Vol. 1, No. 2 (2020); 90–101

Journal of Earth Sciences and Technology

http://www.htpub.org/Journal-Of-Earth-Sciences-And-Technology/

3D Modeling of Olele Eco-Geotourism Area Based on Satellite Imaging, Geology, and Marine Analysis

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Article Information

Article History
Received: 11/11/2020
Accepted: 07/12/2020
Available online: 10/12/2020

Keywords
3D Model
Geosite
Ecosite
Ancient Volcano
Coral Reef

Abstract

The identification of the potential for eco-geotourism is not sufficient to reveal the potential of the Olele area so that technological innovation is needed to model the design of the eco-geotourism area. The purpose of this research is to make a 3D modeling of Olele eco-geotourism area design based on satellite, geological, and marine data analysis. This research method uses satellite image data technology combined with a literature review. Satellite imagery uses the National Digital Elevation Model (DEMNAS) and National Bathymetry (BATNAS) which are processed and analyzed using the GIS application. Literature review refers to books, journals, and maps related to research topics. The results showed that the Olele region has two potential geosites and four potential ecosites. Satellite image data technology not only produces terrestrial topographical models, bathymetry models, and slope class map but also can show the relationship between openings in Jin Cave controlled by geological structures on land, and the unique relationship between Petrosia lignosa and the Olele underwater carbonate shelf model of Olele. Based on the identification and comparison of geosite and ecosite, the Olele area is unique on a local, national, and international scale.

1. Introduction

Ecotourism is defined as a concept of natural tourism while still paying attention to the preservation of ecosystems including the flora and fauna (Sharpley, 2006). On the other hand, geotourism is a tourism concept that focuses on the geomorphological features of an area and the geological processes that play a role in the area (Strba et al, 2020). The combination of these two tourism concepts can produce an eco-geotourism concept, which is a new tourism concept that focuses on the flora and fauna of an ecosystem, as well as the geological processes that shape the morphology.

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The concepts of ecotourism and geotourism have been widely applied in Indonesia and abroad (Faizal et al., 2018; Ginting et al, 2017; Vishwanatha & Chandrashekara, 2014; Strba et al, 2020). The studies conducted are generally limited to identifying potential ecotourism (Zambrano et al, 2010) and geotourism (Faizal et al, 2018; Strba et al, 2020). The identification of Olele's ecotourism potential has been carried out by Mahale et al. (2018) and Hamzah et al. (2020) while the identification of Olele's geotourism potential has never been carried out. Ecotourism and geotourism research which is limited to identifying potentials is not sufficient to reveal existing potentials so that technological innovation is needed to be able to model eco-geotourism area.

A technological innovation that can be utilized is satellite imaging technology. The application of satellite technology can visualize the topography and bathymetry of an area so that it can assist in making regional designs, including the design of Olele's eco-geotourism area. This study aims to make a 3D modeling of the Olele eco-geotourism area design based on satellite imagery, geological, and marine data analysis.

2. Methods

The research area includes the village of Olele and its surroundings, Kabila Bone District, Bone Bolango, Gorontalo. The research area is 20 km from the city of Gorontalo and takes about 1 hour by motor vehicle. Olele's topography is generally dominated by steep hills and someplace composed of plains (figure 1).

This study utilizes satellite image technology combined with the literature review of geological and marine in Olele area (figure 2). Satellite imagery uses DEMNAS and BATNAS released by the Geospatial Information Agency (BIG) in 2018. Literature review refers to books, journals, and maps related to research topics. Satellite imagery has been a breakthrough in science. Satellite imagery helps capture images of the earth's surface by utilizing wavelengths and the electromagnetic spectrum (EMS) (Gupta, 2003). Satellite imagery has been widely used as a preliminary observation of field surveys. An example of satellite imagery is Digital Elevation Model (DEM).

