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Research Article

Comprehensive integration system of saltwater environment on Rote Island using a multidisciplinary approach

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Abstract: Rote Island is one of the islands in southern of Indonesia. This region experiences very high geological and geodynamic processes. This is evidenced by the abundance of seabed rising, and there is a dead sea lake area that has a higher salinity than the sea. Biodiversity on Rote Island has endemic and unique flora and fauna. This study aims to create an integrated system of inland waters resources on Rote Island with a multidisciplinary approach. Inland water resources on Rote Island number more than 80 lakes and ponds. An inland water resource on Rote Island is a saltwater environment. The extraction of geobiophysical information on inland water resources is needed by studying various aspects of multidisciplinary. The aspects studied are limnology, water quality, conservation of forest resources, geology, geodynamics, water resources, geodesy and geomatics engineering. All geobiophysical information needs to be integrated into an integration system. This is useful for efficiency and effectiveness in the utilization of data and information. This integration system (geovisualization) is in the form of WebGIS and storytelling maps. This integration system is dynamic so it can update its latest spatial information. This integration system can be used to promote Rote island tourism. This integration system can be accessed via the website geopark4rote.com. This integration system can be applied in other regions so reached one map policy and a system for inland water resources will be realized in Indonesia.

Keywords: *geopark4rote.com, inland waters, integration system, a multidisciplinary approach, Rote Island*

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Introduction

The territory of the Republic of Indonesia is composed of waters and many large and small islands with more than 17,000 islands, scattered by forming strands as a result of the geological convergence process of some of the crust of the earth's crust that forms it. This process, along with natural events related to weather-climate and ocean dynamics, produces various forms and conditions of nature with various quantities and types of natural resource content. Based on its location and genes, Rote Island is in the range of threats of various extreme events from geological, marine and atmospheric dynamics, and anthropogenic pressure. Rote Island is in East Nusa Tenggara, it is geology, and geodynamic series of Nusa Tenggara islands (Purwandono et al., 2018). Circumstances in inland aquatic ecosystems, including existing lakes, must be assessed for their carrying capacity and potential for tourism target areas set by their local governments.

In the waters of Rote Island, there are coral reefs to hold and break the wave energy coming to the beach. Seaweed coated with sediment eroded from the ground so as not to carry down into the deep waters. Mangroves hold back the waves, while the rooting holds the island from abrasion. Mangroves with nipah and coastal plants (baringtonia) also filter saltwater into the land far away or otherwise lost meteoric freshwater flows into the sea.

The hypothesis of a geological process in the form of uplifting part of the land that produces dead sea lakes (lakes with high water salinity) is found on Rote Island. This is an interesting study that the lake has a unique character that is different from other lakes in Indonesia. The lake environment is dominated by the marine environment (shells, limestone, etc.) but there are freshwater fish such as tilapia and Betok fish.

Furthermore, Rote Island is a natural habitat for snake-necked turtles (*Chelodina mccordi Rhodin*) which is currently critically endangered. Changes in natural ecosystems and human activities led to a drastic reduction in the population of these turtles in the late 90s decade (Endarwin et al., 2005), currently (Kayat et al., 2015). Inland water resources on Rote Island number more than 80 lakes and ponds. An inland water resource on Rote Island is a saltwater environment.

Although it has enormous tourism potential, unfortunately, tourism on the island of Rote, primarily related to inland waters, is still less developed than its coastal tourism. For this reason, it is necessary to map tourism potential from lakes on Rote Island following unique features found in each lake. With the enactment of the Geospatial Information Law No. 4 In 2011, various spatial data related to inland water can be obtained from different data guardians. Thus, the development of a spatial-based information system can be carried out by combining various related data on inland waters throughout Indonesia. In addition, this study was also carried out as a preliminary study to map the lake that is suitable to become a snake-necked turtle's habitat on Rote Island. Visualization method in the form of storytelling map is used to display information about tourism potential, especially the lake in Rote Island.

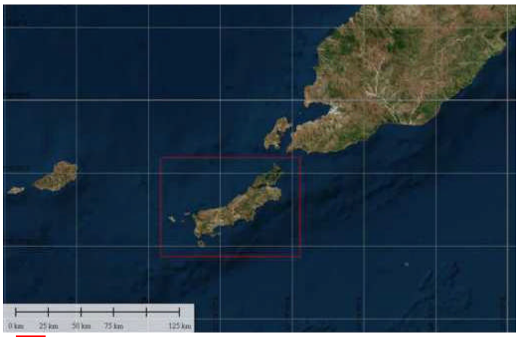
There are several challenges faced in the preservation of rote snake-necked turtles on Rote Island, including (1) Past time of poaching; (2) Habitat of *C. mccordi* outside the forest area; (3) The number of conversion habitats in the form of wetlands into agricultural lands such as rice fields and secondary crops; (4) Pollution of pesticides from agricultural land; (5) The population of livestock belonging to the community increases around the habitat; (6) The presence of predators in the habitat, namely cork fish (*Channa striata* (Bloch, 1792)).

