to be used to a variety of platforms and habitats with little ambiguity. Estimated amount of chlorophyll-a biomass was around 14 mg m^{-3} when the NDCI was equal to zero. Bloom conditions were linked to NDCI values greater than zero, however NDCI less than zero did not indicate an absence of chlorophyll-a biomass (Caneve et al., 2023).

Table 3.3: Formula of NDWI, NDTI and NDCI

Index	Formula	Source
NDWI	$(\text{Green} - \text{Near Infrared}) / (\text{Green} + \text{Near infrared})$	McFeeters (1996)
NDTI	$(\text{Red} - \text{Green}) / (\text{Red} + \text{Green})$	Elhag et al., (2019)
NDCI	$(\text{Near Infrared} - \text{Red}) / (\text{Near Infrared} + \text{Red})$	Kislik et al., (2022)

By combining chlorophyll-a layers and turbidity, predictive models of DO levels was developed and pinpointed regions that might be at risk for low oxygen. Furthermore, buffer zones surrounding urban or agricultural areas sources of pollution will help highlight how these land uses affect the quality of the water.

3.3.3 Accuracy Assessment

Other than that, ground-truth was conducted using DO meter and turbidimeter while facing the water current to avoid disturbances. This was used to measure the dissolved oxygen level and turbidity in the area. The point of the ground truth was also tracked using Global Positioning System (GPS).

The finalized map was assessed its accuracy using confusion matrix. The number of overall accuracies was shown to determine the accuracy of the map. Two essential metrics for assessing the dependability of categorization results in remote sensing are producer and user accuracy. Whereas user accuracy indicates how frequently the categorized results are accurate when utilized by a map user, suggesting commission error, producer accuracy measures how successfully the model recognizes features from the ground truth, indicating omission error. High user accuracy indicates that the categorized characteristics are largely accurate, whereas high producer correctness indicates that few true features were overlooked. These accuracy metrics aid in evaluating the classification's completeness and reliability for analysis and decision-making (Congalton & Green, 2019; Foody, 2002).



Figure 3.5: DO meter and turbidimeter

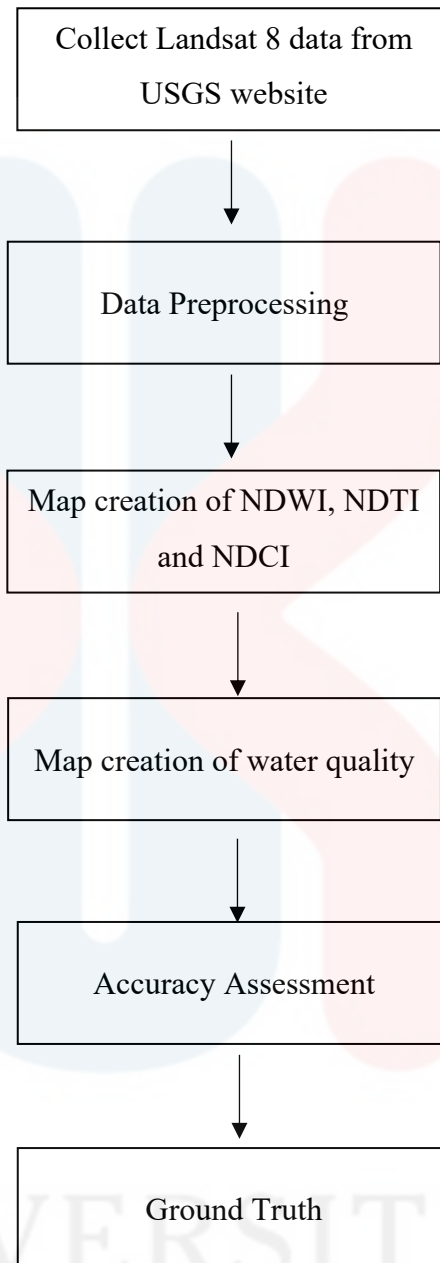


Figure 3.6: Research Flow

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Remote Sensing Indexes

NDWI, NDCI and NDTI maps are done to analyze the remote sensing data. Data Landsat 8 on April 2024 was used to compute the map. Using Google Earth Engine (GEE) and Environment for Visualizing Images (ENVI) software all the data preprocessing had been done before creating the maps.

4.1.1 Normalized Difference Water Index (NDWI)

Detection of water bodies surface in Jeli, Kelantan had been made using Normalized Difference Water Index (NDWI) to focus on the river study area. Ecosystem health could be improved and decision-making is easier using NDWI which combines data from satellite-based remote sensing to detect water patterns and its depth. Based on chapter 3, the formula to calculate NDWI for Landsat 8 is using green which is Band 3 and near infrared that represent by Band 5. The formula Equation 4.1 was inserted to calculate the NDWI in a range of -1 to 1.