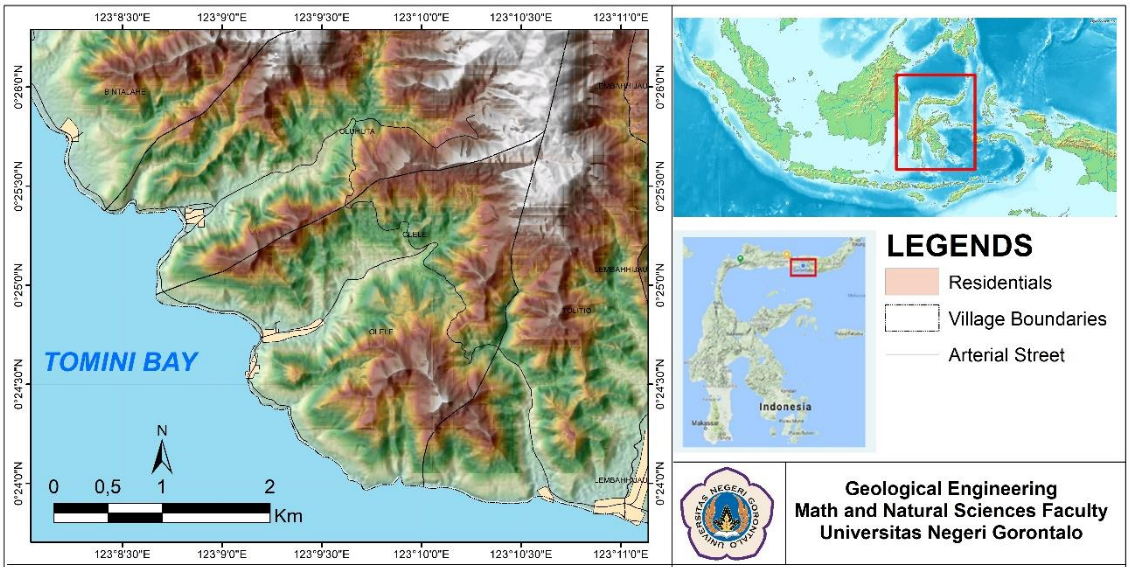

Fig. 1. Research location.

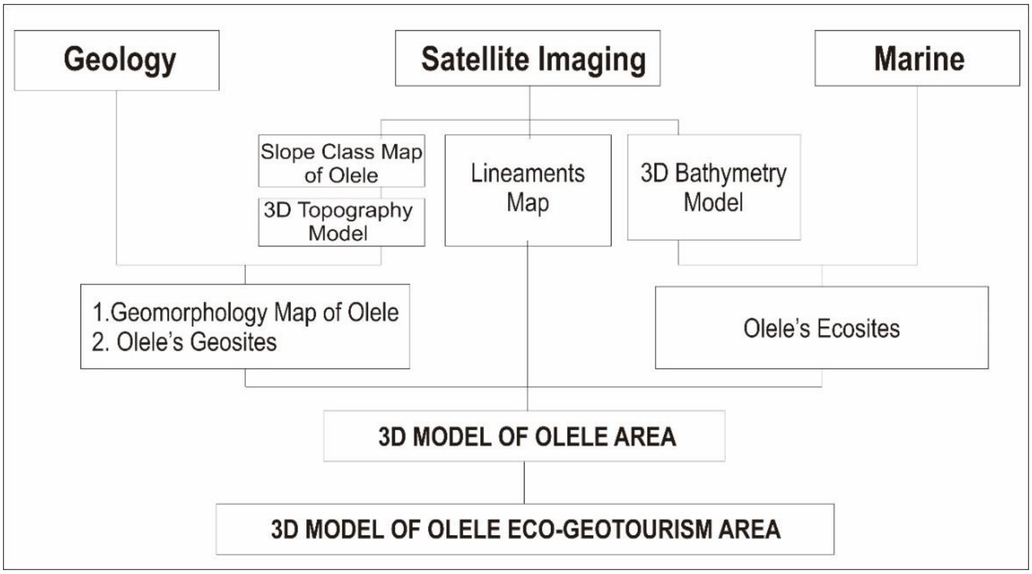

Fig. 2. Research flowchart.

DEMNAS and BATNAS were used to obtain topographic and bathymetric models of the Olele area. DEMNAS and BATNAS are issued by the Geospatial Information Agency (BIG) and can be accessed free of charge through the official website. DEMNAS is taken from IFSAR, TERRASAR-X, and ALOS PALSAR images which have a resolution of up to 5 meters. DEMNAS spatial resolution is 0.27-arcsecond. BATNAS comes from inversion of gravity anomaly data from altimetry data which is added with sounding data with single-beam or multi-beam survey methods. The spatial resolution of the BATNAS is 6-arcsecond. The use of DEMNAS and BATNAS satellite imagery is due to their detailed resolution so that it can visualize a 3D model of Olele's area that is closer to the original. Besides, these satellite images are easy to access and free.

Satellite image data is downloaded from the official website of the Geospatial Information Agency (BIG) and then processed using GIS. The DEMNAS image is the basis for making slope class maps, lineaments maps, and topographic 3D models of the Olele area. The BATNAS image became the basis for the creation of a 3D bathymetry model of the Olele area. Geodiversity and biodiversity data were obtained from literature reviews. The references referred to are maps, books, and journals that discuss geology and marine ecosystem in the Olele area. This is done to get a brief information of the potential for geodiversity and biodiversity of Olele's coral reefs. The results of the study on the potential for geodiversity and biodiversity of Olele's coral reefs were then compared with the potentials in other areas, both locally, nationally, and internationally. This comparison was carried out to determine the uniqueness of the geodiversity and biodiversity in Olele.

