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LITHOLOGICAL IDENTIFICATION USING A DIGITAL ELEVATION MODEL (DEM) AND LANDSAT 8 IMAGERY IN THE WASEGI INDAH AREA, PRAFI DISTRICT, MANOKWARI REGENCY, WEST PAPUA PROVINCE

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ABSTRACT

This study focuses on lithological identification in the Wasegi Indah area, Prafi District, Manokwari Regency, West Papua, using Digital Elevation Model (DEM) and Landsat 8 imagery. Geological surveys traditionally rely on costly and time-consuming fieldwork, but remote sensing technologies, especially DEM and satellite imagery, offer efficient alternatives for geological mapping. This research aimed to process and analyze DEM data alongside Landsat 8 imagery to identify lithological characteristics in the region and compile a lithological boundary map. The study utilized a combination of primary data, including Landsat 8 imagery and DEMNAS data, along with secondary data from geological maps to support geological and lithological interpretation. The results demonstrate that combining Landsat 8 composite images with DEMNAS imagery provides valuable insights into the lithological distribution, aiding in the identification of geological formations such as granite, diorite, and limestone. The findings indicate the potential of remote sensing in geological mapping, although the study also highlights the need for further image processing techniques to improve accuracy. In conclusion, while the lithological maps generated offer regional insights, more detailed mapping is necessary for specific applications like resource exploration and geological hazard management.

Keywords:
Beautiful Landscapes, DEM, Landsat 8 Imagery, Lithology

INTRODUCTION

Geological studies are still primarily carried out terrestrially, or directly in the field, which requires considerable time and cost (Cao et al., 2024; Yang et al., 2022). Remote sensing technology is developing rapidly alongside advances in computerization (software and hardware). This has made it one of the most up-to-date survey methods, capable of being applied continuously. Advances in computer technology have facilitated the development of computer-based spatial data processing systems. Remote sensing applications have increasingly focused on ease of use, interoperability with geospatial information systems, and the growing availability of automated algorithms for remote sensing processing (Chatrabhuj et al., 2024; Dritsas & Trigka, 2025; Musa et al., 2024; Padhiary et al., 2025).

Geological studies continue to be conducted to this day (Gupta et al., 2020; Drury, 2018). One of the contributions of remote sensing techniques to the geological mapping process is the mapping of landforms, geological formations, and structural lineament patterns (Sabins & Ellis, 2020; Pour & Hashim, 2018). The advantages of remote sensing techniques include relatively low cost, efficient processing time, an adequate level of precision, and wide area coverage (Chen et al., 2019; Li et al., 2021). Lillesand and Kiefer (2004) define remote sensing as the science or art of obtaining information about objects, areas, or phenomena through the analysis of data acquired using instruments without direct contact with the object, area, or phenomenon being studied (Weng, 2018; Tiwari et al., 2022).

The Digital Elevation Model (DEM) is an advanced dataset for terrain analysis that provides more detailed information about the Earth's surface and structure by assigning a specific elevation value to each pixel, compared to optical satellite imagery such as Landsat (Guth & Geoffroy, 2018; Grohmann, 2018). DEM data are more practical because they are not affected by weather or atmospheric conditions (Mukherjee et al., 2019; Elkhrachy, 2021). Lineaments are often expressed as ridge and valley alignments, so tectonic lineaments can be used to trace fault zones (Jordan dkk., 2005; Soto-Pinto et al., 2013; Flores-Prieto et al., 2015).

Currently, most researchers use hillshade rendering methods derived from DEM data, either alone or in combination with optical satellite imagery, to extract lineaments (Bonetto dkk., 2015; Radaideh et al., 2016; Masoud and Koike, 2017; Das and Pardeshi, 2018; Thiele et al., 2020; Rahnama et al., 2022). Landsat (Land Satellite) is a United States satellite program first launched in 1972 (Landsat 1). The Wasegi Indah area, Prafi District, Manokwari Regency, is characterized by diverse lithology, represented by several geological formations found within the area (Nugraha et al., 2021). In addition, intrusive rocks are also present in this region (Putra et al., 2020).

The formulation of the problem in this study includes two main aspects: how to identify lithology through the processing of Digital Elevation Model (DEM) data and Landsat 8 imagery, and how to determine the lithological conditions of the study area based on the analysis of these two datasets. In its implementation, this research is limited to lithological analysis using filtering techniques and visual interpretation methods. Furthermore, the study is restricted to determining the lithological conditions of the research area based on the results of remote sensing data processing.