For the needs of his life, the Rote snake-necked turtles require a wetland that is always watery as its habitat. However, the watery area, which is mostly in the form of lakes and swamps, has decreased in function as a result of human activities living around the lake/swamp. The loss of some habitats in the form of lake/swamp siltation and their conversion to agricultural land has caused the population to decline dramatically (Shepherd and Bonggi, 2005; Endarwin et al., 2005). Therefore, observation is needed to monitor the quality of the lake/swamp as a habitat for snake-necked turtles. So that it can be determined that several lakes are still feasible as their habitat, and become an alternative restocking location in the future. However, this study aimed to create an integrated system of inland water resources on Rote Island with a multidisciplinary approach. These approaches included limnology, water quality, conservation of forest resources, water resources, geology, geodynamics, geomatics engineering and others.

Material and Methods

The research location is located in the Dead Sea Lake area on Rote Island, see figure 1. Rote Island has many lakes that have unique characteristics. In the eastern part of Rote Island, there are several saltwater lakes which have very similar ecosystems to the sea, such as Oemasapoka lake, Oeinalaen lake, Oeapa lake, Bisaolifoe lake, Bisafooh lake, Oina lake, Tutui lake, Oekukura lake, and others. Lake Oemasapoka is the largest lake in the whole Rote Island, with an estimated total area of 1005 ha. This lake is also a saltwater-lake, meaning that the salinity of this lake is higher than a normal freshwater lake, or even higher than sea-saltiness. This lake has a higher salt content than seawater and is inhabited by marine biotas such as shellfish and jellyfish.

Geographically, Rote Island is located at 10° 25 '- 11° 00' South Latitude and 121° 49'- 123° 26' East Longitude (Rote Ndao Regency, 2018). Rote Island is located in southern Indonesia, southwest of Timor Island (see Figure 1). This geographical position causes Rote Island to be the southernmost island of the Republic of Indonesia. Rote Island itself consists of at least 94 large and small islands that are included in the area of Rote Ndao Regency. Because of its geographical position and topographic form, Rote Island has very diverse biodiversity.



research area

Figure 1. Rote Island

Likewise, the geological structure of Rote Island causes a variety of natural formations that are very interesting and have quite high tourism potential. Among the uniqueness found on Rote Island are many lakes scattered throughout the Rote Island region, from the west to the east. Some lakes on the island of Rote are unique; namely, their very high salt content makes some of these lakes as dead sea lakes (Nikodemus et al., 2004). The condition of the saltwater lake also allows the development of various unique animal and plant species, thus increasing the overall biological richness of Rote Island (Zitierung et al., 2012).

The method used in this study was remote sensing for preliminary surveys, field mapping surveys to check preliminary survey results and extraction of geobiophysical information directly in the field. Another method used was data integration, which collects all relevant geobiophysical information and was included in an integrated system of geographic information systems and storytelling maps.

In measuring the vertical water quality (water quality profile), a logger version CTD profiler was used with RINKO-Profiler optical fast DO sensors for surveys. As for measuring its depth, Hondex PS-7 Portable Depth Sensor was used with a maximum reading depth of 80 m. It also used the WISP 3 tool for measuring total suspended solid and light attenuation. Differential Global Navigation Satellite System (DGNSS) and Altimeter were used for geodynamics survey.

Figure 2 describes the process of creating a system of inland resource integration systems. The data used is remote sensing satellite imagery. The first process is to extract geobiophysical information consisting of limnology aspects, water quality, conservation of forest resources, geology, geodynamics, water resources, geodesy and geomatics engineering. Remote sensing is used for preliminary surveys, then mapping results are checked in the field to test the accuracy of the spatial information produced (Astaras and Oikonomidis, 2018). In the limnology aspect, a study was carried out related to lake morphometry conditions, salinity measurement, chlorophyll a, temperature, and other limnology parameters. In the aspect of water quality, mapping and measurements related to total suspended solid, light attenuation, and the boundary of lake surface area. This water quality used Landsat 8. Satellite water quality included Total Suspended Solid (TSS) and light attenuation. The results of the water quality mapping were then verified in the field using Rinko and WISP.