2.1. *Integration of satellite image data technology and geology*

DEMNAS satellite image data technology (National Digital Elevation Model) is extracted and processed using the GIS application to produce 3D topographic models and slopes class map. The slope classes refer to the Van Zuidam classification (1985). The slopes class map and 3D topographic model of Olele collaborated with the results of a geological literature study to identify geomorphology and geosites in the Olele area. Geological literature review (Bahutala, 2016; Septian et al, 2019; Rahman et al, 2019; Indarto et al, 2017; Shukla & Sharma, 2017) includes geosite identification and comparison of Olele volcanic breccia with other areas on a local, national, and international scale.

2.2. Integration of satellite and marine image data technology

BATNAS (National Bathymetry) satellite image data technology is extracted and processed using the GIS application to produce a 3D model of Olele's bathymetry. The 3D model of Olele's bathymetry is classified based on the Carbonate Shelf classification (McNeill et al., 2010). The Olele 3D bathymetrical model collaborated with the results of a marine literature study to identify ecosites in the Olele area. Marine literature review (Allen, 2006; Jones, 2014; Wilson, 1925; Putchakarn, 2014; Thacker et al., 2013; Leal et al, 2017) includes identification of ecosite and comparison of ecosite *Petrosia Lignosa* in Olele compared to other regions on local, national, and international scale.

2.3. 3D Modeling of Olele eco-geotourism area design

The entire data processed is then combined to create a 3D model of the Olele area. This 3D model of the Olele area is added with lineaments analysis to become the basis for 3D modeling of the Olele Eco-Geotourism area design. Lineaments analysis is needed as a preliminary indication of the geological structures and water permeability level of the Olele area. Lineament analysis refers to research by Abduh et al., (2020). The design of the Eco-Geotourism Area is based on a combination of Olele's geodiversity and biodiversity perspectives by promoting the principles of conservation, education, and mitigation.

3. Results and discussion

3.1. Satellite image data technology integration and geology

3.1.1. 3D topographic model

The topographic 3D model was obtained from the extraction of National Digital Elevation Model data (DEMNAS) which was plotted according to the area of the Olele area using the GIS software. The extraction and modeling produce 3D topography of the Olele area which is mostly composed of hills and plains morphology (figure 3).

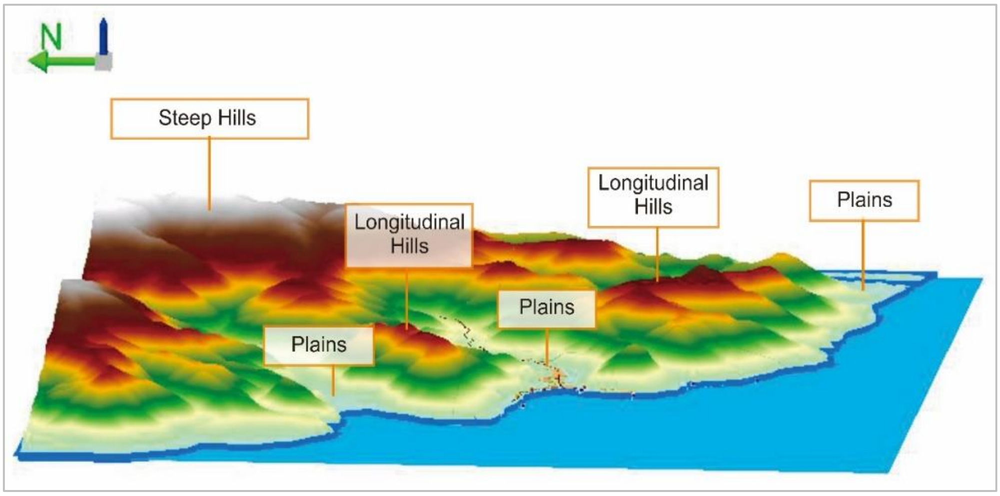

Fig. 3. 3D Topographic model of Olele area.

The hills have a relatively steep slope (35-55^{o}) which can be seen on the slope class map of the Olele and in some places form wavy hills morphology. Plains morphology is located in the southeast and some places are between the wavy hills. This morphology is characterized by a relatively gentle slope (4-8^{o}) to flat. The village of Olele is located in a plain morphology surrounded by longitudinal hills with a steep slope. The slope class in Olele area is shown in figure 4.