The purpose of this study is to analyze Digital Elevation Model (DEM) data and Landsat 8 imagery to identify the lithology of the study area, as well as to evaluate and produce a lithological boundary map based on the interpretation results. The expected benefits of this study include providing updated information related to the boundaries of geological formations in the research area and contributing to the advancement of remote sensing applications in geology, particularly using DEM data and Landsat 8 imagery. In addition, the results of this study are expected to serve as a reference for future research related to lithological analysis and geological mapping based on remote sensing data.

METHOD

Data Processing and Analysis

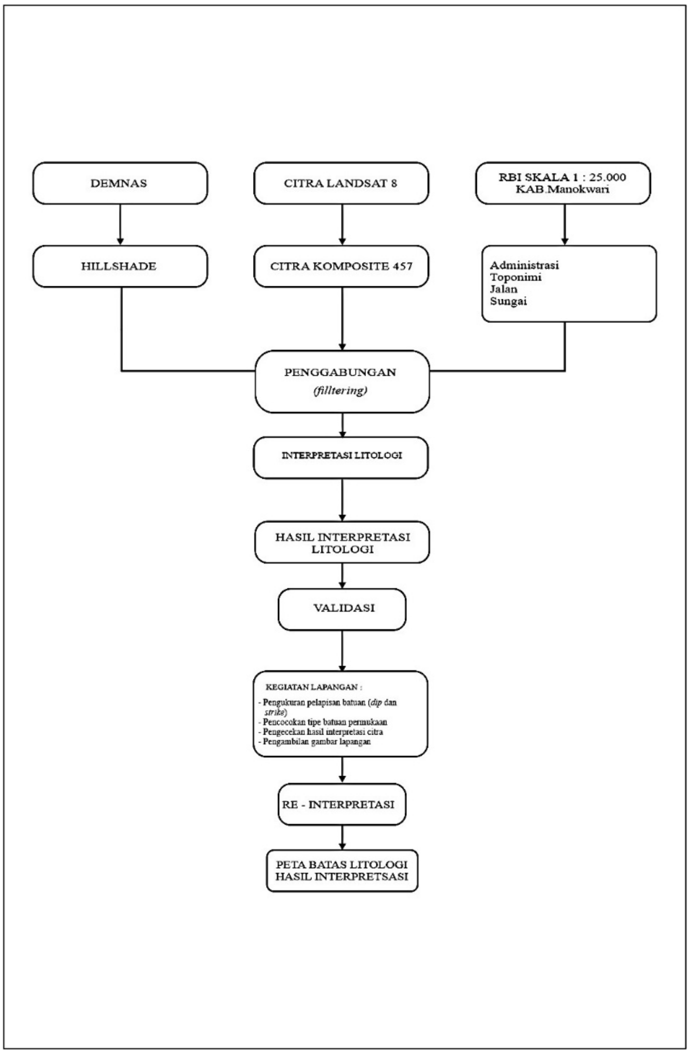


Figure 1 Data Analysis Flow Chart

The data used in this study consisted of primary and secondary data. Primary data included the results of Landsat 8 band extraction and the extraction of National Digital Elevation Model (DEMNAS) data, which supported topographic analysis and geological interpretation. Secondary data included the Manokwari Sheet Indonesian Terrain Map, the Manokwari Sheet Regional Geological Map, Landsat 8 imagery, and DEMNAS data. These datasets served as references and support in the lithological interpretation process and the preparation of geological maps of the research area.

Geological mapping using remote sensing data was based on geological interpretation, which included the analysis of geological structures and lithology in the research area. This interpretation process was carried out through several stages: detection, identification, analysis, and classification. The interpretation method used in this study referred to the JICA–LEMIGAS (1994) guidelines, which divide the process into two main stages: basic interpretation and analytical interpretation.

In the basic interpretation phase, visible geological features were interpreted using the imagery to obtain an overview of the study area. This phase included the interpretation of geological features to support the analysis of the distribution of geological structures and lithology. Assumptions were made based on the uniformity of rock units.

The analytical interpretation phase focused on interpreting subsurface conditions and refining the distribution of geological structures and lithology. This stage resulted in maps of structural and lithological distribution, as well as the identification of geological structures supported by geological cross-sections. The final output was a geological map that more comprehensively represented the geological conditions of the research area.