$$NDWI: \frac{(B3 - B5)}{(B3 + B5)} \quad (4.1)$$

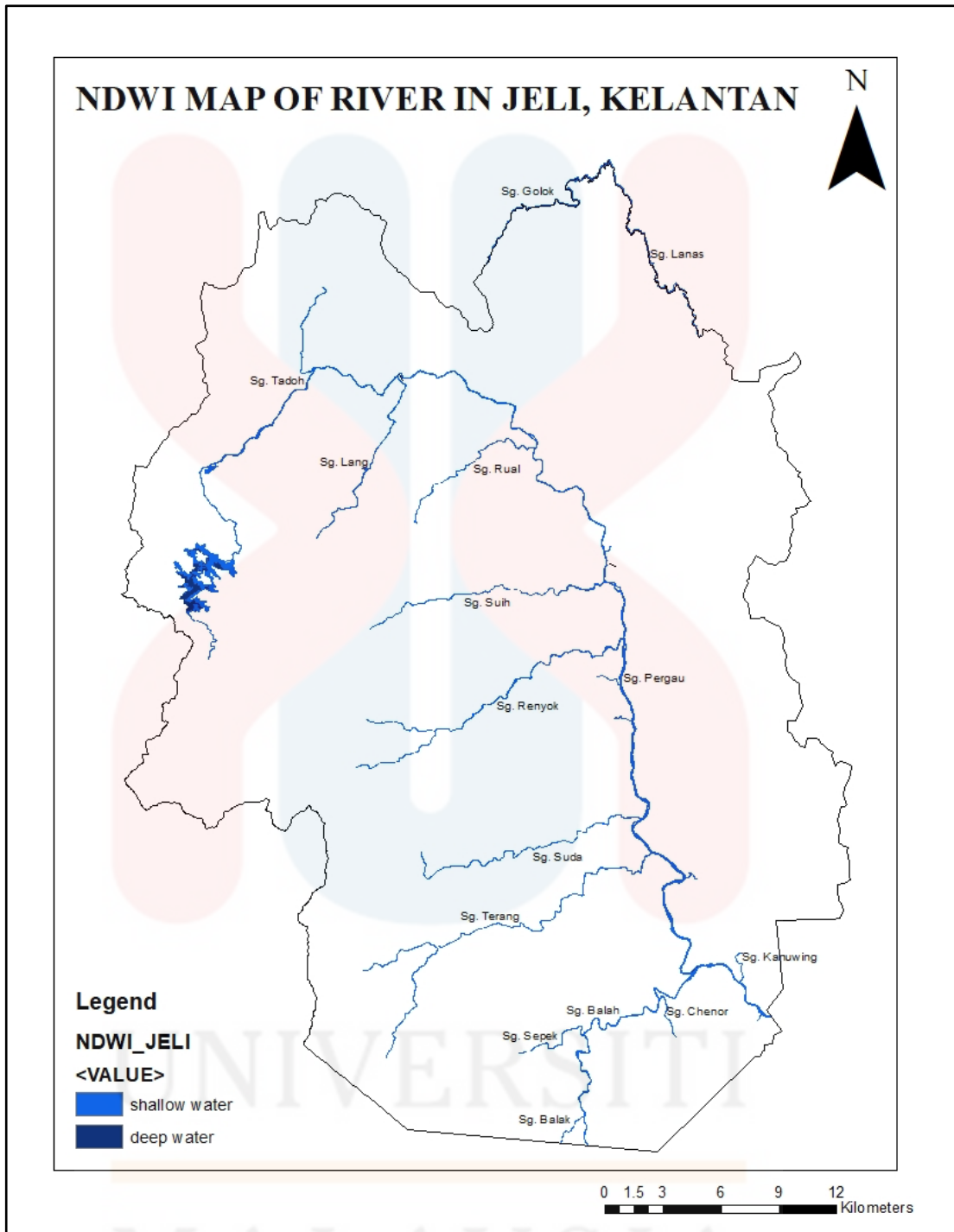


Figure 4.1: NDWI Map of River in Jeli, Kelantan

Figure 4.1 above shows the results of NDWI map of river in Jeli which are categorized into two types which are shallow water and deep water. While deeper water concentrations are more noticeable in the northwest, the Jeli district's spatial distribution of water features show large shallow water zones along tributaries and smaller canals. These patterns might be associated with isolated accumulation zones, natural topographical depressions, or even man-made structures like reservoirs or dams (Xu, 2006). This regional heterogeneity is consistent with results from earlier research that showed that NDWI is a useful tool for identifying different surface water extents (Gao, 1996).

NDWI has drawbacks even if it works well for locating open water bodies. Due to spectral confusion between water and vegetation or built-up regions, mixed pixels might decrease classification accuracy, particularly in narrow or vegetated river portions. Moreover, seasonal fluctuations, cloud cover, and atmospheric impacts can all impact NDWI results, therefore multi-temporal analysis and cloud-free images are required to track water changes across time (Pekel et al., 2016).

4.1.2 Normalized Difference Turbidity Index (NDTI)

Turbidity in Jeli's river can be detected using NDTI without going directly to the field. Suspended particulates in water could be detected by the reflectance in the red and green spectral bands which are band 4 and band 3. These bands reflect the sign of turbidity levels which indicate the index number in the range of -1 until 1. It then classified into three classes, slightly turbidity, fairly turbidity and high turbidity. The formula was then put in the band math toolbox by Equation 4.2 below:

$$NDTI: \frac{(B4 - B3)}{(B4 + B3)} \quad (4.2)$$

From figure 4.2, it shows that there has been greater turbidity in Pergau Lake, especially close to the upper catchment, as seen by the red and yellow hues. Then, it will flow the water on this region to nearby tourist destinations like Lata Kashmir and Lata Turbo, which may see an increase in human activities like deforestation and path clearance. According to Bilotta & Brazier (2008) these disturbances have the potential to promote soil erosion and contribute silt to downstream rivers.