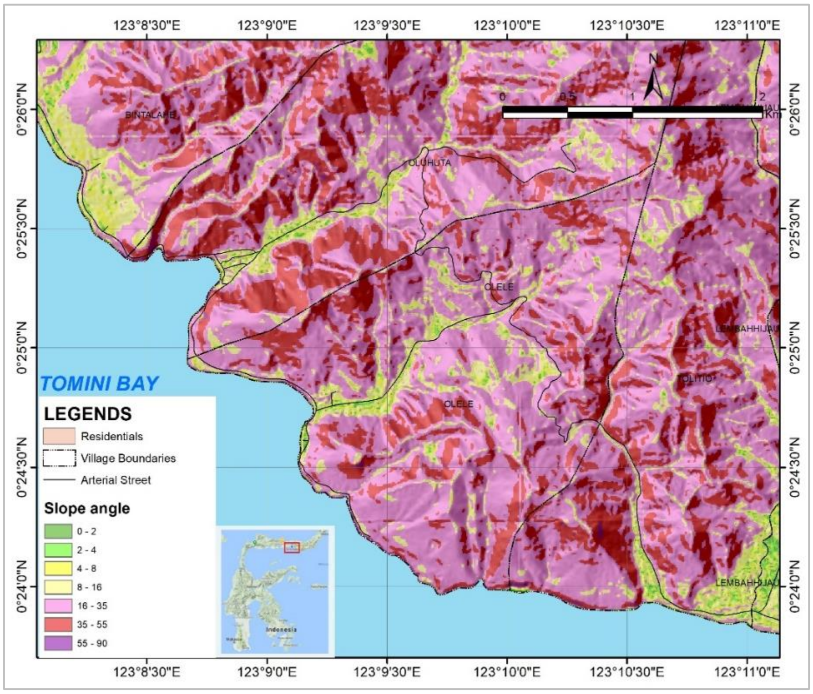

Fig. 4. Slope class map of Olele area.

3.1.2. Geological Review

The geomorphology of the Olele area is classified based on contour patterns and rock distribution based on Bahutala (2016). The geomorphology of the Olele area consists of three geomorphological units, namely volcanic hill units, solutional hills, and fluvio-marine plains (figure 5). The determination of this unit is based on observations of contour patterns extracted from the DEM image combined with the geological mapping in the Olele area by Bahutala (2016). The Olele area is composed of volcanic breccia and coral limestone (Bahutala, 2016). Volcanic breccias are volcanic eruption products, while reef limestones are rocks that are formed in shallow marine. Based on this study, there are two potential geosites in the Olele area that can be determined, namely the Ancient Volcanism geosite and the Shallow Sea Uplift geosite.

Volcanic breccia in the Olele refers to volcanic breccia from Pinogu Volcanics Formation (TQpv). This kind of rock is widely distributed in Gorontalo province, especially in east part of Gorontalo province, as in the research of Manyoe & Hutagalung (2020). But Olele volcanic breccia has several unique features.

The volcanic breccias of the Olele area are unique and interesting (table 1). Olele volcanic breccias and Tanjung Kramat volcanic breccias studied by Septian et al., (2019) are located on the south coast of Gorontalo. But, the uniqueness of Olele volcanic breccia is that the volcanic breccias have direct contact with reef limestones that are formed in shallow marine environments. This uniqueness is not owned by the volcanic breccia in Tanjung Kramat. Besides, the rock fragments in the Olele volcanic breccia have a porphyry texture different from the volcanic breccias in the northern part of Gorontalo studied by Rahman et al., (2019). This porphyry texture makes the Olele volcanic breccias have different mineral crystal sizes compared to volcanic breccias in the northern part of Gorontalo.

On a national scale, the Olele volcanic breccia is unique because it is a product of ancient volcanoes (Tertiary age). Although the center of the volcano is no longer visible, this volcanic breccia outcrop is the evidence of Tertiary era volcanic activity (65-2 million years ago) in the Olele area. In contrast to research by Indarto et al., (2017) in the active volcano Slamet in Purwokerto and research by Suhada and Hastuti, (2019) in Muara Enim which is a quarter-aged volcano.

On an international scale, the Olele volcanic breccia is unique in terms of magma type and magma source. The type of magma can be described from the Olele volcanic breccia rock fragments, namely andesitic. According to Marti and Ernst (2005), andesitic magma comes from magma with intermediate composition, which is formed in the subduction area of the oceanic and continental plates, resulting in magma mixing. In contrast to the type of rhyolitic magma in volcanic breccia fragments in India in the study of Shukla and Sharma (2017) shows an acidic composition.

