

Spectroscopy

by Guntur Pamungkas

Submission date: 30-May-2024 11:57AM (UTC+0700)

Submission ID: 2009434400

File name: 30052024_Geoplanning_Guntur_et_al_Spectroscopy_1.docx (4.89M)

Word count: 5619

Character count: 33186

Land Cover Classification of Indonesian Archipelago Using Digital Spectroscopy

Keywords:

Spectroscopy, remote sensing, project-based learning

*Corresponding author(s) email: gunturbagus1@ecampus.ut.ac.id

Guntur Bagus Pamungkas^{1*}, Muhammad Reffi Firmansyah¹, Ratna Sari¹, Anindya Putri Tamara², Rahadian Zainul³

1. Urban and Regional Planning, Universitas Terbuka, Indonesia
2. Urban and Regional Planning, Universitas Semarang, Indonesia
3. Chemistry, Universitas Negeri Padang, Indonesia

DOI: 10.14710/geoplanning.8.1.pp-pp

Abstract

In the context of urban and regional planning, this study aims to produce land classification products covering 230 pathrows throughout Indonesia, which can be an important tool in supporting planning and research projects. The research method used combines remote sensing in Geographic Information Systems (GIS) with the utilization of spectroscopy through QGIS software with dzetsaka plugins (semi-automatic classification tools). Land cover classifications that include water bodies, vegetation canopies, green open spaces, vacant land, settlements, and built-up areas, as well as additional classifications of cloud cover, provide a comprehensive overview of land conditions in Indonesia. The results of this classification are then verified through field observation surveys to ensure their accuracy and validity. The output of this research is a land classification product that can be used as an important tool in project-based learning and planning studio courses. With target users that include students, practitioners, and academics, this product can be an invaluable support in land cover analysis for various research and planning projects in various fields. In addition, this study offers a more potential alternative in using Landsat 8 OLI 2022 satellite imagery data from the USGS as a basis for a more in-depth and accurate analysis of land classification. Thus, the results of this study not only contribute to mapping and understanding land use in Indonesia but also provide useful tools in supporting natural resource planning and management as well as infrastructure development and sustainable development policies in Indonesia.

5
Copyright © 2021 GJGP-Undip

This open access article is distributed under a Creative Commons Attribution (CC-BY-NC-SA) 4.0 International license

1. Introduction

In an era of globalization characterized by rapid technological development, global issues such as climate change, rapid urbanization, and environmental degradation are becoming increasingly important to address within the context of regional and urban planning (Stevanović et al., 2023). Land cover change plays a crucial role in addressing these issues because it directly affects land use, environmental quality, and community welfare (Bongasie et al., 2024). For example, the conversion of green land to urban areas can increase local temperatures and reduce air quality, while deforestation exacerbates the effects of climate change and reduces biodiversity. Therefore, a deep understanding of geospatial conditions and land cover is essential to formulate effective and sustainable policies. The use of accurate and up-to-date geospatial data, such as satellite imagery, is essential to support comprehensive analysis in urban and regional planning, ensuring that policies can effectively address these global challenges (Wiatkowska et al., 2021).

Despite significant advancements in geospatial technologies and the availability of various data sources, a critical gap exists in the accessibility and resolution of geospatial data needed for detailed regional and urban planning (Yu & Fang, 2023). High-resolution data is often required to capture the complexities of land cover and land use changes accurately. However, many existing datasets either lack the necessary detail or are not readily

accessible, posing a significant challenge for researchers, planners, and students engaged in planning studios (Buchori, 2007). Geospatial-based data, such as satellite imagery, land use maps, and building density maps, are critical to support urban and regional planning analysis. Spatial data forms the basis for establishing a spatial database system to produce geospatial information beneficial to government and society (Meidodga et al., 2023).

One area that receives special attention in this context is geomatics, a multidisciplinary discipline that integrates geospatial technologies for the analysis and mapping of territories. Geomatics utilizes geospatial-based data or data that has a specific coordinate system within a region or city (Padmini et al., 2023). Despite the availability of applications, including those developed by ESRI, that provide land cover data, there is criticism regarding the level of detail these applications offer, particularly for complex regional mapping. For example, applications using Sentinel-2 data with an accuracy of 10 meters still fall short in providing the high-resolution data needed for detailed analysis (Polyakova et al., 2023; Vanderhoof et al., 2023).

To address this gap, this study proposes using Landsat 8 OLI satellite imagery data from 2022 as a more suitable alternative. Landsat 8 OLI has proven to have adequate accuracy in remote sensing, especially in classifying land in the Indonesian region from Sabang to Merauke, and even on a global scale (Sitinjak et al., 2023). This study aims to evaluate the effectiveness of Landsat 8 OLI in providing the higher-resolution data necessary for detailed and accurate land cover analysis in Indonesia. By addressing the current limitations in data resolution and accessibility, this research seeks to enhance the precision of geospatial analyses and support the development of more effective and sustainable regional and urban planning policies. Sp. ETS

Moreover, integrating spectroscopy technology with urban and regional planning offers a novel approach to overcoming these data challenges. Spectroscopy, which involves the measurement of the interaction between light and matter, can provide detailed information about the composition and properties of various materials, including soil, vegetation, and urban surfaces. By incorporating spectroscopic data, planners can achieve a more nuanced understanding of land cover and land use changes. Spectroscopy can enhance the detection of pollutants, assess soil health, and monitor vegetation stress, thereby offering critical insights into environmental quality and sustainability (Wang et al., 2024).

The application of spectroscopic techniques in conjunction with satellite imagery can significantly improve the accuracy of geospatial analyses. For instance, hyperspectral imaging, which captures a wide spectrum of light across numerous bands, can identify specific materials and their conditions more precisely than traditional multispectral imaging. This capability is particularly valuable in urban areas where diverse materials and land covers coexist nearby. By integrating hyperspectral data with Landsat 8 OLI imagery, planners can refine their analyses, leading to more targeted and effective policy interventions (Li et al., 2023).

Furthermore, the synergy between geospatial data and spectroscopic analysis can enhance predictive modeling in urban and regional planning. By utilizing machine learning algorithms, planners can predict future land cover changes and assess their potential impacts on urban environments. This predictive capability is crucial for proactive planning and sustainable development, allowing planners to anticipate and mitigate adverse effects before they manifest (Srivastava & Maity, 2023).