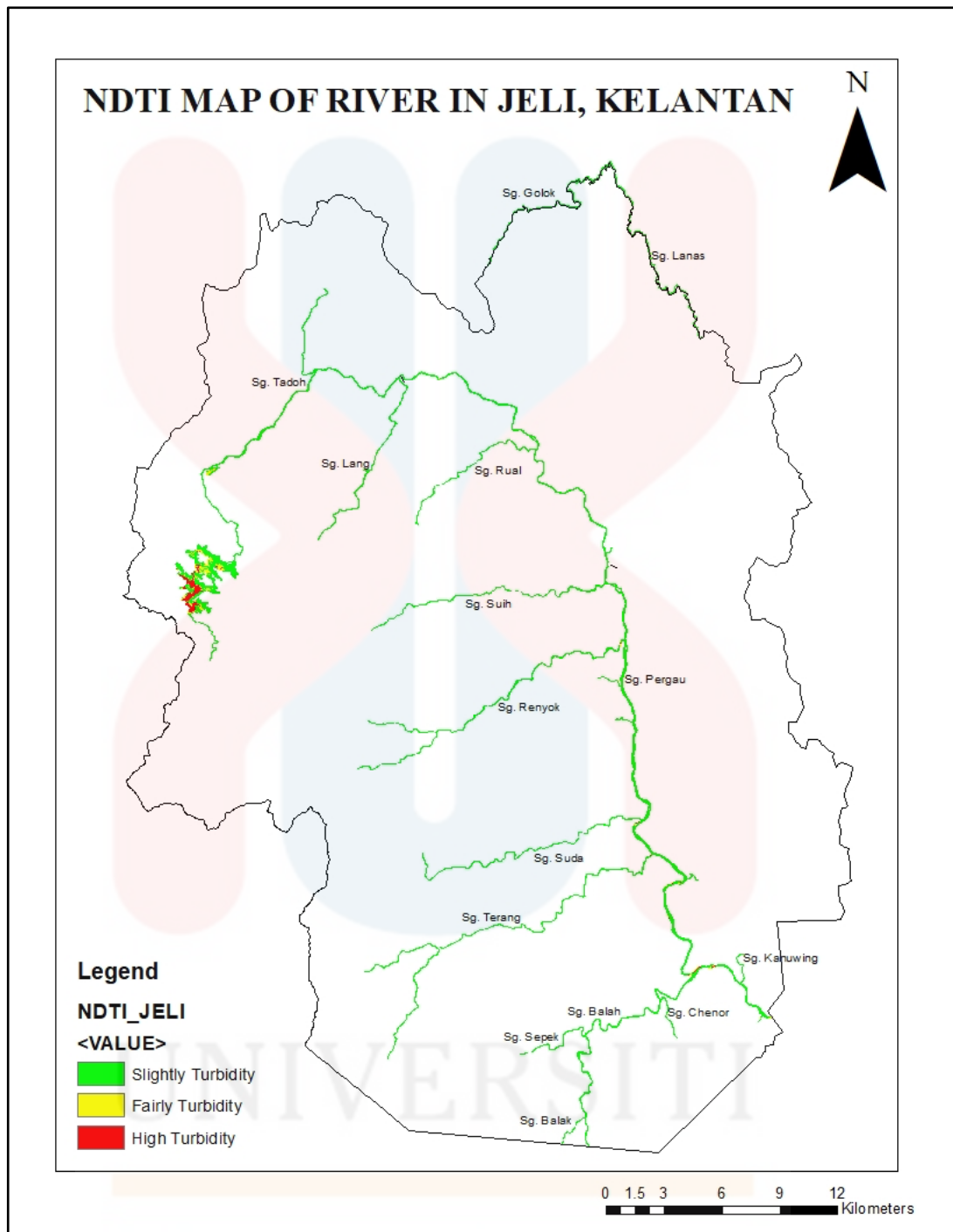


Figure 4.2: NDTI Map of River in Jeli, Kelantan

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Sungai Lanas and the middle and eastern portions of the Sungai Pergau and its tributaries on the other hand, show primarily slightly turbid conditions, indicated by green colours, indicating improved water quality and a lower concentration of suspended particles. These areas could have more vegetation or be under less human strain, which would enhance natural filtering and lessen surface runoff.

One important measure of river ecosystem health is turbidity. High turbidity can suffocate benthic habitats that are essential for fish and invertebrate populations, as well as lessen light penetration, which impacts photosynthesis in aquatic plants (Han et al., 2016). Consequently, areas with higher NDTI values may be under ecological stress, particularly during the monsoon season when rainfall increases the movement of sediments (Lacaux et al., 2007).

4.1.3 Normalized Difference Chlorophyll Index (NDCI)

As a way to evaluate the health of the river ecosystem in the Jeli area of Kelantan, this study also used the Normalized Difference Chlorophyll Index (NDCI). In river systems, the NDCI acts as an estimation tool for chlorophyll-a concentration, a crucial measure of algal biomass, and an early indicator to nutrient enrichment or eutrophication (Mishra & Mishra, 2012). Regarding the increasing need for effective, extensive water quality monitoring and remote sensing methods is a cost and time effective alternatives. Based on Table 3.3, formula applied to measure NDCI index used near infrared and red band that equivalent with band 5 and band 4. In order to get range between -1 to 1, this formula of Equation 4.3 was calculated:

$$NDTI: \frac{(B5 - B4)}{(B5 + B4)} \quad (4.3)$$

Figure 4.3 shows the distribution of NDCI map of river in Jeli that classified into three classes which is low chlorophyll concentration, moderate chlorophyll and high chlorophyll. Higher the number of NDCI and near 1, it indicates higher chlorophyll concentrations detected by the reflectance of the wavelength. Then, supposedly the area with higher chlorophyll will have lower dissolved oxygen level.

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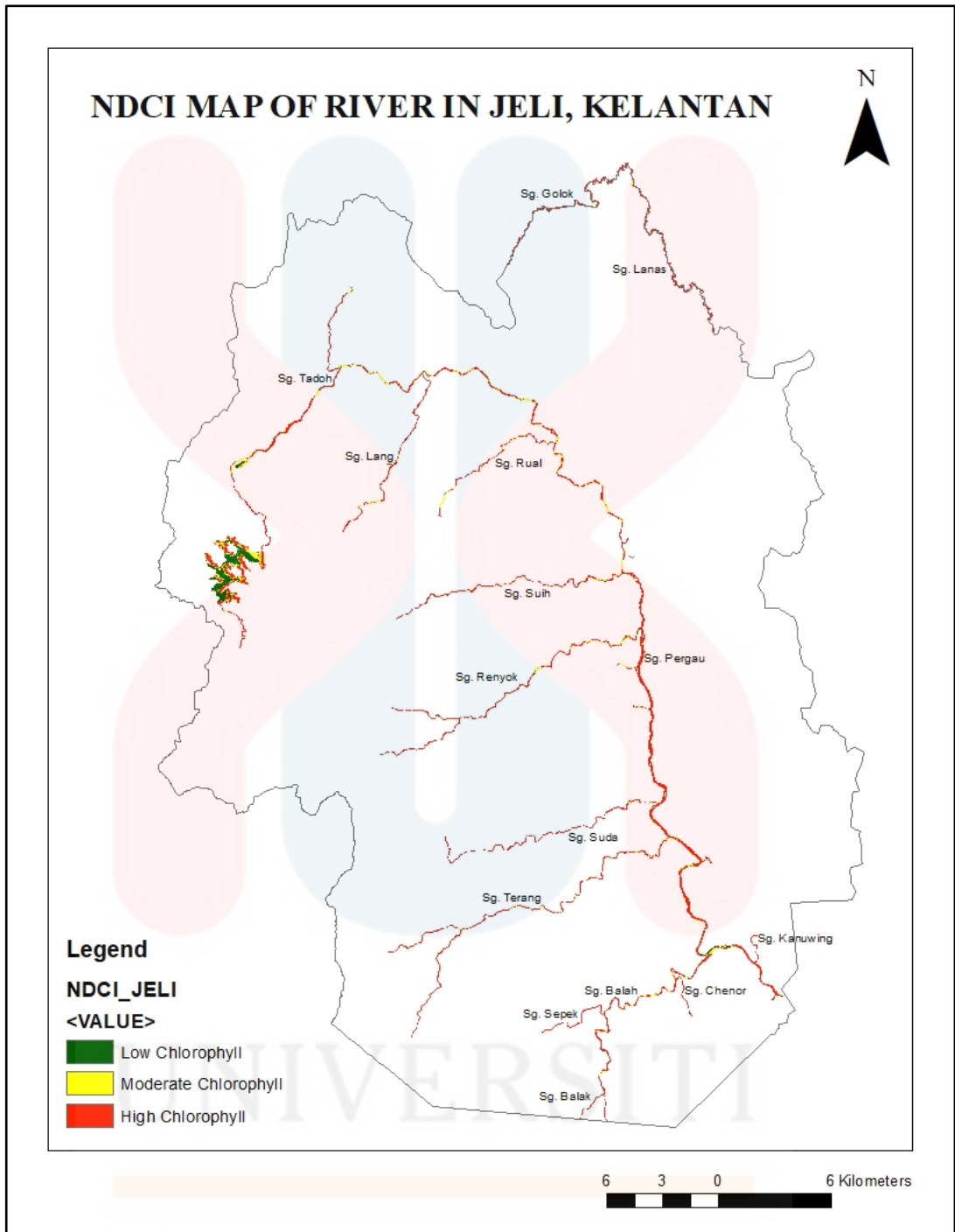