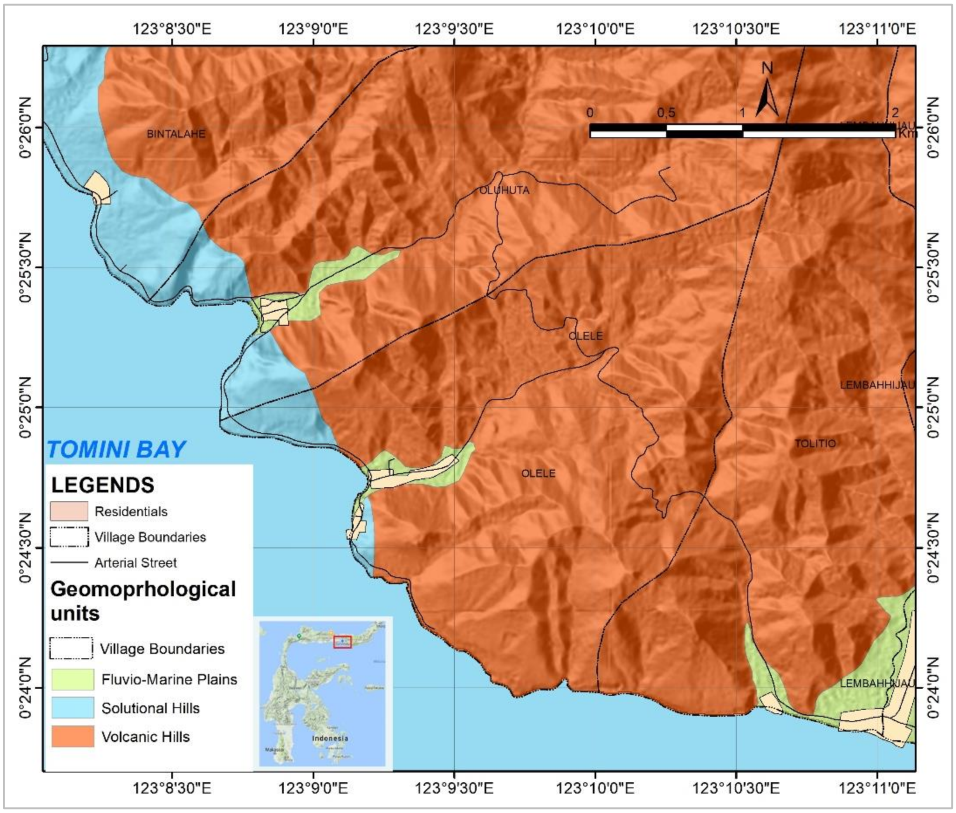

Fig. 5. Geomorphology of the Olele area.

Table 1. Volcanic Breccia comparison study.

Unit	Researcher	Fragments	Matrix	Location	Age
Volcanic Breccias	Bahutala, 2016	Porphyry Andesite	Tuff and Volcanic Glass	Olele, Gorontalo	Pliocene - Pleistocene
Volcanic Breccias	Septian et al, 2019	Porphyry Andesite, Basalt	Tuff and Volcanic Glass	Gorontalo City	Pliocene - Pleistocene
Volcanic Breccias	Rahman et al, 2019	Andesite, Basalt, Granodiorite, Scoria	Volcanic Glass	Limbato, North Gorontalo	Miocene - Pliocene
Volcanic Breccias	Suhada et al, 2019	Andesite	Tuff	Muara Enim,	Holocene
Volcanic Breccias	Indarto et al, 2017	Andesite	Tuff	Purwokerto	Holocene
Volcanic Breccias	Shukla and Sharma, 2017	Rhyolite	Tuff, Tuff lapilli	India	Late Paleocene

Geological history shows that the Olele area in the Tertiary era was in a volcanic area. Volcanic eruptions at that time produced Tertiary age volcanic breccia (65-2 million years ago) and formed the Olele area. The Olele mainland then experienced subsidences, ends in shallow marine environments, and forms a quaternary limestone reef (<2 million years ago) that grows on volcanic breccias. Quaternary tectonic events result in the uplift of reefs to the surface and become reef limestones that are exposed on surface nowadays.

3.2. Integration of satellite data technology and marine

3.2.1. 3D bathymetry model

Olele's 3D bathymetric model was obtained from the extraction and processing of BATNAS images released by the Geospatial Information Agency (2018). Olele regional bathymetry was identified based on the Carbonate Shelf Environment model (McNeill et al., 2010). This condition is because the Olele is dominated by coral reefs. Olele coral reef grows upright in Olele waters and forms a reef wall morphology. In the 3D bathymetric model, several morphologies of the carbonate shelf model can be seen, such as the fore reef slope, deep reef slope, proximal fore reef, and distal fore reef (figure 6). Fore reef slope with a steep slope resulting in a submarine morphology that decreases suddenly. According to Jones (2014), this morphology has benefits as a habitat for reef species that are vulnerable to exposure to shallow water waves so that it is very supportive of the development of coral reef ecosystem species.

3.2.2. Olele's potential ecosite

Olele's coral reef is an ecosystem for hundreds of unique and rare species. Hamzah et al., (2020) recorded that 174 species of reef fish in Olele waters and there are coral ecosystems on the Olele coast. In the northern part of the Olele area, there is a reef conservatory area that has been established by Bone Bolango Marine and Fishery Agency (DKP) (2009). There are also some unique and rare marine species such as orangutan crab, colemani shrimp, soft coral crab, Sarasvati shrimp, Colemani shrimp, Lionfish, and several types of nudibranch that can be observed at the Goa Jin spot (Allen, 2006; Mahale et al., 2018).