The aspect of conservation of forest resources examines the related flora and fauna found in the dead sea area of Rote Island. One of the endemic fauna on Rote Island is the Rote snake-necked turtles. Geological and geodynamic aspects of studying related to geological processes and vertical deformations that occur in Rote Island. In addition, it also mapped the formation process of the formation of dead sea lakes and elevation of the seabed, causing the evolution of flora and fauna. The aspect of water resources examines springs located around the dead sea lake area as well as mapping related to irrigation and surrounding agricultural land. All aspects of the study for the extraction of geobiophysical information are then combined into one integrated system in the form of geovisualization. All of these geobiophysical parameters are tested for accuracy in accordance with the mapping standards. If it has met accuracy tolerance, then system integration is done (Hernandez, 2015). The integration system chosen for this activity is geovisualization. Geovisualization that will be made includes WebGIS, WebMaps, and storytelling maps. All geo visualizations will display a thematic information portal for inland water resources. Figure 3 describes the location of measurements and testing of field tests related to water quality. There are two measurement locations. The first location is 200 m from the southern edge of Lake Oemasapoka. The second location is 350 m from the first location or 550 m from the southern edge of Lake Oemasapoka. Sampling points at station 1 and station 2 included the measurement of limnology and water quality parameters such as salinity, temperature, chlorophyll a, turbidity, Dissolved Oxygen (DO), Total Suspended Solids (TSS), and light attenuation. Measurement distance was around 550 m.

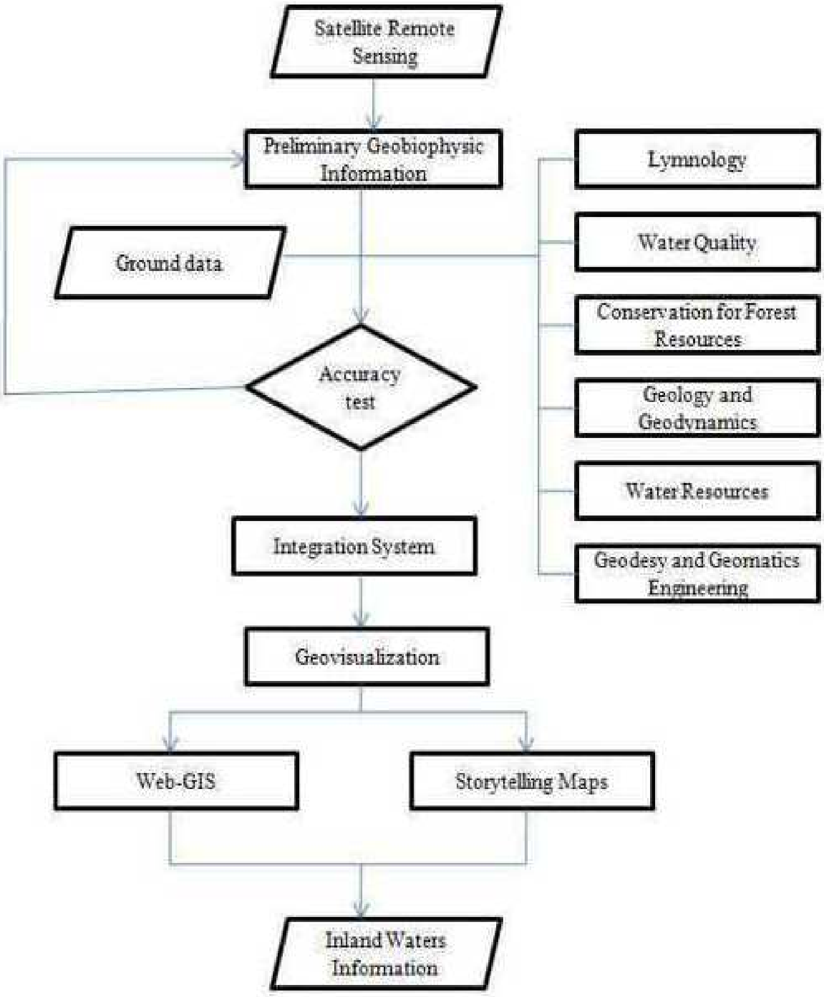


Figure 2. Research flowchart

Figure 3. Preliminary data survey results on Rote Island

Result and Discussion

The results of the integration system are geovisualization of the combined results of geographic information systems and storytelling maps.