Figure 4.3: NDCI Map of River in Jeli, Kelantan

High amounts of chlorophyll, indicated by red colour on the map, mostly found in the southern and central portions of the river system. The nearby land uses, especially urbanization and agriculture are probably causing crucial nutrient enrichment in these areas. Excess nitrogen and phosphorus were introduced into the water system by fertilizers, pesticides, and untreated wastewater. Water quality and aquatic habitat may be harmed by this nutrient loading, which speeds up algae development and frequently results in eutrophic conditions. Occurrences on eutrophication and nutrient enrichment emphasizing the possible ecological concerns in these river parts (Ansari et al., 2011).

In contrast, moderate chlorophyll levels, seen in yellow, typically observed in transitional zones that connect nutrient-rich downstream areas to relatively pure upstream parts. These transitional zones impacted by seasonal hydrological fluctuations like rainfall and river discharge, as well as diverse land use patterns. These places may act as ecological buffers, where nutrient levels begin to vary and provide early signs of environmental change. Monitoring these zones is essential for recognizing water quality changes and applying proactive management techniques.

As a result, the northeastern upstream of the river system have low chlorophyll concentrations shown in green. These areas ought to have dense forest cover and little human interference, resulting in more stable and cleaner water conditions. Natural vegetation in these upstream areas serves to filter runoff, trap sediments, and minimize nitrogen input to the river. Because this location contains deep water, its reflectance may be disrupted. Consequently, the NDCI result in this area may be queried.

4.2 Jeli's River Ecosystem Health Assessment

After analyzing three of the remote sensing indexes, the map was stacked to get the water quality map of river in Jeli, Kelantan which shows in figure 4.4, the map then categorized into three thresholds. By combining these indexes, this map could show the water quality which then will indicate the river ecosystem health in Jeli whether it is poor, moderate or in good health of the ecosystem.

Results show most of the rivers are in good health which means that they have low turbidity and might have higher dissolved oxygen. The areas have appeared on the map by green color. Even when this study does not really generate the land use map. Areas with yellow color are known to be near the development areas, agriculture or livestock farm. Excessive nutrient and runoff from sediment is frequently linked to these land use types, which can worsen water clarity and encourage the growth of algae. Not only that, but it is also the place where recreation is often done by visitors. These areas are in moderate ecosystem health as this area might have eutrophication from the nutrient runoff. Apart from that, Pergau Lake shown in red means that area is of poor water quality which could be assume it also in an unhealthy ecosystem. However, lake is different from our study as it has different assessments. Hence, by generating this map the objective of this study is achieved.

Although this map was successfully generated, it comes with limitations which the river in Jeli, Kelantan was a small river and hardly identified accurately its index. Geographical structure in Jeli and weather make it harder to detect reflectance and clouds were hardly removed in preprocessing step.