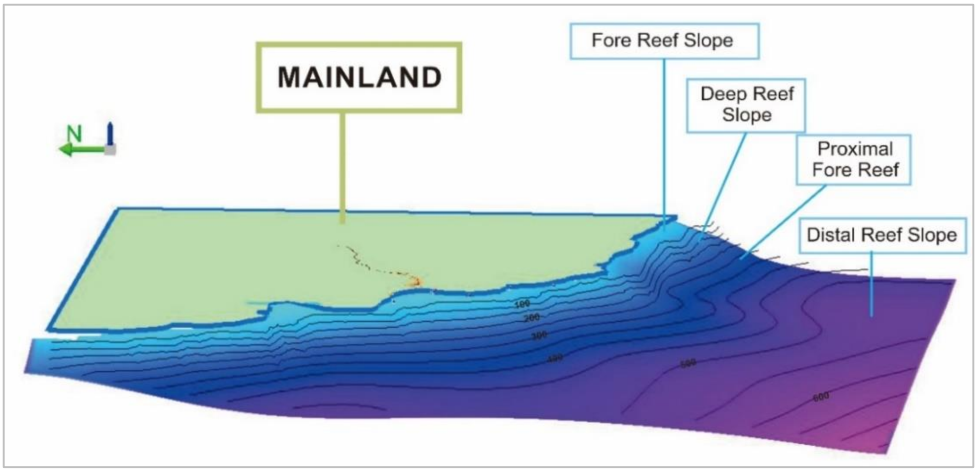

Fig. 6. 3D bathymetry model of Olele.

The main attraction of the Olele waters is the sponge Petrosia lignosa. On a national and international scale, Olele's *Petrosia lignosa Sponge* is unique in terms of color, shape, pattern, and size (table 2). The colors, patterns, and sizes of Petrosia lignosa in Olele are more diverse, artistic, beautiful, and larger compared to Petrosia lignosa on Togean Island (Wilson, 1925), The Gulf of Thailand (Putchakarn, 2014), San Francisco (Thacker et al., 2013), and Brazil (Leal et al., 2017).

Differences of Olele's *Petrosia lignosa* and other areas are distinguished by the morphology of their environment. Petrosia lignosa in the Olele area grows on the morphology of the fore reef slope with depths ranging from 20 meters and steep slope morphology. This condition makes the reef slope morphology not influenced by shallow sea waves, making it an ideal area for the growth of the *Petrosia lignosa* species. This can be seen in the 3D bathymetry model of the Olele area. The steep fore-reef slope morphology contributes to the uniqueness of the color, shape, pattern, and size of *Petrosia lignosa* of Olele compared to other areas with relatively gentle slopes under the sea.

Table 2. Comparison study of *Petrosia lignosa* species.

Species	**Researcher**	**Color**	**Shape**	**Style**	**Size**	**Location**
Sponge Petrosia Lignosa	Allen, 2006; Jones, 2014	Dark brown, green, light gray	Elongated like a cone, the surface pattern is intricate and artistic.	Salvador Dali	Up to 3 meters	Olele, Gorontalo
Sponge Petrosia Lignosa	Wilson, 1925	Dark brown, gray	Elongated like a cone	Irregular	310 mm	Togean, Central Sulawesi
Sponge Petrosia Lignosa	Putchakarn, 2014	Dark brown	Extends upwards like a cone	-	-	Gulf of Thailand
Sponge Petrosia Lignosa	Thacker et al., 2013	Dark brown	Extends upwards like a cone	-	-	San Francisco
Sponge Petrosia Lignosa	Leal et al, 2017	Dark brown	Extends upwards like a cone	-	-	Brazil, Atlantic Ocean

Based on data and satellite image modeling and marine studies, four potential ecosites of the Olele area were obtained. The Olele ecosites consists of the Salvador Dali ecosite, the coral ecosite, the Goa Jin ecosite, and reef conservatory area.

3.3. 3D Model of Olele eco-geotourism area

The 3D model of Olele's area is obtained from combining topographic 3D models, bathymetric 3D models, and geomorphology of Olele's area (figure 7). The 3D model of the Olele area is used as the basis for making a 3D model of the Olele Eco-Geotourism area. The 3D model of the Olele eco-geotourism area design focuses on the village of Olele as the center of eco-geotourism area.

Olele 3D model obtained from combining 3D topographical and 3D bathymetry of Olele. This 3D model is then combined with Olele lineament analysis results (Abduh et al., 2020) to make the 3D model of Olele's eco-geotourism area design. This 3D model is a proposed design of the Olele future eco-geotourism area. Olele's eco-geotourism area design is based on the principles of conservation, education, and mitigation.

Olele area presents exotic natural landscapes, such as views of the open seas, steep volcanic hills, solutional hillside slopes, and fluvio-marine plains so that it can be optimized by building a landscape observatory point on open land in the surrounding hills. The peak of this landscape observation can also be an assembly point for tsunami disaster evacuations. The Olele eco-geotourism area has 6 potential sites consisting of Ancient Volcanic geosite, Shallow Sea uplift geosite, Coral ecosite, Goa Jin ecosite, Salvador Dali ecosite, and reef conservatory areas. The detailed proposed design of the Olele eco-geotourism area is divided into four sectors, including the central sector, the north sector, the south sector, and the diving sector (figure 8).