Limnology aspect

Based on the type of formation, the lake can be divided into several types (Haryani, 2013), Dead sea lake area in Rote Island can be included in Faulted Lake type, but it has its uniqueness, which is high salinity water (above seawater salinity). There were two sampling locations at Lake Oemasapoka. Sampling could not be much because of inadequate ship transportation in this lake. Field measurements at station 1 include salinity, temperature, chlorophyll a, turbidity, and DO (see Figure 4). Salinity at point 1 is about 40 ‰ starting at a depth of 1-12 m.The temperature at point 1 is 29^0 C on the surface and then drops to 26^0 C at a depth of 1-12 m. Chlorophy a values stability at a depth of 1-11m and begins to increase at a depth of 11 m. DO, and turbidity values are also relatively stable at a depth of 1-12m. At station 2 also carried out field measurements for parameters of salinity, temperature, chlorophyll a, turbidity, and DO (see Figure 5. Salinity at point 2 is also worth around 40 ‰ starting at a depth of 1-16 m. The temperature at point 2 is slightly different compared to point 1. The temperature is $26{,}5^0$C on the surface and then rises to 28^0 C at a depth of 1 m. At a depth of 1-16 m, the temperature drops to 26.3^0 C. Chlorophy a values stability at a depth of 1-14m and begins to increase at a depth of 15 m. DO and turbidity values are also relatively stable at a depth of 1-12 m. The creation of an inland water resources integration system on Rote Island uses a multidisciplinary approach. The approach is in the form of limnology aspects, conservation of forest resources, aspects of water quality, aspects of water resources, aspects of geology and geodynamics. All of these approaches are combined into one integrated Rote Island inland water system. The results of this integration system are geo visualization of the combined results of geographic information systems and storytelling maps.