RESULTS AND DISCUSSION

Composite Image Creation

The preparation of composite images is carried out to produce a better visual image according to the capabilities of each band used. The band combination in the Landsat 8 imagery is different from the band combination in the previous generation Landsat imagery. In Landsat 8 there is a blockage of two new bands, namely band 1 and band 9. Figure 2 shows the appearance of a true colour visual composite at the research site, namely composite 432.

Figure 2 Landsat Composite 432 imagery (*Natural Colour*)

In the image above, the appearance of the object is the same as the actual appearance in the field. Vegetation appears green and forests appear green but tend to be darker than grass or rice fields, dry soil is light brown while wet (moist) soil has a dark brown color with dark or cloudy water bodies. However, with these images, it is still not possible to interpret the lithological boundaries. Therefore, it is necessary to make an image composite that can show in more detail the geological object, in this case the lithological boundary at the research site.

The band combination used in this study is a combination of band 567 because it is considered very capable of showing terrain conditions well such as flow patterns, reliefs, vegetation, culture, and other geological appearances. The new image is composed of band 5 (near inreared), band 6 (mid-infrared I), and band 7 (infrared II) which are each divided into three colors, namely red, green, blue (RGB) consecutively. Each band has different characteristics and abilities in identifying objects that appear in the image. Each object on the

Earth's surface also gives a different spectral response to the sensor during the recording process.

Band 5 is very sensitive to the biomass content of vegetation and coastlines, so it is very helpful in distinguishing the boundaries between soil, vegetation, and water bodies from the resulting hue/color. This band is also useful in the introduction of suspension deposits or sand burns. In addition, it is also very good at identifying vegetation because it is very sensitive to vegetation objects. The image of this band shows that the vegetation appears to have a brighter hue than the soil and the body of water. The body of water has the darkest hue compared to other objects because in this band the water is completely absorbed so the reflection is very low.

Gambar 5.2 Citra Landsat 8 Natural Colour

Gambar 5.3 Citra Landsat 8 Band 5

Band 6 is useful in distinguishing soil moisture content (soil moisture) and vegetation and can penetrate thin clouds. In the image, objects with humid water content appear to be darker in color compared to objects with less water content. The band is also suitable for cultural introduction/land use, such as urban objects or built-up land. In this band, the soil has the highest sprektral reflection so that in the image the soil object appears brighter in color than the vegetation and water bodies. Band 7 is also useful in distinguishing soil moisture content which is useful in vegetation classification, water and land boundary recognition, and land shape. The band is also excellent at rock type recognition. Band 7 and band 6 in the Landsat 8 imagery have relatively not much different characteristics in displaying existing objects. The vegetation in the band provides a lower spectral reflection than in band 6 so that it appears darker in color.

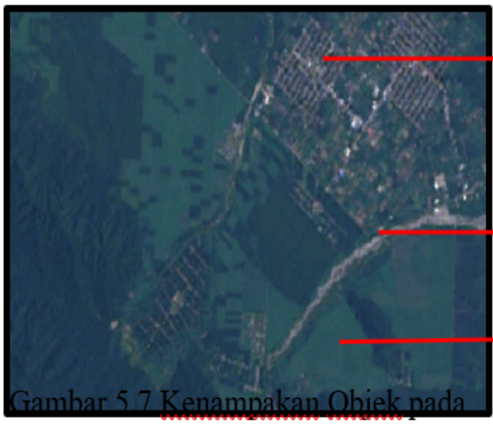
Gambar 5.4 Citra Landsat Natural Colour

Gambar 5.5 Citra Landsat Band 6

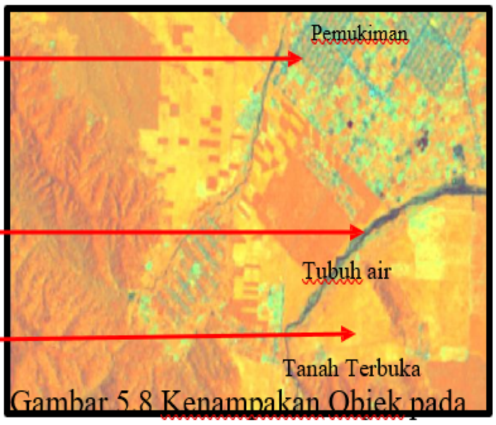
Gambar 5.6 Citra Landsat Band 7

The merger of the three channels produces a new image with an appearance that is not the same as the reality in the field, but can highlight certain aspects of the terrain that help in the identification of geological objects. The colors produced in this composite image 567 highlight the characteristics of each object, and it is easier to distinguish one object from another based on the color produced. This new composite image is very helpful in identifying the physical aspects of the terrain in more detail compared to the original color composite which is still difficult to identify objects. The new image shows that the water body appears black, vegetation is reddish-brown, the land or built land is bright blue, and the open land is bright white.