In the context of Indonesia, where diverse ecological and urban challenges exist, the integration of spectroscopy and geospatial technologies can provide a robust framework for addressing these issues. Indonesia's varied landscapes, from dense urban centers to remote forested areas, require detailed and accurate data to inform planning decisions. The use of Landsat 8 OLI, supplemented with spectroscopic data, can offer a comprehensive view of land cover dynamics across the country. This integrated approach can support efforts to combat deforestation, manage urban sprawl, and protect biodiversity, aligning with national and global sustainability goals (Sitinjak et al., 2023).

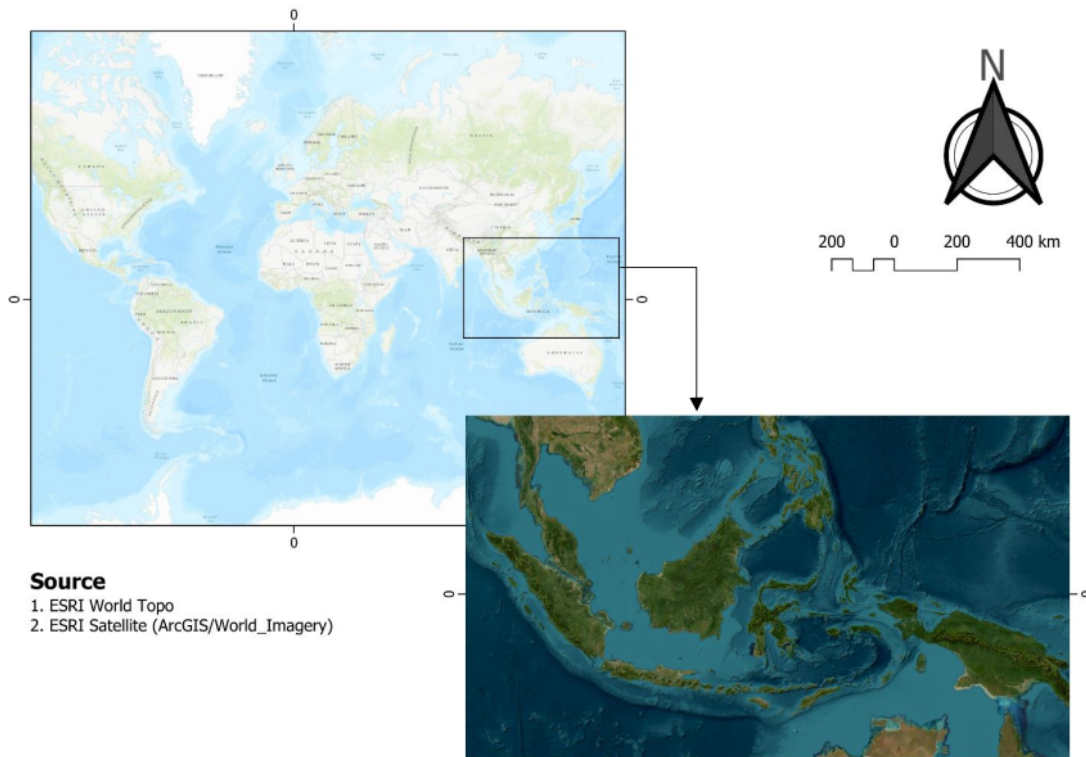
In conclusion, this study proposes a novel methodology that combines Landsat 8 OLI satellite imagery with spectroscopic analysis to enhance geospatial data resolution and accessibility for urban and regional planning in Indonesia. By leveraging the strengths of both technologies, this approach aims to fill existing data

gaps, improve the precision of land cover analyses, and support the development of effective and sustainable planning policies. This integrated framework not only addresses current challenges but also provides a scalable solution that can be applied to other regions facing similar issues. Through this research, we aim to contribute to the advancement of geospatial science and its application in urban and regional planning, ultimately fostering more resilient and sustainable urban environments.

2. Data and Methods

2.1. Study Area

This research was conducted on a very wide and diverse area, namely the entire archipelago of the Republic of Indonesia, consisting of thousands of islands with various geographical, climatic, and ecosystem characteristics (Nunn et al., 2024). Indonesia is the largest archipelagic country in the world, consisting of five large islands namely Sumatra, Kalimantan, Sulawesi, Papua, and Java, as well as thousands of small islands scattered between the Indian Ocean and the Pacific Ocean (Adnan, 2023; Simarmata et al., 2023). This study area covers 230 pathrows of Landsat 8 OLI imagery tracks covering the entire land area of Indonesia, from the western border of Aceh to the eastern border of Papua.



Source: Researcher, 2024

Figure 1. Study Area in the Indonesian Archipelago

The research area in Figure 1 covers a wide range of ecosystems, including dense tropical rainforests, dense urban areas, large tracts of agricultural land, and coastal and marine areas rich in biodiversity (Dong,

2024). This diversity reflects a complex and diverse variety of land uses, which include water bodies, vegetation canopies, green open spaces, vacant land, settlements, and built-up areas. Each of these classes has different characteristics and requires a specific classification approach to obtain accurate results.

The study also considered geospatial factors affecting land classification, such as diverse topography ranging from high mountains to lowlands, as well as significant climate variability from island to island (Tenorio et al., 2023). This research uses satellite imagery with cutting-edge technology and sophisticated GIS software to process this large-scale data, address technical challenges such as high cloud cover, and ensure that land classification results can be used to support better planning and management of natural resources in Indonesia. With such a broad scope and detail, this research makes a significant contribution to mapping and understanding land use in Indonesia, which is important for a wide range of scientific and practical applications.

2.2. Spectroscopy

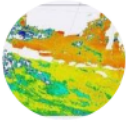

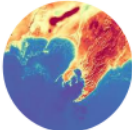

Spectroscopy can be defined simply as the science of matter and its properties through the analysis of radiant energy, sound, and particles absorbed, emitted, or dispersed by observed substances. The science of spectroscopy has expanded to a wide range of electromagnetic spectra, from short-wavelength X-rays to long-wavelength microwaves (Mikheyev & Korzhimantov, 2023). Spectroscopy is generally a science that can detect changes in soil quality, and crop cover, and can predict soil classification based on various land use categories (Delcourt et al., 2023). This science studies the interaction of energy in the form of electromagnetic radiation with materials. This radiation interaction is a function of the wavelengths reflected (reflection), absorbed (emission), or emitted (scattered) by the material (Hede & Heriawan, 2020). The application of spectroscopy in remote sensing is associated with reflectance and hyperspectral imaging, which have shown accuracy in obtaining mineralogical information in inaccessible or remote areas, or in situations where such information is difficult to obtain through alternative exploration methods (Falcioni et al., 2023). The spectroscopic method is highly efficient as a fast, reproducible, and relatively inexpensive method in remote sensing (Levi et al., 2022).