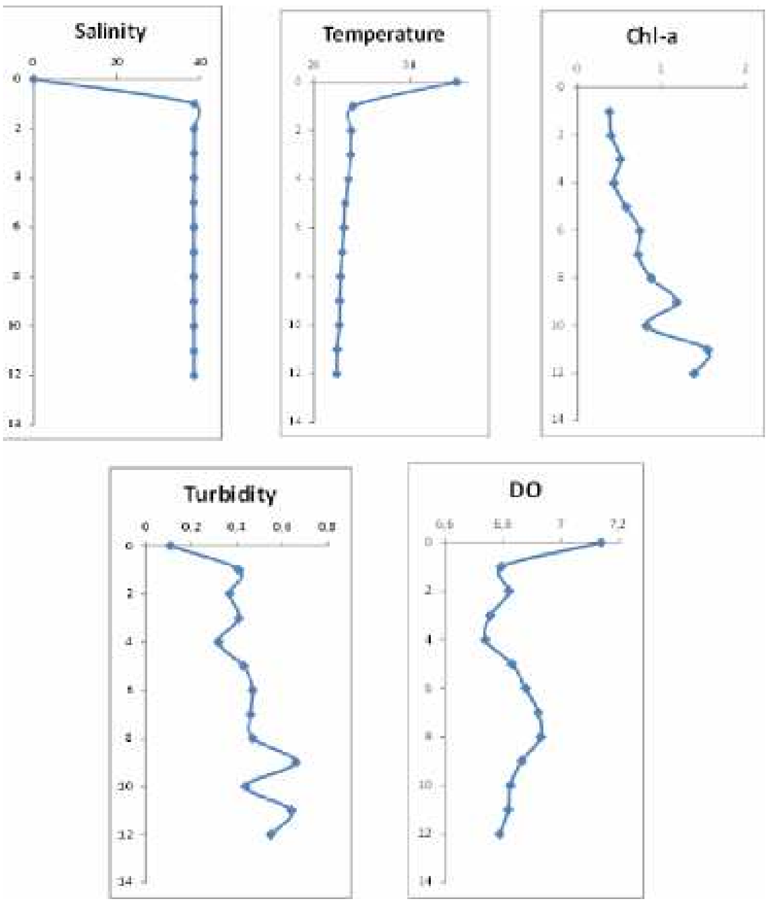


Figure 4. Ground measurement of station 1 in Lake Oemasapoka

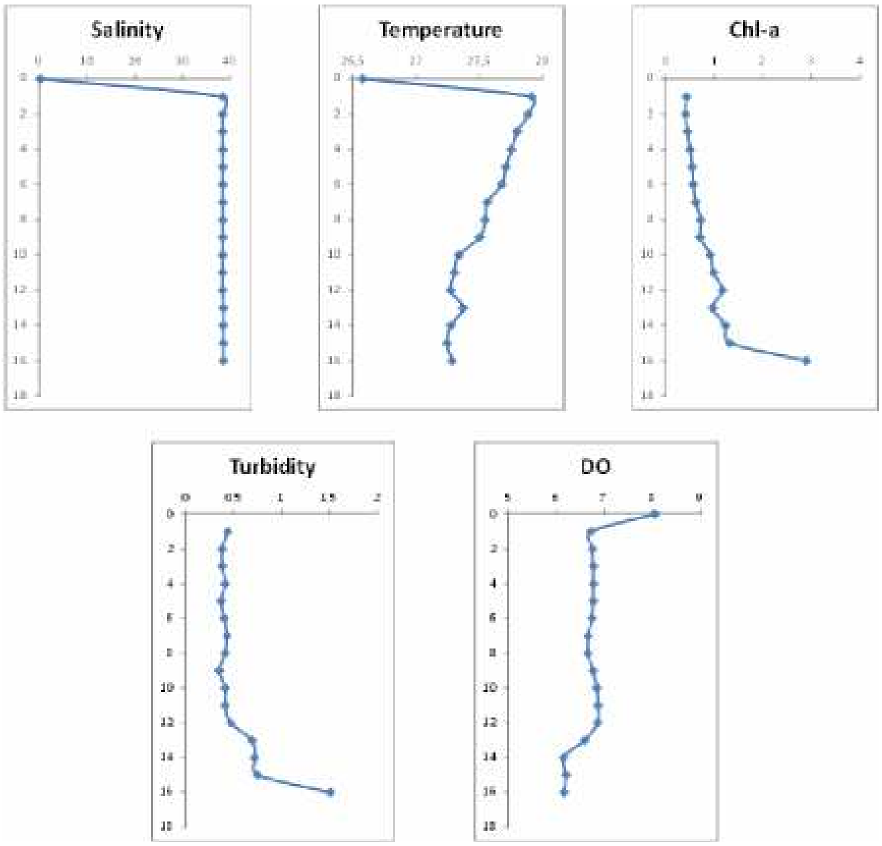


Figure 5. Ground measurement of station 2 in Lake Oemasapoka

From the measured data, salinity in the Dead Sea Lake is very high, ranging from 38 (‰) (see Figures 4 and 5). With DO values of > 6 mg / L to the bottom of the lake measured, biota/fish can still live at the bottom of the lake. Whereas the value of Chl-a and Turbidity is relatively small indicating that the quality conditions of the lake waters are still quite good. For reference, Lake Oendui was also measured, with a salinity of 0 (see Table 2), indicating that freshwater conditions and salinity in Oseli Beach are 34 ‰ indicating the condition of sea water (see Table 1). Of these two locations, confirmed that the Dead Sea Lake is unique in its condition.

Table 2 describes the measurement of salinity in Lake Oendui. In this lake, the salinity conditions have a value of 0 ‰. The uniqueness of this lake is located at a lower orthometric height compared to Lake Oemasapoka. Lake Oendui is bounded by coral hills to the south with the sea and coral hills to the north with Lake Oemasapoka.

Table 1. The ground measurement of Oeseli Beach

Depth (m)	Temp. (deg C)	Sal. (‰)	Density (kg/m^3)	Chl-a (µg/L)	Turb-M(FTU)	DO (mg/L)
0	25.713	0.158	996.981	0.16	0.05	8.160
1	27.314	34.02	1021.884	23.09	522.9	6.509

Table 2. The ground measurement of Lake Oendui

Depth (m)	Temp. (deg C)	Sal. (‰)	Density (kg/m^3)	Chl-a (µg/L)	Turb-M(FTU)	DO (mg/L)
0	30.66	0	995.448	-0.2	0.06	7.414

Water quality aspect

Water quality in this study includes TSS and light attenuation. Figure 6 describes the location of TSS and light attenuation measurements at Lake Oemasapoka and Lake Oeinalaen. The satellite imagery is obtained from the big data engine. Figure 7 describes the location of TSS and light attenuation measurement at Lake Oemasapoka and Lake OeiInalaen. The image is obtained from the big data engine.