The color difference between the bodies of water, vegetation, and soil is very evident in this composite image of 567. The body of water, which is blue, on composite 567 appears dark blue to blackish. With a darker hue in the image, the identification of the physical aspects of the field in the form of flow patterns and flow density becomes very clear. The vegetation in the image is relatively brownish red (orange). Darker orange indicates vegetation with high density, for example forests or gardens found in hilly areas. A lighter orange color indicates vegetation with a lower density, such as grass and rice fields. Denser vegetation reflects more perfect waves, so the resulting hue is also sharper. The open ground object, which is in fact light brown, in composite image 567 appears to be bluish-white with a bright hue, while the area of the built land is shown with a more bluish hue due to the reflection of the roof of the building made of a variety of materials.



Gambar 5.7 Kenampakan Objek pada Citra Landsat 8 Natural Colour



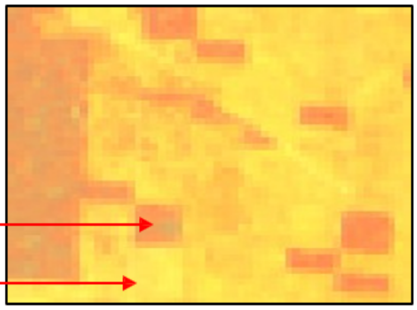
Gambar 5.8 Kenampakan Objek pada Citra Landsat 8 Komposit 567

The morphological appearance of this new image is quite visible, so it helps in distinguishing the type of rock from the level of resistance of the rock. The lithological boundaries can be well identified. In addition to the hue produced, the identification of geological objects that appear in the image is also based on other interpretive elements, such as reliefs/morphology of the region, shapes, patterns, textures, and so on. The new image of the 567 composites will help in identifying the geological conditions of the area in the form of geological structures and rock types (lithology) in the study area based on the physical aspects of the terrain seen in the image. The identification of objects from these images is mostly based on the key to hue/color interpretation, so it is not very strong in recognizing geological objects in the study area.

Characteristics of Landsat 8 Imagery on the Lithological Boundary of the Wasegi Indah Area and Its Surroundings

Landsat 8 Composite 567 imagery produces hue, pattern, shadow, and texture that help in identifying lithological boundaries in the study area. However, the results from the Landsat 8 composite 567 images cannot identify lithology directly because this processing only results in the interpretation of surface conditions. In identifying lithological boundaries, this processing is assisted by using image interpretation keys.

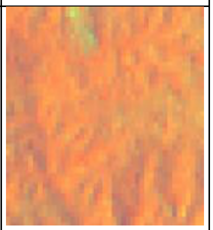
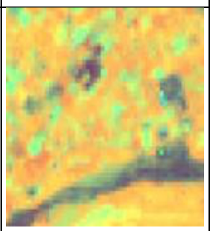
Gambar 5.25 Kenampakan perkebunan sawit yang membentuk pola beraturan



Gambar 5.26 Kenampakan perkebunan sawit pada Citra Landsat 8 komposit 567

Based on the image above, it can be seen that there is a difference in hue contained in the results of the interpretation, where dense vegetation has a reddish-orange hue, while for vegetation that rarely has a bright yellow hue, in addition to that if it is connected to social and cultural aspects, community behavior tends to make oil palm plantations on a flat topography. The plains have lithology in the form of sedimentary deposits dominated by conglomerates.