Spectroscopic techniques use electromagnetic waves with wavelengths visible to near-infrared (VNIR) 350–1,300 nm, short infrared (Shortwave Infrared / SWIR) 1,300–2,500 nm, and Long-Wave Infrared (LWIR) 8,000–14,000 nm (Hede et al., 2019). Most multi-spectral and hyperspectral optical sensor imagery belongs to the VNIR-SWIR spectrum, and reflectance information can be obtained from the digital amount of satellite imagery so spectroscopic imaging is currently evolving along with the development of optical sensor satellite imagery. Because reflectance data in the VNIR-SWIR range have been established for more than three decades for a wide range of geological mapping applications, they are widely used in terrestrial and space research and are considered an accurate technique. With a variety of optical sensor images planned or developed, including images from Landsat 8, Sentinel-2, Hyperion, and EnMAP (Hede & Heriawan, 2020). In Pedrotti (2008) spectroscopy is divided into 3 (three) general types of spectroscopy, namely absorption spectroscopy, emission spectroscopy, and scattering spectroscopy. In this study, a commonly used type is scattering spectroscopy which in theory scattering or reflection spectroscopy identifies the observed characteristics emitted through the analysis of the energy dispersed by the object. The scattering process is much faster than absorption and emission spectroscopy. So it can be understood as a function of the wavelength/frequency and polarization of electromagnetic radiation that appears. Scattering spectroscopy is of great interest in exploring the characteristics of swamps, forests, and vegetation that in the process continuously return sunlight to the atmosphere.

2.3. Remote Sensing

In essence, mapping requires a fairly long process both from the aspect of observation in the field and using geospatial technology. One technology that is often used is related to remote sensing. In fact, since 1972, NASA released satellite imagery data with the first Landsat model, Landsat-1 (Wulder et al., 2022; Crawford et al., 2023). Please note that Remote Sensing has several components and types as shown in Table 1.

Table 1. Satellite Imagery Data Types for Remote Sensing Surveys

No	Name	Type	Model	Temporal Resolution	Spatial Resolution	Spectral Resolution	Cost	Source
1.	Modis	✓ ✓	Terra Aqua 	Every 1-2 Days	✓ 250 m ✓ 500 m ✓ 1000 m	36 Band	Free	NOAA
2.	Sentinel	✓ ✓ ✓ ✓	1A, 1B 2A, 2B 3A 4A 	Every 5 Days	✓ 10 m ✓ 20 m ✓ 60 m	13 Band	Free	ESA
3.	Landsat	✓ ✓ ✓	5 TM 7ETM + 8/9 OLI 	Every 16 Days	✓ 15 m ✓ 300 m	7 Band (5 TM) 8 Band (7 ETM+) 11 Band (8/9 OLI)	Free	USGS
4.	Pleiades, Quickbird, Spot 6/7, Rapid Eye	Resolusi tertingg Sp. ETS Sp. ETS Sp. ETS		Everyday	5 m	5 Bands	At Cost	NASA LAPAN

2.4. Project-based Learning

In the context of the Urban and Regional Planning Study Program, Project-Based Learning (PBL) or Studio Planning has a central role in shaping students' skills and knowledge. PBL is defined as a learning approach that provides practical experience through projects or case studies, creating an environment that allows direct integration between theory and practice. According to Safithri, Syaiful, & Huda (2021), PBL can be one solution to support students' problem-solving abilities.

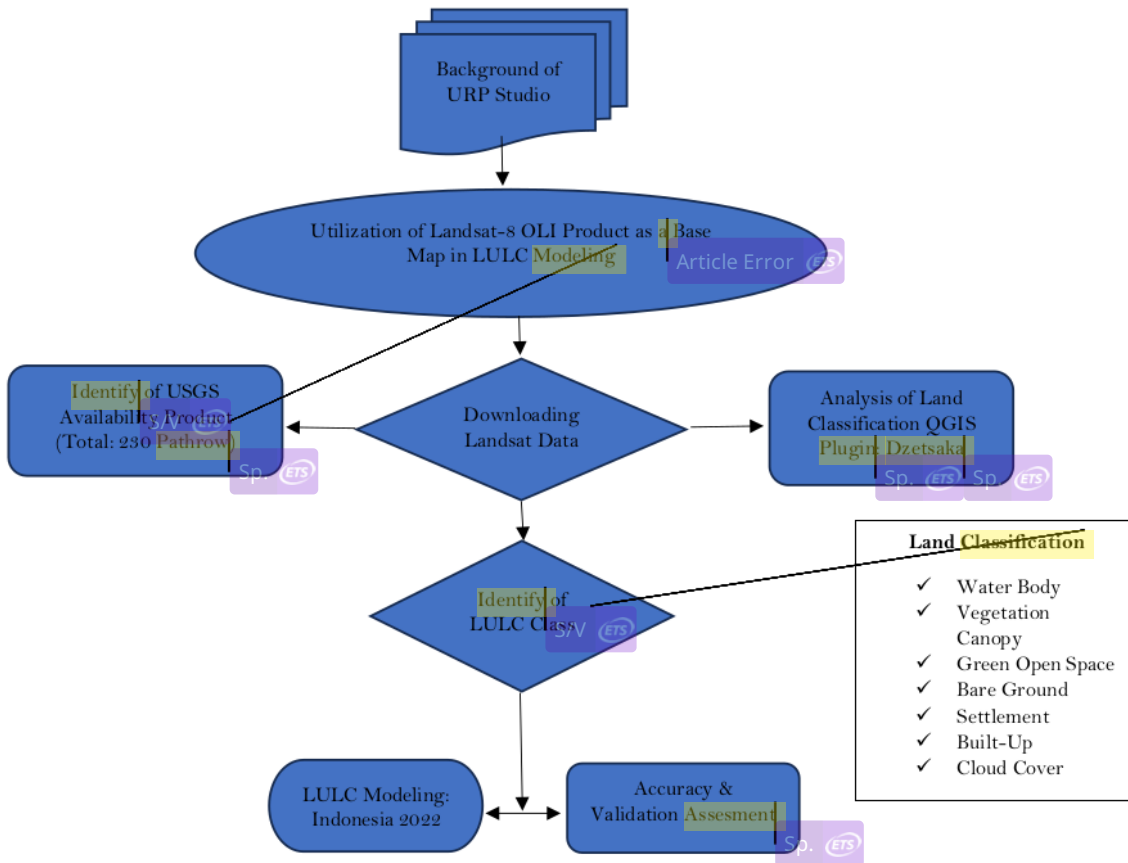
PBL emphasizes active and collaborative learning, focusing on solving real-world problems. In planning studios, PBL includes the use of real projects that reflect the complexity of challenges in urban and regional planning. PBL aims to develop student's analytical, creative, and problem-solving skills. According to Nguyen et al (2024), this approach can improve concept understanding, research skills, and the ability to communicate and work together in teams. PBL also creates a direct link between academic theory and real-world situations. According to Swandi, et al., (2021), there is a Gold Standard PBL method that is implemented through 7 steps, namely (1) Problem or Question Challenge, (2) Continuous Study, (3) Authenticity Test, (4) Student Role, (5) Reflection, (6) Criticism and Revision, (7) Product Publication.