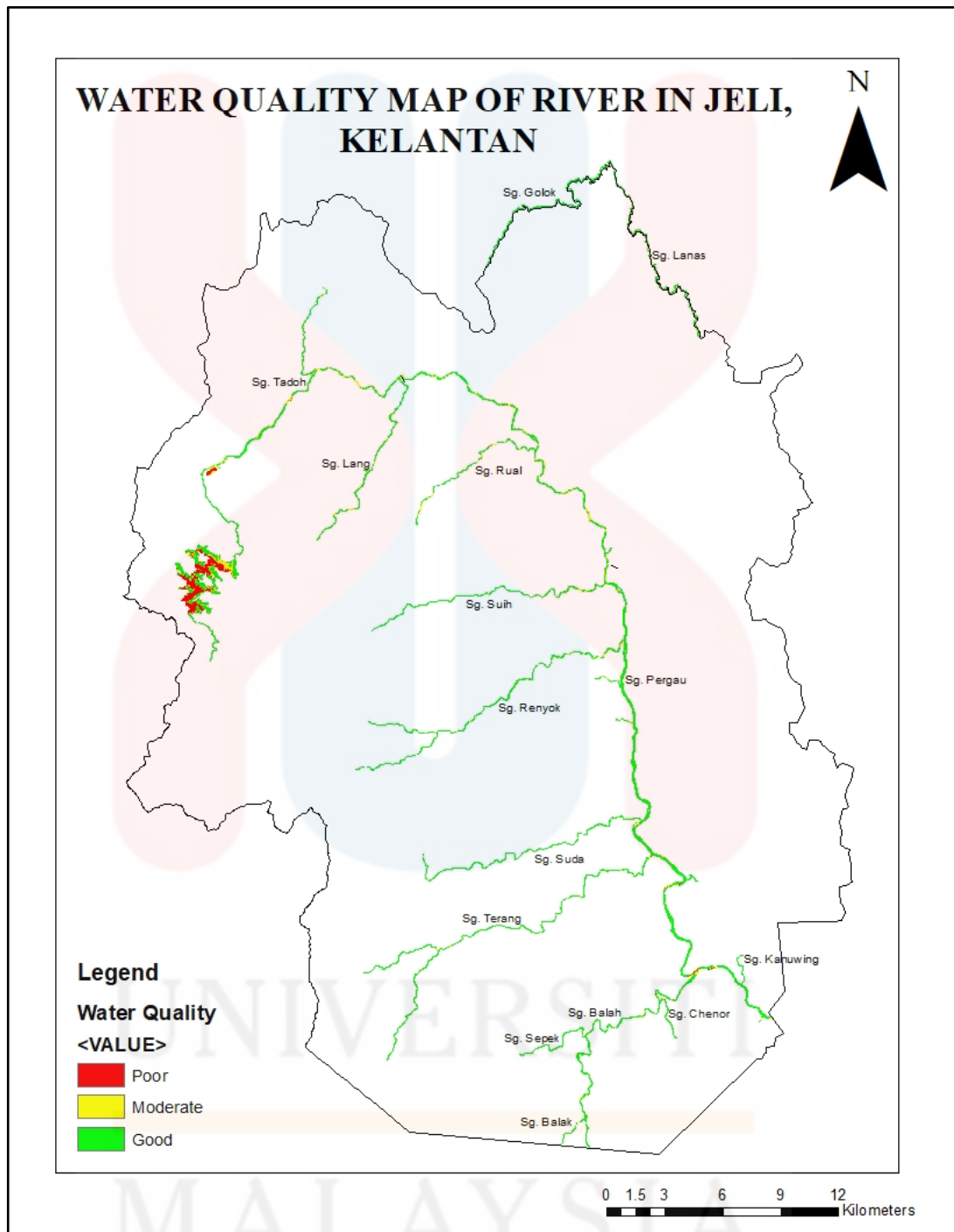


Figure 4.4: Water Quality Map of River in Jeli, Kelantan

4.3 Accuracy Assessment

In order to verify the dependability of classification, outputs obtained from remote sensing indices, accuracy assessments is an essential step. By analysing them with ground truth data, the Normalized Difference Turbidity Index (NDTI) and the Normalized Difference Chlorophyll Index (NDCI) were used in this work to assess the accuracy of the turbidity and dissolved oxygen (DO) classifications, respectively. This remote sensing method could not be justified just from secondary data. The result of the map and the data was supported and compared by the ground truth data of turbidity and Dissolved Oxygen (DO) level and the classification accuracy.

4.3.1 Ground Truth Comparison

Figure 4.5 shows the map of distribution of ground truth turbidity data in Jeli, Kelantan. Based on Chapter 3, turbidimeter was used to collect ground truth data of turbidity that can be compared to NDTI index. From the data collected in 11 points on different locations. Most of the data are in class I where it is suitable for water supply and no treatment is necessary. This class can also support very sensitive aquatic species in the fishery industry which indicates how healthy the ecosystem in this area. Based on Department of Environment (2021), turbidity that below 5 NTU and 50 NTU fall into class I, IIA and IIB. Conventional treatment required for water supply that falls into class IIA and suitable for sensitive aquatic species while class IIB still eligible for recreational use with body contact.