Table 1 Lithological Characteristics Based on the Merger of Landsat 8 and DEMNAS Images

Litholo	Relief/ Topograph	Texture	Hue/color	Vegetation &	Appearance of Image
Granite	Hills	Rough	Garden red and yellowish red	Forest	
Granodiorit	Hills	Rough	Yellowish red	Forest	
Diorit	Hills	Rough	Yellowish red	Forest	
Limestone	Hills	Roug h	Reddish orange	Forest	
Aluvium deposits	Flat - Landai	Smoot h	Bright Yellow, dark black (contains water) mixed with turquoise	Ponds, Settlements, Rice Fields, Plantations SawIt	

Evaluation of Image Accuracy

Image Processing Ability Test

The ability test was carried out to determine the ability of each stage of image processing techniques in providing information on geological objects in the form of geological and lithological structures in the study area. This ability test will provide an overview of the processing capabilities of Landsat 8 composite 567 imagery and DEMNAS imagery in recognizing geological objects in the processed images.

The assessment is based on 4 classes based on the level of clarity of objects that can be recognized in the image, including very clear, clear, lacking class, and invisible which in each criterion are explained in the Table....Each class is determined from the ease of the object to be identifiable based on the characteristics or characteristics that appear in the processed image. An object or physical aspect of the field falls into the "very clear" class, meaning that the object is very clear and very easily identifiable in the processed image, and when field activities are carried out there is no significant difference from the identified object. The more difficult it is for objects or physical aspects of the terrain to be recognized, the lower the ability of the processed image to provide information about an object and fall into the "unclear" class. The object also usually cannot be proven to be true in the field.

For example, in identifying the physical aspects of the terrain in the form of relief or regional morphology, it can be easily done in the image resulting from the combination of Landsat 8 imagery and DEMNAS imagery so that it is included in the highest class, which is "very clear". In the reality in the field, the physical aspect of the terrain can also be proven to be true, or in accordance with the reality in the field. However, the introduction of the relief is very difficult to do in Landsat 8 Composite 567 imagery because it does not display the morphological information of the area well and is included in the lowest class, which is "unclear".

It is different with hillshade images from DEMNAS data which show the morphological conditions of the area very well so that it is very helpful in presenting the physical aspects of the terrain, especially in the identification of geological structure objects. However, this hillshade image has a weakness in identifying the physical aspects of the terrain that uses elements of hue/color interpretation in the identification of objects, such as vegetation and other land uses.

This hillshade image can also be used in lithological identification seen from the aspect of relief/morphology of the area, which shows the level of resistance of the rock. In relatively flat reliefs, the hue/color interpretation element of Landsat 8 plays a greater role in lithological identification, for example in the flat relief in the northern part of the study area. These hues/colors help in distinguishing lithology based on the differences in colors that appear in the image.

Table 2 Image Processing Ability Test Criteria

Remarks	Rating	Criteria
***	Very Clear	If the physical aspects of the interpreted terrain appear to be
**	Clear	If the physical aspects of the interpreted terrain are clear enough
*	Less Clear	If the physical aspect of the interpreted field is somewhat blurry and there were some mistakes with the reality on the
	No	If the physical aspect of the terrain interpreted to be

	Clear	It is not visible after image processing.

The results of the image processing ability test are presented in Table 2. The table shows that the combination of Landsat 8 composite 567 images with DEM data from DEMNAS images is the best processing technique in providing lithological information in the study area. It is especially good at recognizing rock types in images because they provide very good information on the morphology and resistance level of rocks which helps in recognizing rock types in images. The spectral aspect of the Landsat 8 imagery is also not lost and can still be preserved, which is very helpful in recognizing land cover and vegetation from the resulting hue/color. These hues/colors are also useful in distinguishing the boundaries between rocks (lithology) in the image. The introduction of geological objects in the form of geological structures in various image processing results is quite difficult because most areas have undergone erosion and erosion.

Table 3 Image Processing Ability Test Results

Physical phenomena/aspects of the field		**Image Processing**	
		***Hillshade* DEMNAS**	**Composite Landsat imagery 567**
Lithology	Rock Coating	***	*
	Rock Types		*
	Resistance	***	

CONCLUSION

The study revealed notable differences between the Regional Geological Map of the Manokwari Sheet and the interpretations produced, although the processed data were generally consistent with field conditions and considered representative of the area’s geology. These findings suggest that remote sensing–based interpretation can effectively support regional geological analysis, despite some discrepancies with existing maps. However, the resulting geological maps remain broad and limited to surface-level characterization, indicating the need for more detailed and site-specific mapping to better identify resource potential, such as hydrocarbon traps and limestone deposits. Future research should focus on enhancing methodological approaches by incorporating advanced image processing techniques, such as image fusion and complementary analytical methods, to improve the accuracy, resolution, and effectiveness of geological interpretations.

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