The implementation of PBL in the planning studio involves several stages, including project identification, problem formulation, planning, implementation, and evaluation. Students work in groups to develop planning solutions that can be implemented in the field. In the digital age, technology integration is an important aspect of PBL. The use of planning and GIS software can increase efficiency in spatial data analysis, modeling, and presenting project outcomes. Although PBL has many benefits, some challenges arise, such as time management, group dynamics, and project sustainability. Effective strategies include active lecturer mentoring, collaborative mentoring, and structured reflection. Case studies of PBL implementation in the Urban and Regional Planning Study Program show an increase in student understanding of the complexity of planning problems (Ayerbe-

López & Perales-Palacios, 2023). These projects also make a real contribution to the development of the region and the city.

PBL or Studio Planning in the Urban and Regional Planning Study Program is a very effective learning approach to prepare students to face real-world challenges. PBL encourages understanding of concepts, practical skills, and professional attitudes, creating graduates who are ready to contribute to the planning and development of regions and cities.

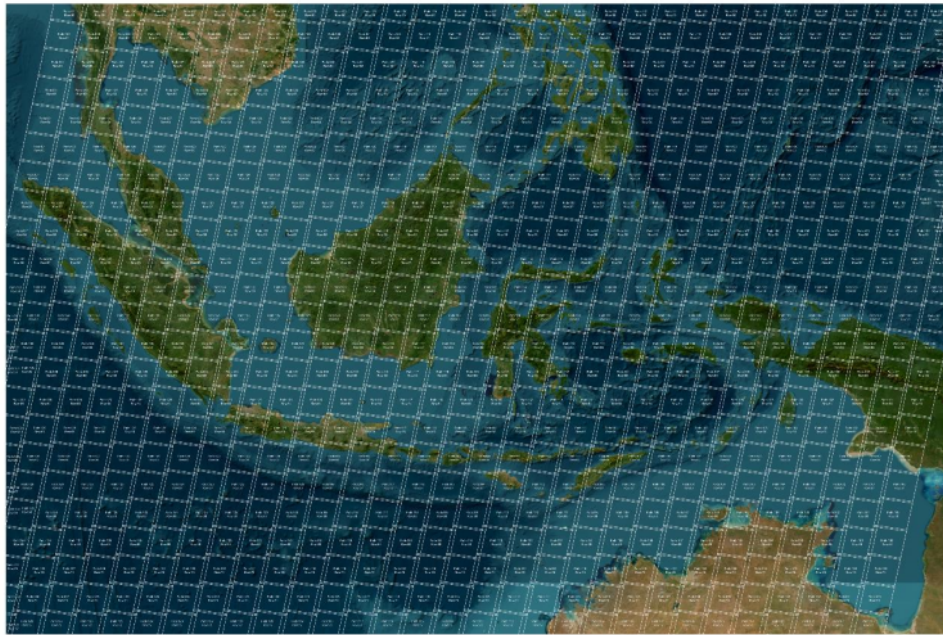
2.5. Methodology



Source: Researcher, 2024

Figure 2. Research Framework

In Figure 2, The method used in this study is a remote sensing survey by obtaining Landsat-8 OLI satellite image data where this data is a USGS product that has high accuracy in terms of land classification. The visualization provided by this image cannot be separated from the combination of bands as a diverse coloring source often called multispectral (Carrasco et al., 2019). He also does not deny that the Landsat-8 OLI data acquisition technique uses the term pathrow (Ferdous et al., 2019). For the pathrow, Indonesia's coverage from Sabang to Merauke has been listed in Figure 3 and Table 2.



Source: Researcher, 2024

Figure 3. Pathrow Concept for Landsat 8 OLI Data Acquisition

Table 1. Pathrow of Province in Indonesia

No.	Province	Path/Row
1.	Aceh Darussalam (NAD)	131-130/56
		131-129/57
		131-129/58
2.	North Sumatra	129/57-60
		128/58-60
3.	West Sumatra	128/59-61
		127/60-62
4.	Riau	128/58-59
		127/58-60
		126/59-61
5.	West Sumatra	125/60-61
		128/59-61
		127/60-62
6.	Bengkulu	126/62
		125/64-62
		124/63
7.	Jambi	126-125/61
		126-125/62
8.	South Sumatra	126/62
		125/61-62
		124/63-61
		123/62-63

No.	Province	Path/Row
9.	Riau Islands	125/59-60 124/60
10.	Bangka Belitung	124/61 123/61-62 122/62
11.	Lampung	124-123/63 124-123/64
12.	West Kalimantan	122-119/59 122-119/60 122-120/61 121-120/62
13.	Central Kalimantan	120/60-62 119/60-62 118/60-62 117/61
14.	North Kalimantan – East Kalimantan	118/60-57 117/62-57 116/61-58
15.	Banten	122-123/65 122-123/64
16.	Jakarta	122/64
17.	West Java	122-121/65 122-121/64
18.	Central Java	121-119/65 119/66
19.	Special Region of Yogyakarta	120/65 119/66
20.	East Java	119-117/66 119-117/65
21.	North Sulawesi	113/59 112/58-59 111/59
22.	Gorontalo	114-113/59 114-112/60
23.	Central Sulawesi	113-115/59 113-115/60 112-115/61 113/62
24.	West Sulawesi	115/61-62 114/61-62
25.	South Sulawesi	113/64-65 114/61-64 113/62
26.	Southeast Sulawesi	113/62-64 112/63-64 111/64
27.	Bali	117/66 116/66
28.	West Nusa Tenggara	116/66 115/66 114/66
29.	East Nusa Tenggara	114/66

No.	Province	Path/Row
		113/66
		112/66
		111/66
		110/66
30.	North Maluku	111/61
		110/58-63
		109/58-63
31.	Maluku	110/65
		109/65-66
		109/62-63
		108/62, 65, 66
		107/62, 63, 65, 66
		106/63-66
		105/64
		104/64-65
32.	West Papua	108/60-61
		107/60-62
		106/60-63
		105/61-63
33.	Papua	105/62
		104/61-63
		103/61-63
		102/62
34.	East Papua	102/61-66
		101/62-66
		100/63-66

For analysis techniques use the dzetsaka plugin (Classification Tool) that is available in QGIS (Sejati et al., 2019). Previously, the acquired Landsat-8 OLI satellite imagery combined multiple bands (1-7) to generate a Virtual Map of the area corresponding to the **pathrow**. Then the visualization result is changed according to the rules of composite coloring. Figure 4 below is a combination of ribbon (4, 3, 1) with **pathrow** Region (113/66).