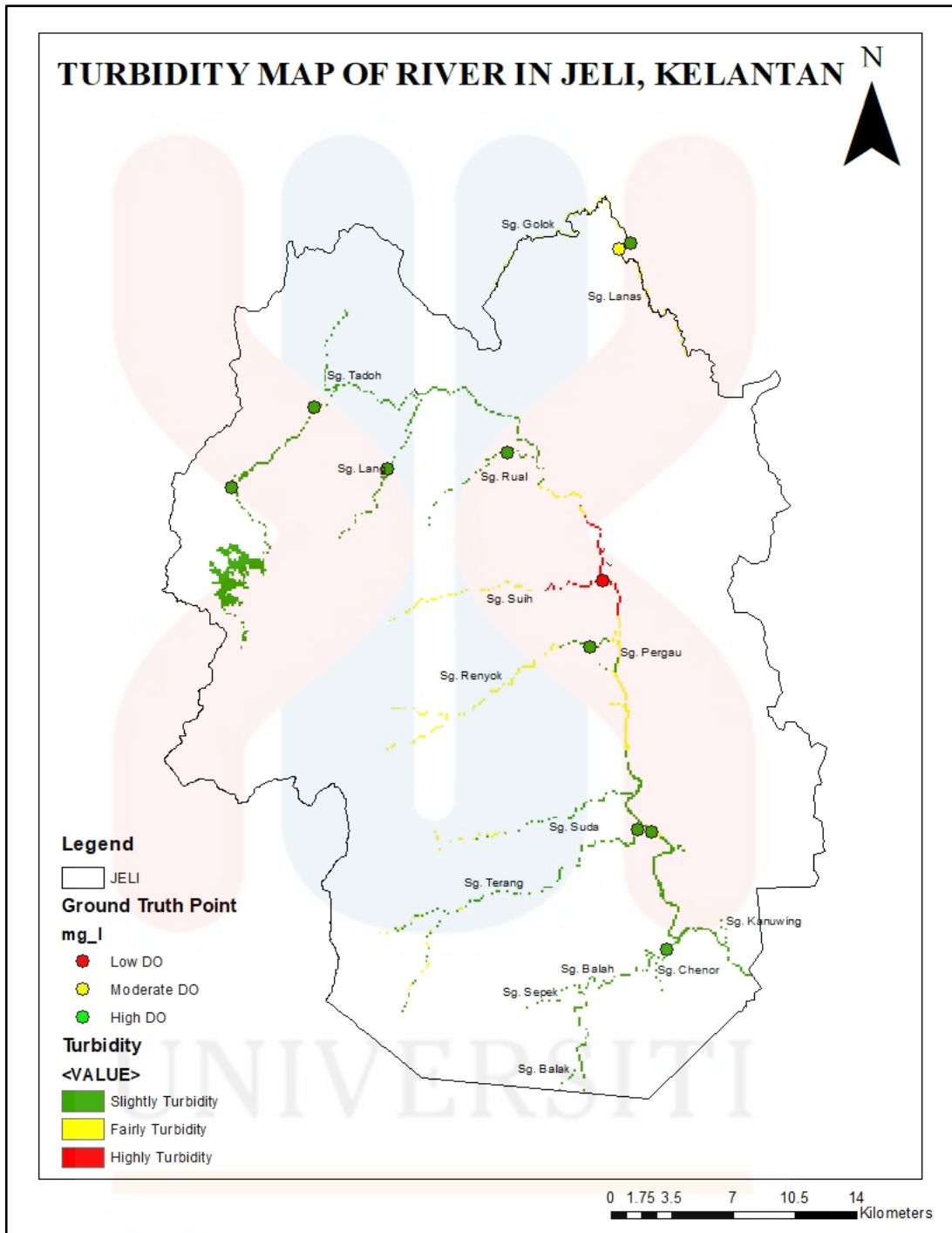


Figure 4.5: Turbidity Map of River in Jeli, Kelantan

From ground truth data, it then categorizes into specific threshold to emphasize targeted management in Jeli area which is slightly turbidity, fairly turbidity and high turbidity. Most of the areas in Jeli's river have slightly turbidity. While the green color conquered most of the map, Kampung Chegar Bedil recorded high turbidity during ground truthing and it will impact nearby area of the river. This can be seen in red color on the map. Sungai Lanas also shows fairly turbidity as this river data was collected and indicated by yellow hue. Other recreational areas like Lata Janggut, Lata Turbo and Lata Renyok fall within class I category and as stated it safe to do recreational activities with body contact in this area.

Dissolved oxygen (DO) level could justify the accuracy of NDCI. Higher the number of NDCI, it means higher chlorophyll detected in the area. It makes the reading of DO level decreasing. Data collected for ground truth was then displayed in the map shown in Figure 4.6 based on the reading recorded from DO meter in 11 locations. It results also divided into three levels which are low DO, moderate DO and high DO represented by red, yellow and green color.

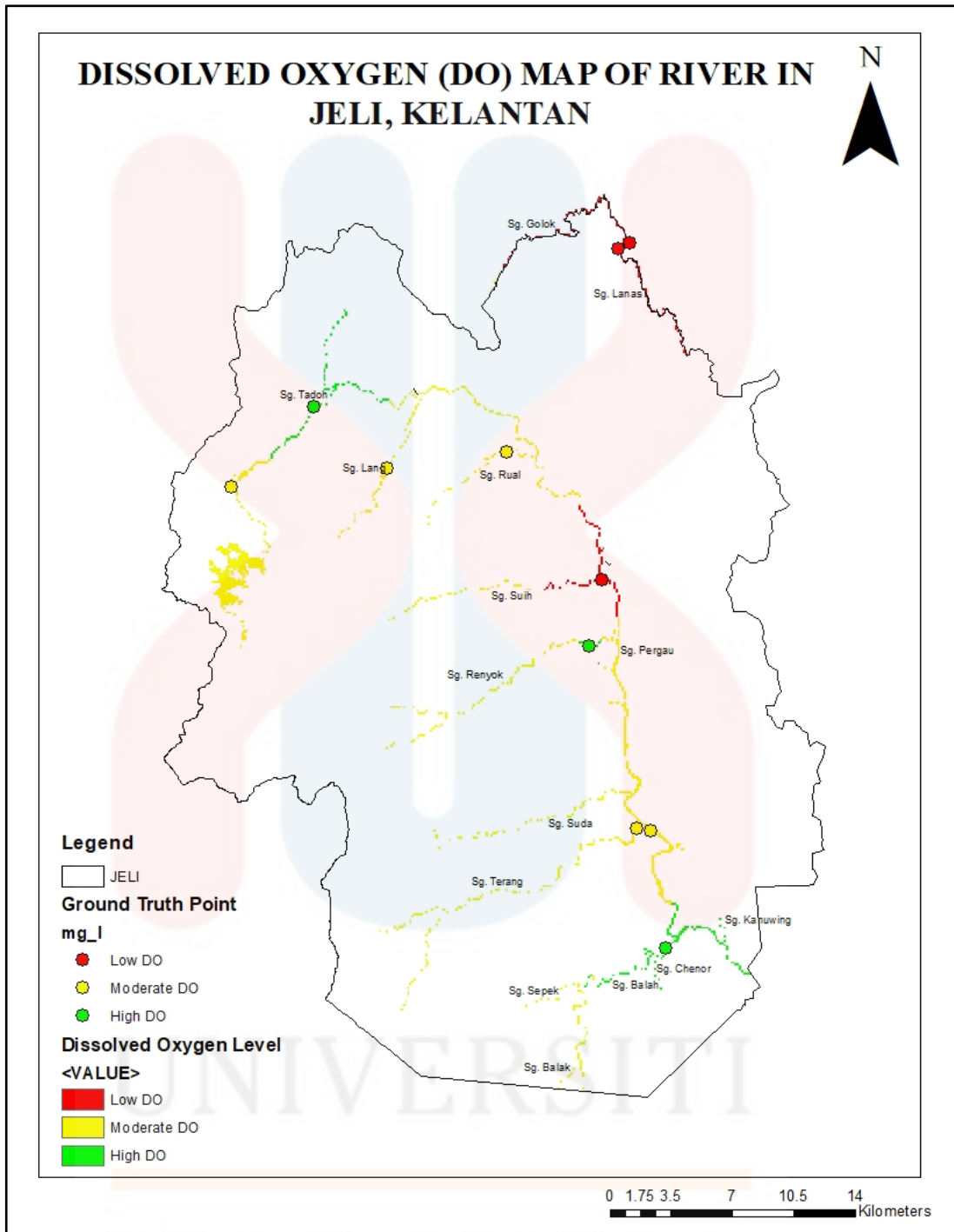


Figure 4.6: Dissolved Oxygen (DO) Map of River in Jeli, Kelantan

All of the recorded data fall into class I which its DO level is more than 7 mg/l, but for easier decision making in smaller scope and area, the data range was divided to identify which area needed extra attention and focused on treatment (DOE, 2021). Kampung Chegar Bedil stays as a location with low DO level indicate by red in map. Sungai Lanas also have low DO in upper right of the map. Based on the map, most of the color is yellow which means moderate DO level recorded. Lastly, high DO is present in Sungai Balah and near the upstream of Sungai Pergau area. It is displayed green on the map.

However, all these ground truth data might have issues whether the meters have been calibrated or not. If it is inaccurately calibrated, a systematic error might occur. This issue was overcome by learning how to calibrate and have control sample. Not only that, but the readings were also recorded three times to get average data. Failure to get the reading in the middle of the river might affect the actual measurement. Shallow place was preferred to do ground truth to get easier access and safety concern. Weather also plays a crucial role in determining the record, readings after rain could be disturbed by wash off and runoff from the rainwater. It is compulsory to record the meters while facing the water current as the readings will impact the DO level if the water current is disturbed.