The central sector is the center area of the village. The design proposed in this area includes the eco-geotourism gallery, souvenir shops, and local culinary delights, as well as a sediment trap reservoir that reduces the supply of sediment to the sea to preserve the coral reef ecosystem of Olele. The north sector includes cottage/villa areas, ancient volcano geosite, reef conservatory area, and landscape observatory point. The South sector includes shallow sea uplift geosite, corals ecosites, and landscape observatory point. The diving sector includes the Goa Jin ecosite and the Salvador Dali ecosite (figure 9).

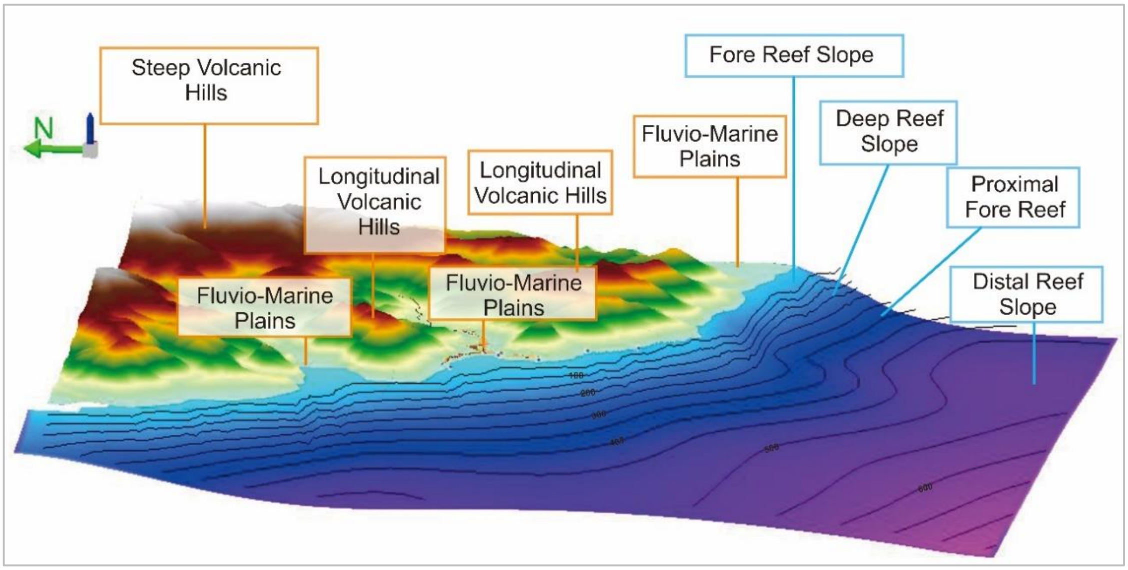

Fig. 7. 3D model of Olele.

Geosite and the ecosite in the Olele area can be a means of education for tourists, the public, and academics regarding the history of formation and the ecosystem of the Olele area. Therefore, at Olele geosite and ecosite sites conservation steps need to be applied so that their sustainability can be maintained. From the disaster mitigation aspect, this area needs evacuation steps for geological disasters, especially landslide disasters and tsunami. The north and south sectors are far from main road access, so there is a need for additional evacuation routes that are easily accessible and located near the north and south sectors. This is what underlies the design of the spot landscape observatory point. This spot serves as a gathering point. Lineaments density map shows that this spot is on a ridge which is composed of volcanic breccia rock which is relatively stable (Abduh et al., 2020) so that it can provide security for tourists and the community. The geological structure control indication on the lineaments density map affects the openings at Jin Cave.

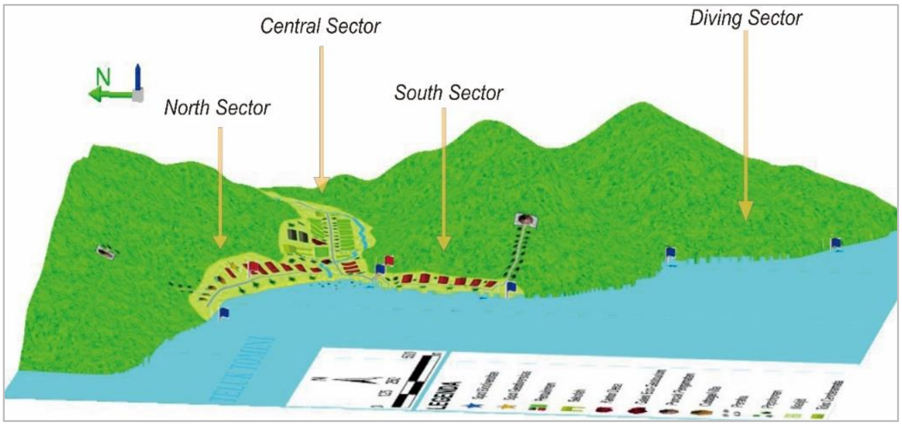

Fig. 8. 3D model Olele's eco-geotourism area design.