Source: Researcher, 2024

Figure 4. One of the base maps of Landsat 8 OLI, Band Combination 4, 3, 1, Path-113/Row-066

3. Result and Discussion

Spectroscopy is one of the most important analytical methods in chemistry and physics, involving the measurement of the interaction between matter and electromagnetic radiation (Prasad et al., 2024). The spectroscopic procedure, although it varies depending on the type of spectroscopy used (e.g., UV-Vis spectroscopy, infrared (IR), or nuclear magnetic resonance (NMR)), essentially involves several main stages. First, sample preparation is carried out to ensure that the sample is in suitable conditions for analysis. In UV-Vis spectroscopy, the sample is usually a clear solution, whereas in IR spectroscopy, the sample can be a solid, liquid, or gas placed in a specialized cell.

The second stage is sample irradiation, in which the sample is subjected to electromagnetic radiation at a specific wavelength. In UV-Vis spectroscopy, ultraviolet radiation or visible light is used, while in IR spectroscopy, infrared radiation is applied. Next, the detector measures the radiation emitted or absorbed by the sample, and this data is processed to produce a spectrum. This spectrum is a visual representation of the interaction between radiation and the sample, showing characteristic peaks related to electron transition energy or molecular vibration (Kuttruff et al., 2023).

Analysis of spectral data is the final and critical stage in the spectroscopic procedure. These data are analyzed to determine the chemical or physical characteristics of the sample, such as the identification of functional groups in molecules, molecular structure, or concentration of components in mixtures (Karpukhina et al., 2023). For example, in IR spectroscopy, peaks in the spectrum may indicate the presence of functional groups

such as hydroxyl (-OH) or carbonyl (C=O), which provide important information about the molecular structure of the sample.

In a recent study, spectroscopy-based image processing technology was applied to land classification using Landsat 8 OLI imagery with acquisition in 2022 (Manetu et al., 2023; Yuan et al., 2023). The use of GIS (Geographic Information System) software with the dzetsaka plugin, a semi-automatic classification tool, allows for more accurate and detailed visualization of land classification. The research resulted in the classification of land into seven main classes: water bodies, vegetation canopy, green open spaces, vacant land, settlements, built-ups (buildings), and cloud cover. The Landsat 8 OLI imagery used covers the entire archipelago of the Republic of Indonesia, consisting of 230 pathrows, allowing comprehensive and extensive analysis.

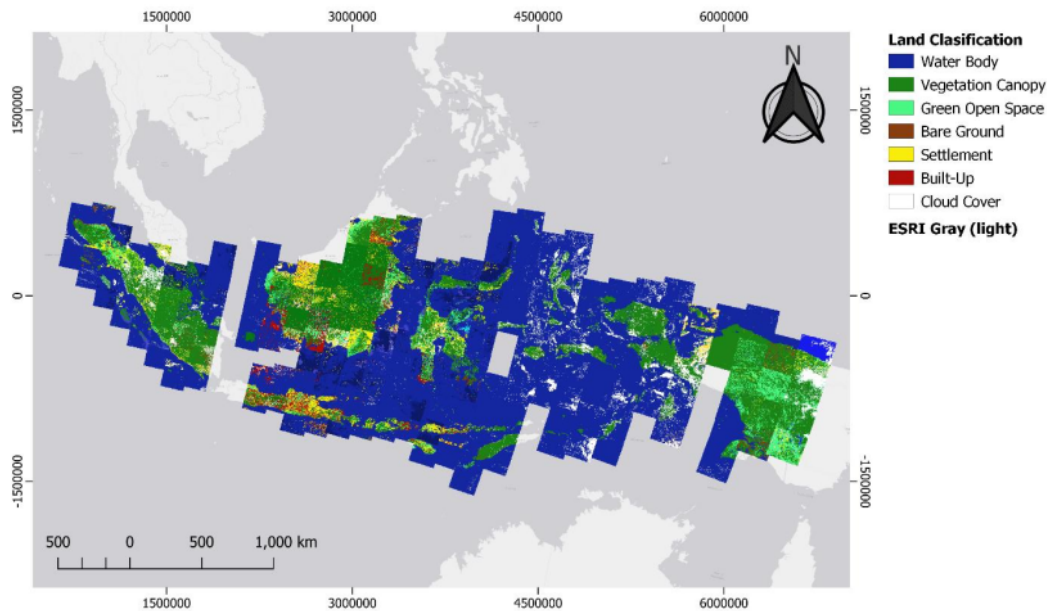
The advantage of the GIS method with the dzetsaka plugin compared to other methods lies in several aspects. First, the accuracy and detail of the resulting classification are very high, allowing clear identification of different types of land use. Secondly, this method allows a very wide scope of analysis, which is difficult to achieve with traditional methods. For example, manual analysis of land use for the entire territory of Indonesia would take enormous time and resources. Third, efficiency is another advantage of this method. The use of GIS software and semi-automated plugins speeds up the analysis process, saving valuable time and resources.

This method has an important role in planning science. Accurate information about land use is essential for urban planning, infrastructure development, and natural resource management (Kalfas et al., 2023). For example, by knowing the distribution and extent of green open space areas, governments and urban planners can design strategies to improve the quality of the environment and public health. Environmental monitoring is also one of the main benefits of this method. Changes in land use, such as deforestation or urbanization, can be monitored in real-time, enabling faster and more effective prevention or mitigation actions (Singh et al., 2022).

Data-driven decision-making in spatial planning, disaster mitigation, and development planning becomes easier with this method (Carramiñana et al., 2024). Data generated from land classification can be used to identify disaster-prone areas, such as floods or landslides, and plan for safer and more sustainable infrastructure development. In addition, this information is also important in environmental conservation efforts and natural resource management, ensuring that the development carried out does not damage the existing ecosystem.