4.3.2 Classification Accuracy

The confusion matrix for classifying turbidity is shown in Table 4.1. Total overall accuracy of 81.82% was achieved by properly classifying 9 out of the 11 validation samples. With eight out of eleven samples properly identified, the slightly turbidity class showed the best agreement with ground truth data. The accuracies for this class were 89% for both the producer and the user, demonstrating good performance in identifying and representing slightly turbid conditions.

Table 4.1: Classification Accuracy for turbidity compared with NDTI

		Predicted			Total
		High Turbidity	Fairly Turbidity	Slightly Turbidity	
Actual	High Turbidity	1	0	0	1
	Fairly Turbidity	0	0	1	1
	Slightly Turbidity	0	1	8	9
	Total	1	1	9	11

The fairly turbidity class, on the other hand, was not well identified. The only sample in this category had a 0% accuracy rate across producers and users due to its incorrect classification as fairly turbid. This implies that, in this instance, the NDTI index would not be able to differentiate between reasonable turbidity circumstances, perhaps as a result of spectral similarity or a lack of ground truth samples to adequately represent the variability within this category. Similar difficulties distinguishing between intermediate water quality levels because of overlapping reflectance readings have been noted in earlier research (Jensen, 2015).

Despite being based on a single data, the high turbidity class demonstrated excellent categorization, with 100% accuracy for both producers and users. Although the results are encouraging, it should be taken cautiously because of the small sample size, which restricts the possibility of generalization (Congalton & Green, 2019). Future classifications would be accurate if there were more field samples, especially in underrepresented groups.

Table 4.2: Accuracy percentage for each turbidity class

	User's accuracy (%)	Producer's accuracy (%)
High Turbidity	100	100
Fairly Turbidity	0	0
Slightly Turbidity	89	89

With 8 out of 11 samples properly identified, the overall accuracy for DO classification using NDCI in Table 4.3 was 72.70%. With a producer accuracy of 100% and a user accuracy of 71.43%, the moderate DO class performed the best, which suggests that moderate DO levels were accurately identified and sufficiently represented in the classification model.

The producer's accuracy was only 66.67%, suggesting that one sample was incorrectly classified as high DO. In contrast, the low DO class had 100% user accuracy, implying that all pixels labeled as low DO were in fact right. Reflectance may be affected by external environmental variables like sedimentation or the presence of algae, or it may be the result of overlapping spectral signals between high and low DO regions (Brezonik et al., 2015).

Table 4.3: Classification Accuracy for DO level compared with NDCI

		Predicted			Total
		High	Moderate	Low	
Actual	High	1	2	0	3
	Moderate	0	5	0	5
	Low	1	0	2	3
	Total	2	7	2	11

The categorization performance of the high DO class was comparatively poor, with a producer accuracy of 33.33% and a user accuracy of 50%. The result misrepresented this class, since two of the three real high DO samples were mistakenly categorized as moderate. The effect of ambient noise, the short sample size, or restrictions in the NDCI's spectral sensitivity for differentiating greater DO levels might all be pointed to for this incorrect identification.

Overall, the findings show moderate to good classification performance, especially under moderate DO and somewhat turbid circumstances. Nonetheless, the decreased precision in identifying somewhat turbid and high DO classes highlights the need of an effective sampling strategy and the possible advantage of using more complex classification methods or other indices to enhance class differentiation.

Table 4.4: Accuracy percentage for each DO level class

	User's accuracy (%)	Producer's accuracy (%)
High	50	33.33
Moderate	71.43	100
Low	100	66.67

The limited sample number, particularly for high and moderate turbidity classes, and the possible subjectivity in field-based turbidity and DO classification are limitations of this accuracy evaluation. Unbalanced or small sample sizes can distort accuracy metrics and lower the validity of inferences made from them (Foody, 2002).

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In summary, this study effectively fulfilled its objectives of assessing the river ecosystem health in Jeli, Kelantan and generating a themed water quality map utilizing remote sensing and GIS techniques. The study produced precise spatial representations of water quality by using NDWI, NDTI, and NDCI and combining them with ground truth data on turbidity and DO. With overall accuracies over 70%, validates the dependability of classification, especially when it came to detecting waters that were moderate level of dissolved oxygen and slightly turbid. These findings show that river ecosystem conditions may be effectively assessed using remote sensing techniques, particularly in places with insufficient monitoring infrastructure.

By creating a thematic map that illustrated the spatial range of water quality in Jeli, Kelantan, the second objective was accomplished. The map showed that most of the river ecosystem health was in good condition, but that land use had an impact on the water quality since moderate and poor-quality zones were located close to built or recreational areas. This output offers a crucial starting point for further management and monitoring initiatives. In conclusion, the combination of GIS and remote sensing proven to be a useful and realistic method for evaluating the health of rivers and provides an adaptable method to continuously monitor ecosystems in areas like Jeli.

5.2 Recommendations

Several recommendations are made for future studies evaluating the health of river ecosystems to improve the validity and relevance of the results. First off, the geographical resolution and accuracy of water body identification may be greatly increased by using upgraded indices like the Modified Normalized Difference Water Index (MNDWI) or higher-resolution satellite datasets like Sentinel-2 (Xu, 2006). Next, seasonal monitoring is highly recommended to record changes in water quality over time, particularly during the monsoon or dry seasons, which might affect dissolved oxygen levels and turbidity. This would enable a more thorough evaluation of ecosystem dynamics all year round.

Furthermore, a more comprehensive knowledge of river health would be possible by broadening the scope of water quality metrics, such as pH, temperature, and the presence of macroinvertebrates, by integrating physical, chemical, and biological indicators. The reliability of the data and classification accuracy of the results would also be improved by expanding the number of ground truth sampling sites and making sure that each categorized category is fairly represented. Finally, by identifying possible sources of contamination and understanding the consequences of nearby human activities, incorporating land use data into GIS analysis can improve the interpretation of water quality trends. These recommendations are intended to improve decision-making in river ecosystem protection and management, as well as the methodological quality of future research.

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APPENDIX A

This is the data collected from ground truth turbidity then compared with value from NDTI.