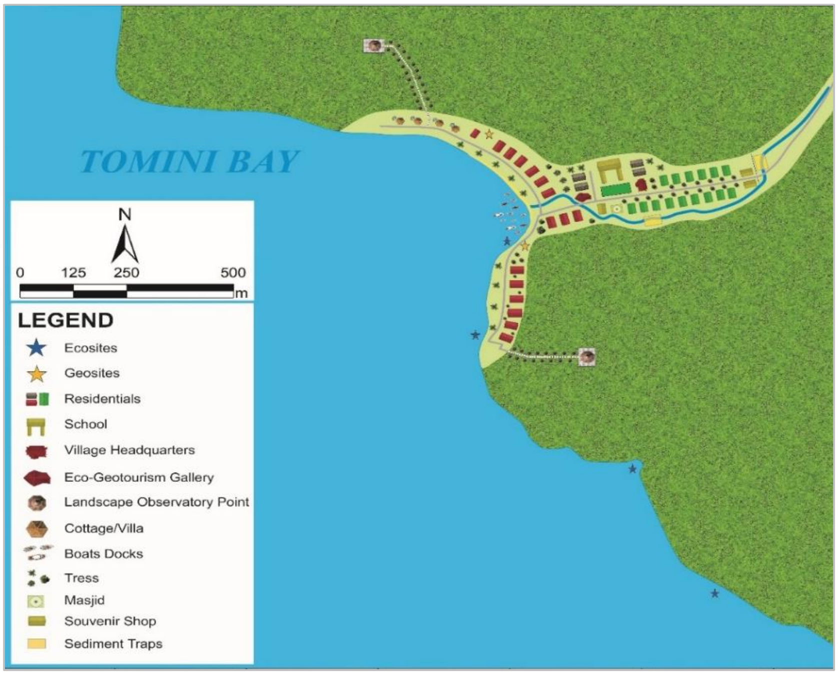

Fig. 9. Olele's eco-geotourism area design.

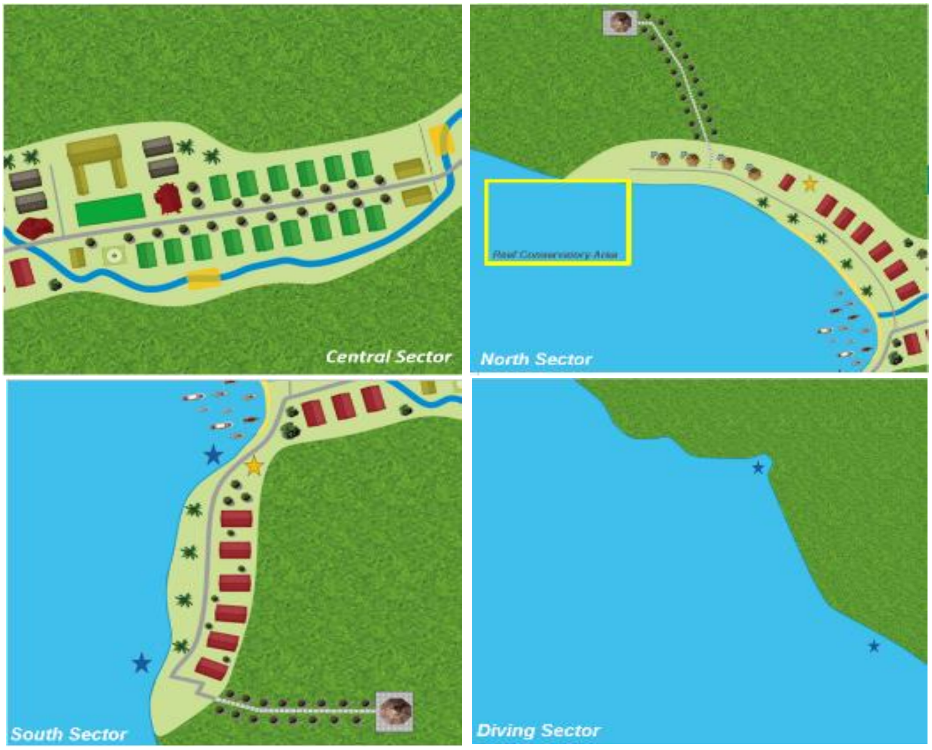

Fig. 10. Detailed development sectors of Olele's eco-geotourism area design.

Conclusion

3D modeling of the Olele eco-geotourism area design has been carried out by integrating satellite image data technology with geological and marine studies. Satellite image data technology not only produces terrestrial topographical models, submarine bathymetry models, slope class, and lineaments density but is also able to show the relationship between openings in Jin Cave with control structures on land and the unique relationship between Petrosia lignosa and the Olele underwater carbonate shelf model. Based on the identification and comparison of geosite and ecosite, the Olele area is unique on a local, national, and international scale.

Acknowledgments

We deliver our big appreciation to KEMDIKBUD as a funding sponsor of this research. Big thanks to all parties involved in helping this research to be done.

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