In further discussion with related articles, this study describes the use of Landsat 8 OLI imagery and GIS software with the dzetsaka plugin for land classification throughout the archipelago of the Republic of Indonesia. The classification results shown in Figure 5 of the study provide a clear and comprehensive visualization of land use in the region. This provides invaluable information for a wide range of resource planning and management applications.

Overall, spectroscopic methods and GIS-based image processing technologies provide many advantages in accurate and efficient data analysis (Shaikh & Birajdar, 2024). With the ability to provide detailed information about the chemical and physical characteristics of samples, as well as land use on a large scale, the method plays an important role in research and practical applications. The application of this technology in land classification research shows how accurate and detailed data can be used to support better planning and more effective decision-making (Abdelkarim, 2023). It emphasizes the importance of technology in obtaining and analyzing data efficiently and accurately, as well as its application in various fields to improve the quality of life and environmental sustainability.



Source: Researcher, 2024

Figure 5. Results of Spectroscopic Analysis with GIS, Scope of All Islands in the Republic of Indonesia.

4. Conclusion

Research on land classification modeling using Landsat 8 OLI imagery across the archipelago of the Republic of Indonesia has produced maps covering seven main classes: water bodies, vegetation canopy, green open spaces, vacant land, settlements, built-ups (buildings), and cloud cover. Although the method of using GIS software with the dzetsaka plugins allows accurate and detailed visualization, there are some obstacles faced, especially the presence of clouds that interfere with the visibility of satellite imagery. This causes some areas not to be classified properly because the surface of the earth is not visible. In addition, Landsat 8 data has limitations in terms of temporal and spectral resolution, which can affect the accuracy of land classification.

To overcome this problem, further research is recommended to use cloud remover methods available in GIS software to reduce or eliminate the influence of clouds on satellite imagery. In addition, the integration of radar data, such as from the European Space Agency's (ESA) Sentinel-1, can be an effective solution because the radar can penetrate clouds and provide accurate data even if atmospheric conditions are not ideal. The use of higher-resolution satellite data, such as Sentinel-2, can also improve land classification detail and enable more frequent and accurate monitoring of land change. The development and application of more sophisticated classification algorithms, such as machine learning or deep learning, can improve classification accuracy by recognizing more complex patterns in satellite imagery data.

In addition, more extensive field validation is needed to ensure that the resulting land classification matches real conditions on the ground. This is important to increase the accuracy and confidence in the results of the study. This research provides a solid foundation for a wide range of applications, including urban planning, natural resource management, and disaster mitigation. With the improvement of methods and technology in advanced research, it is expected to make a significant contribution to the science of environmental planning and management. The use of more advanced satellite image processing technologies will strengthen the ability to monitor and manage land use change in real-time, thus supporting better and effective decision-making and ensuring sustainable and environmentally friendly development.

5. Acknowledgments

We, on behalf of the Research Team, would like to thank LPPM Universitas Terbuka for providing research grants in 2023 with No. ID. PN2022-00003845.

6. References

- Abdelkarim, A. (2023). Monitoring and forecasting of land use/land cover (LULC) in Al-Hassa Oasis, Saudi Arabia-based on the integration of the Cellular Automata (CA) and the Cellular Automata-Markov Model (CA-Markov). *Geology, Ecology, and Landscapes*, 1-32.
- Adnan, R. S. (2023). The Dynamic Role of Moslem in Building Indonesia as a Nation-State. *Indonesian Journal of Religion and Society*, 5(1), 58-69.
- Ayerbe-López, J., & Perales-Palacios, F. J. (2023). Evaluating a Secondary Education Urban Ecology Project within the Framework of a Problem-Based Learning Methodology. *Education Sciences*, 13(9), 915.
- Bongasie, A., Dhakal, T., Ayalew, A., Kim, T. S., Lee, Y., & Jang, G. S. (2024). Analysis of forest cover change and its driving factors in Senan district, Amhara Region, Ethiopia. *Environmental Monitoring and Assessment*, 196(4), 339.
- Buchori, I. (2007). *Ilmu Geomatika Perencanaan dalam Pendidikan Perencanaan Wilayah dan Kota untuk Menghadapi Tantangan Global Abstrak Pendahuluan*.
- Carramiñana, D., Bernardos, A. M., Besada, J. A., & Casar, J. R. (2024). Towards resilient cities: A hybrid simulation framework for risk mitigation through data-driven decision-making. *Simulation Modelling Practice and Theory*, 133, 102924.
- Carrasco, L., O'Neil, A. W., Daniel Morton, R., & Rowland, C. S. (2019). Evaluating combinations of temporally aggregated Sentinel-1, Sentinel-2, and Landsat 8 for land cover mapping with Google Earth Engine. *Remote Sensing*, 11(3). <https://doi.org/10.3390/rs11030288>
- Crawford, C. J., Roy, D. P., Arab, S., Barnes, C., Vermote, E., Hulley, G., ... & Zahn, S. (2023). The 50-year Landsat collection 2 archive. *Science of Remote Sensing*, 8, 100103.
- Delcourt, N., Silva, A. M. F. D., Rébufa, C., Foli, L., & Dupuy, N. (2023). Land Use Legacy Footprint In the Mediterranean Forest Soils: An Infrared Spectroscopy Approach. *Geoderma*: 430, 1-12.
- Dong, C., Qi, S., Dai, Z., Qiu, X., & Luo, T. (2024). Research on accurate and effective identification of ecosystem surface based on the human footprint index. *Ecological Indicators*, 162, 112013.
- Falcioni, R., Antunes, W. C., Demattê, J. A. M., & Nanni, M. R. (2023). Reflectance Spectroscopy for the Classification and Prediction of Pigments in Agronomic Crops. *Plants*, 12(12), 2347.
- Ferdous, J., Ur Rahman, M. T., & Ghosh, S. K. (2019). Detection of Total Dissolved Solids from Landsat 8 OLI Image in Coastal Bangladesh. *June*, 35-44. <https://doi.org/10.17501/2513258x.2019.3103>
- Geospatial Information Agency (2011). *Law No.4 of 2011 concerning Geospatial Information*.
- Hede, A. N. H., & Heriawan, S. M. N. (2020). *Pemanfaatan Spektroskopi Reflektansi Dalam Penginderaan Jauh Sensor Optis Untuk Eksplorasi Mineral*. PROSIDING TPT XXIX PERHAPI, 1-12.
- Kalfas, D., Kalogianmidis, S., Chatzitheodoridis, F., & Toska, E. (2023). Urbanization and land use planning for achieving The Sustainable Development Goals (SDGs): A case study of Greece. *Urban Science*, 7(2), 43.
- Karpukhina, E. A., Volkov, D. S., & Proskurnin, M. A. (2023). Quantification of lignosulfonates and humic components in mixtures by ATR FTIR spectroscopy. *Agronomy*, 13(4), 1141.
- Kuttruff, J., Romanelli, M., Pedrueza-Villalmanzo, E., Allerbeck, J., Fregoni, J., Saavedra-Becerril, V., & Maccaferri, N. (2023). The sub-picosecond collapse of molecular polaritons to pure molecular transition in plasmonic photoswitch nanoantennas. *Nature Communications*, 14(1), 3875.
- Levi, N., Karnieli, A., & Kagan, T. P. (2022). Airborne Imaging Spectroscopy For Assessing Land-Use Effect On Soil Quality In Drylands. *ISPRS Journal of Photogrammetry and Remote Sensing*: 186, 34-54.
- Li, F., Yigitcanlar, T., Nepal, M., Nguyen, K., & Dur, F. (2023). Machine learning and remote sensing integration for leveraging urban sustainability: A review and framework. *Sustainable Cities and Society*, 104653.
- Manetu, W. M., Mironga, J. M., & Ondiko, J. H. (2023). Remote Sensing for Land Resources: A Review on Satellites, Data Availability and Applications.
- Meidodga, I., Syahrin, A., Putra, R. T., Warfandu, F., & Bimasena, A. N. (2023). Pemanfaatan Data Geospasial dalam Mewujudkan Sistem Informasi Pertanahan Multiguna Bagi Multipihak. *Widya Bhumi*, 3(1), 62-80.