ID	Longitude	Latitude	Turbidity (NTU)	Class			Class_rs
Sungai Lanas (besar)	101.889655	5.784757	31.8	Fairly turbidity	moderate	0.649517	low
Sungai Lanas	101.895116	5.787581	5.437	slightly turbidity	low	0.543802	low
Sungai Balah	101.914595	5.424873	4.48	slightly turbidity	low	0.458124	low
Sungai Terang	101.899621	5.486566	5.66	slightly turbidity	low	0.294463	moderate
Sungai Pergau	101.906454	5.485344	14.2	slightly turbidity	low	0.620639	low
Sungai Pergau (Chegar Bedil)	101.881104	5.614307	69.97	High turbidity	high	0.35169	high
Sungai Pergau (Lata Turbo)	101.690878	5.661785	4.053	slightly turbidity	low	0.663562	low
Sungai Pergau (balai polis)	101.733257	5.703182	3.89	slightly turbidity	low	0.438492	low
Sungai Long (Lata Janggut)	101.770597	5.671618	6.33	slightly turbidity	low	0.528524	low
Sungai Rual (Lata Goleng Jambatan)	101.832042	5.680097	5.18	slightly turbidity	low	0.492659	low
Sungai Renyok (Lata Renyok)	101.874875	5.580111	4.913	slightly turbidity	low	0.387832	low

This is the data collected from ground truth dissolved oxygen then compared with value from NDCI.

ID	Longitude	Latitude	mg/l	Class		Actual class
Sungai lanas (besar)	101.889655	5.784757	8.26	low	0.696566	low
Sungai lanas	101.895116	5.787581	8.17	low	0.820923	low
Sungai balah	101.914595	5.424873	8.57	high	0.359708	high
Sungai terang	101.899621	5.486566	8.48	moderate	0.666808	moderate
Sungai pergau	101.906454	5.485344	8.31	low	0.414698	high
Sungai pergau (chegar bedil)	101.881104	5.614307	8.11	moderate	0.550383	moderate
Sungai pergau (lata turbo)	101.690878	5.661785	8.4	moderate	0.668752	moderate
Sungai pergau (balai polis)	101.733257	5.703182	8.73	high	0.562993	moderate
Sungai long (lata janggut)	101.770597	5.671618	8.37	moderate	0.558261	moderate
Sungai rual (lata goleng jambatan)	101.832042	5.680097	8.44	moderate	0.6606	moderate
Sungai renyok (lata renyok)	101.874875	5.580111	8.52	high	0.602838	moderate

APPENDIX B



These are some sampling times to collect ground truth data of turbidity and dissolved oxygen.

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APPENDIX C

ASSESSING RIVER ECOSYSTEM HEALTH USING REMOTE SENSING AND GIS TECHNIQUES: A CASE STUDY IN JELI, KELANTAN

AINAA NABILA BINTI AZIMIN (E22A0008)
SUPERVISOR: GS. TS. DR. SHAPARAS BINTI DALIMAN

RIVER ECOSYSTEM

- Services**
 - Aquatic species' habitat
 - Water Supply
 - Recreation
- Human Impact**
 - Agriculture
 - Pollution
 - Increasing tourism
- Monitoring**
 - Large scale
 - Detect changes

Lack baseline data related to river ecosystem health in Jeli

- To evaluate the current health status of the river ecosystem in Jeli, Kelantan.
- To develop a thematic map of water quality for the rivers in Jeli, Kelantan using remote sensing and GIS techniques.

SCOPE OF STUDY

Use Landsat 8

Chemical characteristics

- DO
- turbidity

River in Jeli, Kelantan

SIGNIFICANT OF STUDY

- Provide Data
- Targeted Management
- Ecosystem Conservation

- River Ecosystem Health**
 - Ability of a river system to recover from disturbances
 - Maintain its ecological functions
 - Sustain the services it provides (Rapport et al, 1999)
- NDWI**
 - Detects water bodies from satellite images (Geo, 1996)
- NDTI**
 - Measures turbidity using red and green light bands (Locaux et al., 2007)
- NDCI**
 - Estimates chlorophyll-a to reflect DO levels (Mishra & Mishra, 2012)

METHODS

- Landsat 8 data (April 2024) was collected
- Map processing in ArcGIS, ENVI and GEE
- Collect data for ground truth
- Turbidity and DO level
- Accuracy Assessment: Confusion Matrix
- Overall Accuracy

NDWI

- Green & NIR bands
- Higher NDWI = deeper water
- Pergau Lake deeper water
- Effective for outlining rivers (Xu, 2006)

$$NDWI = \frac{(B3 - B5)}{(B3 + B5)}$$

NDTI

- Red & Green reflectance
- High NDTI = high turbidity
- Pollution linked to agriculture & tourism (Dilotta & Brazier, 2008)

$$NDTI = \frac{(B4 - B3)}{(B4 + B3)}$$

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NDCI

- Red & NIR bands
- High NDCI = high chlorophyll, low DO
- Indicates eutrophication (Mishra & Mishra, 2012)

$$NDCI = \frac{(B5 - B4)}{(B5 + B4)}$$

JELI'S RIVER ECOSYSTEM HEALTH

- Combined NDWI, NDTI, NDCI
- Thresholds: natural breaks + ground truth comparison

WATER QUALITY MAP OF RIVER IN JELI, KELANTAN

TURBIDITY MAP OF RIVER IN JELI, KELANTAN

DISSOLVED OXYGEN (DO) MAP OF RIVER IN JELI, KELANTAN

ACCURACY ASSESSMENT

Accuracy of NDTI vs. Turbidity Comparison

Overall Accuracy of NDCI vs. DO Comparison

CONCLUSION

Remote sensing and GIS
successfully assess river ecosystem health

Indexes and data
NDWI, NDTI, and NDCI were combined with ground truth data (turbidity & DO).

Classification accuracy
Over 70% overall classification accuracy was achieved

Water quality map
A thematic water quality map was produced, showing the spatial distribution of ecosystem health.

Ecosystem condition
Most areas are in good condition, while moderate-poor zones are linked to nearby land use.

RECOMMENDATION

Sentinel 2 Data

- Higher resolution

Expand Sampling

- Increase ground truth site
- Longer time
- Correlate with Land Use

Increase Parameter

- pH
- Biological characteristics
- Chemical characteristics

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THANK YOU

These are the slides that are used for viva presentations.