- Mikheytysev, N. A., & Korzhimanov, A. V. (2023). Generation of synchronized X-rays and mid-infrared pulses by Doppler shifting of relativistically intense radiation from near-critical-density plasmas. *Matter and Radiation at Extremes*, 8(2).
- Nguyen, L. T. V., Cleveland, D., Nguyen, C. T. M., & Joyce, C. (2024). Problem-based learning and the integration of sustainable development goals. *Journal of Work-Applied Management*.
- Nunn, P. D., Kumar, R., Barrowman, H. M., Chambers, L., Fifita, L., Gegeo, D., & Waiwai, M. (2024). Traditional knowledge for climate resilience in the Pacific Islands. *Wiley Interdisciplinary Reviews: Climate Change*, e882.
- Padmini, Y., Rao, M. S., & Rao, G. R. (2023). Temporal Analysis of Land Use and Land Cover Changes in Vizianagaram District, Andhra Pradesh, India using Remote Sensing and GIS Techniques. *Geoplanning*, 10(1), 1–10.
<https://doi.org/10.14710/GEOPLANNING.10.1.1-10>
- Polyakova, A., Mukharamova, S., Yermolaev, O., & Shaykhutdinova, G. (2023). Automated recognition of tree species composition of forest communities using Sentinel-2 satellite data. *Remote Sensing*, 15(2), 329.
- Prasad, R. D., Prasad, R. S., Prasad, R. B., Prasad, S. R., Singha, S. B., Singha, D., & Navathe, G. J. (2024). A review on modern characterization techniques for analysis of nanomaterials and biomaterials. *ES Energy & Environment*, 23, 1087.
- Simarmata, H. A., Rafliana, I., Herbeck, J., & Siriwardane-de Zoysa, R. (2023). Futuring 'Nusantara': Detangling Indonesia's Modernist Archipelagic Imaginaries. In *Ocean Governance: Knowledge Systems, Policy Foundations and Thematic Analyses* (pp. 337-363). Cham: Springer International Publishing.
- Sitinjak, K. P. H., Ibrahim, A. M., Putra, G. M., Mahlil, T., Januriyadi, N. F., & Rasyif, T. M. (2023). Probabilistic Analysis of the Tsunami Disaster on the Vulnerability Level of Buildings in Painan City, West Sumatra based on the Earthquake Ratio with the Logic Tree Method. In *E3S Web of Conferences* (Vol. 447, p. 01010). EDP Sciences.
- Safithri, R., Syaiful, S., & Huda, N. (2021). Pengaruh penerapan problem based learning (PBL) dan project based learning (PJBL) terhadap kemampuan pemecahan masalah berdasarkan self efficacy siswa. *Jurnal Cendekia: Jurnal Pendidikan Matematika*, 5(1), 335-346.
- Sejati, A. W., Buchori, I., & Rudiarto, I. (2019). The spatio-temporal trends of urban growth and surface urban heat islands over two decades in the Semarang Metropolitan Region. *Sustainable Cities and Society*, 46(July 2018), 101432.
<https://doi.org/10.1016/j.scs.2019.101432>
- Shaikh, M., & Birajdar, F. (2024). Advancements in Remote Sensing and GIS for Sustainable Groundwater Monitoring: Applications, Challenges, and Future Directions. *International Journal of Research in Engineering, Science and Management*, 7(3), 16-24.
- Singh, B., Venkatramanan, V., & Deshmukh, B. (2022). Monitoring of land use land cover dynamics and prediction of urban growth using Land Change Modeler in Delhi and its environs, India. *Environmental Science and Pollution Research*, 29(47), 71534-71554.
- Srivastava, A., & Maity, R. (2023). Assessing the potential of AI-ML in urban climate change adaptation and sustainable development. *Sustainability*, 15(23), 16461.
- Stevanović, M., Pavličević, P., Vujinović, N., & Radovanović, M. (2023). International relations challenges and sustainable development in developing countries after 2022: conceptualization of the risk assessment model. *Energy, Sustainability and Society*, 13(1), 48.
- Swandi, A., Rahmadhanningsih, S., Viridi, S., Nurhayati, N., Putri, R. A., & Suryadi, A. (2021). Simulasi gerak translasi dan gerak melingkar menggunakan vba macro excel melalui project-based learning (PBL). *Jurnal Pendidikan Fisika*, 9(1), 33-42.
- Tenorio, E. A., Montoya, P., Norden, N., Rodríguez-Buriticá, S., Salgado-Negret, B., & Gonzalez, M. A. (2023). Mountains exhibit a stronger latitudinal diversity gradient than lowland regions. *Journal of Biogeography*, 50(6), 1026-1036.
- Vanderhoof, M. K., Alexander, L., Christensen, J., Solvik, K., Nieuwlandt, P., & Sagehorn, M. (2023). High-frequency time series comparison of Sentinel-1 and Sentinel-2 satellites for mapping open and vegetated water across the United States (2017–2021). *Remote Sensing of Environment*, 288, 113498.
- Wang, L., Cheng, Y., Meftaul, I. M., Luo, F., Kabir, M. A., Doyle, R., & Naidu, R. (2024). Advancing soil health: challenges and opportunities in integrating digital imaging, spectroscopy, and machine learning for bioindicator analysis. *Analytical Chemistry*.

- Wiatkowska, B., Słodczyk, J., & Stokowska, A. (2021). Spatial-temporal land use and land cover changes in urban areas using remote sensing images and GIS analysis: The case study of Opole, Poland. *Geosciences*, 11(8), 312.
- Wulder, M. A., Roy, D. P., Radeloff, V. C., Loveland, T. R., Anderson, M. C., Johnson, D. M., & Cook, B. D. (2022). Fifty years of Landsat science and impacts. *Remote Sensing of Environment*, 280, 113195.
- Yu, D., & Fang, C. (2023). Urban remote sensing with spatial big data: A review and renewed perspective of urban studies in recent decades. *Remote Sensing*, 15(5), 1307.
- Yuan, X., Tian, J., & Reinartz, P. (2023). Learning-Based Near-Infrared Band Simulation with Applications on Large-Scale Landcover Classification. *Sensors*, 23(9), 4179.

Spectroscopy

ORIGINALITY REPORT

16%

SIMILARITY INDEX

12%

INTERNET SOURCES

3%

PUBLICATIONS

8%

STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Universitas Bengkulu Student Paper	7%
2	spie.org Internet Source	2%
3	ejournal.undip.ac.id Internet Source	1%
4	www.researchgate.net Internet Source	1%
5	Submitted to Universitas Indonesia Student Paper	1%
6	digilib.uinkhas.ac.id Internet Source	1%
7	Ninon Delcourt, Anne-Marie Farnet-Da Silva, Catherine Rébufa, Lisa Foli, Nathalie Dupuy. "Land use legacy footprint in Mediterranean forest soils: An infrared spectroscopy approach", Geoderma, 2023 Publication	<1%
8	journal.stkipsingkawang.ac.id Internet Source	

<1 %

9

www.bizmanualz.com

Internet Source

<1 %

10

Zaflis Zaim, Imam Buchori, Iwan Rudiarto.
"Land tenure system and utilization of
Bengkok land in Indrokilo sub-village, Lerep
Village, Semarang Regency", AIP Publishing,
2019

Publication

<1 %

11

www.jefferson.edu

Internet Source

<1 %

12

www.vensters.nl

Internet Source

<1 %

13

Nathan Levi, Arnon Karnieli, Tarin Paz-Kagan.
"Airborne imaging spectroscopy for assessing
land-use effect on soil quality in drylands",
ISPRS Journal of Photogrammetry and
Remote Sensing, 2022

Publication

<1 %

14

www.thejakartapost.com

Internet Source

<1 %

15

eosps0.gsfc.nasa.gov

Internet Source

<1 %

16

jurnalmarcapada.stpn.ac.id

Internet Source

<1 %

17	link.springer.com Internet Source	<1 %
18	www.ceom.ou.edu Internet Source	<1 %
19	Ahmet Salih Değermenci. "Spatio-temporal change analysis and prediction of land use and land cover changes using CA-ANN model", Environmental Monitoring and Assessment, 2023 Publication	<1 %
20	Indica Mohan, Babita Joshi, Deepak Pathania, Sunil Dhar, Brijmohan Singh Bhau. "Phytobial remediation advances and application of omics and artificial intelligence: a review", Environmental Science and Pollution Research, 2024 Publication	<1 %
21	Quoc Bao Pham, Sk Ajim Ali, Farhana Parvin, Vo Van On et al. "Multi-spectral remote sensing and GIS-based analysis for decadal land use land cover changes and future prediction using random forest tree and artificial neural network", Advances in Space Research, 2024 Publication	<1 %
22	Zhen Qian, Min Chen, Zhuo Sun, Fan Zhang, Qingsong Xu, Jinzhao Guo, Zhiwei Xie, Zhixin	<1 %

Zhang. "Simultaneous extraction of spatial and attributional building information across large-scale urban landscapes from high-resolution satellite imagery", Sustainable Cities and Society, 2024

Publication

23

edepot.wur.nl

Internet Source

<1 %

24

eprints.undip.ac.id

Internet Source

<1 %

25

fdocuments.in

Internet Source

<1 %

26

iksadyayinevi.com

Internet Source

<1 %

27

news.discovery.com

Internet Source

<1 %

28

oidaijsd.com

Internet Source

<1 %

29

ses.library.usyd.edu.au

Internet Source

<1 %

30

Manjari Upreti, Amit Kumar. "Landscape modeling for urban growth characterization and its impact on ecological infrastructure in Delhi-NCR: An approach to achieve SDGs", Physics and Chemistry of the Earth, Parts A/B/C, 2023

<1 %

Publication

Exclude quotes On

Exclude bibliography On

Exclude matches Off

Spectroscopy

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

/0

PAGE 1



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Article Error You may need to use an article before this word.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Missing ", " You may need to place a comma after this word.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Article Error You may need to remove this article.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.

PAGE 3



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.

PAGE 4



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.

PAGE 5



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Article Error You may need to remove this article.



Possessive This word may be a plural noun and may not need an apostrophe.



Missing "," You may need to place a comma after this word.

PAGE 6



Article Error You may need to remove this article.



S/V This subject and verb may not agree. Proofread the sentence to make sure the subject agrees with the verb.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



S/V This subject and verb may not agree. Proofread the sentence to make sure the subject agrees with the verb.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Article Error You may need to use an article before this word. Consider using the article **the**.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.

PAGE 8

PAGE 9



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Article Error You may need to use an article before this word.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.

PAGE 10



Article Error You may need to use an article before this word. Consider using the article **the**.



Article Error You may need to remove this article.

PAGE 11



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Article Error You may need to use an article before this word.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Missing ", " You may need to place a comma after this word.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.

PAGE 12



Article Error You may need to use an article before this word. Consider using the article **the**.



Article Error You may need to use an article before this word.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.



Possessive This word may be a plural noun and may not need an apostrophe.



Missing ", " You may need to place a comma after this word.

PAGE 13



Sp. This word is misspelled. Use a dictionary or spellchecker when you proofread your work.

PAGE 14

PAGE 15