Figure 6. Sampling station for water quality mapping

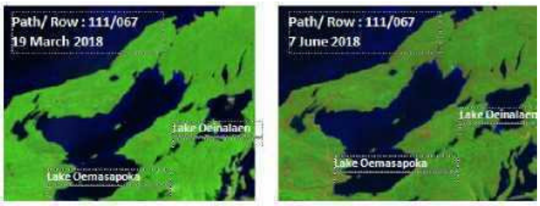
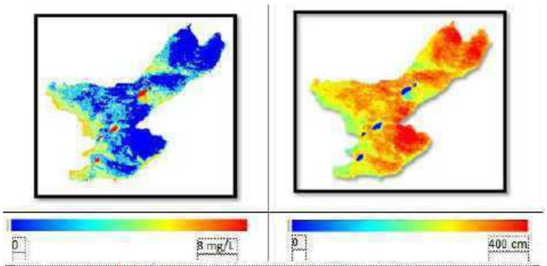


Figure 7. Landsat 8 for water quality mapping

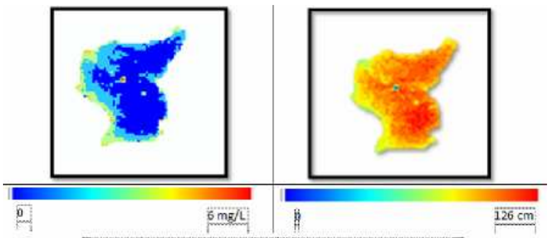
Water quality measurement uses Landsat 8 imagery with the date of acquisition March 19, 2018, and June 7, 2018. Landsat imagery is chosen for water quality monitoring because it can be applied on a national scale. Landsat imagery used must have been carried out by radiometric and geometric corrections. At Lake Oemasapoka, the TSS value obtained from the processing of satellite imagery ranges from 3-8 mg/L. Then this information is checked in the field. Field TSS values were obtained around 3-6 mg/L. The brightness value of the satellite image processing results ranges from 250-390 cm, while the field brightness value is around 210-345 cm. This water quality description of Lake Oemasapoka can be seen in Figure 8. The surface area of Lake Oemasapoka based on satellite imagery is obtained around 1170 ha.

At Lake Oeinalaen the TSS value obtained from the processing of satellite imagery ranges from 3.7 to 6 mg / L while the brightness value of satellite imagery processing ranges from 100-126 cm. The explanation of the water quality of Lake Oeinalaen can be seen in Figure 9. The surface area of Lake Oeinalaen based on satellite imagery is obtained around 120 ha.



No Station	Ground TSS (mg/L)	Image TSS (mg/L)	Ground Light Attenuation (cm)	Image Light Attenuation (cm)	Area (Ha)
1	8	6	250	210	1170
2	4	4	305	290	
3	6	4	270	255	
4	3	3	390	345	

Figure 8. Water quality of Lake Oemasapoka



No Station	Image TSS (mg/L)	Image Light Attenuation (cm)	Area (Ha)
1	6	100	120
2	5,6	119	
3	3,7	126	

Figure 9. Water quality of Lake Oeinalaen

Conservation of forest resources aspect

Observations at the Oemasapoka Dead Sea Lake showed a unique form of finding fauna of fish that usually live in fresh water, namely Tilapia (*Oreochromis niloticus*) and Betok fish (*Anabas testudineus* (Bloch, 1792)) and fish commonly found in sea or brackish water, namely glodok fish (*Periophthalmus sp.*), see Figure 10. Figure 10 explains that in Lake Oemasapoka there are freshwater fish namely Nila, Betok, and Glodok. Nila (Tilapia) in Figure 10 (a), Betok in Figure 10 (b), and Glodok in Figure 10 (c). In addition to water fauna, aves / water birds such as white storks (*Ciconia ciconia*), rice cormorants (*Phalacrocorax sulcirostris*), and grouse ducks (*Dendrocygna javanica*) were also found in the Oemasapoka Dead Sea Lake, Sipuk Village, Sotimori Village (10 units) and in the village of Nusa Paralain, Deaurendale Village (4 units).Observations in the Dead Sea Lake OeInalen found fish fauna that generally lives in fresh water, namely Tilapia (*Oreochromis niloticus*). In addition to the water fauna in the form of fish in the Dead Sea Lake OeInalaen. In

Lake Oemasapoka also found estuarine crocodiles (*Crocodylus porosus*). Like the Oemasapoka Dead Sea Lake, the water birds found were white storks (*Ciconia ciconia*), rice cormorants (*Phalacrocorax sulcirostris*) and grouse ducks (*Dendrocygna javanica*). Seen from the Rote snake-necked turtles, the two lakes are not suitable as their habitat because the water is not fresh (salt water). Whereas Rote snake-necked turtles are turtles that live in freshwater areas.

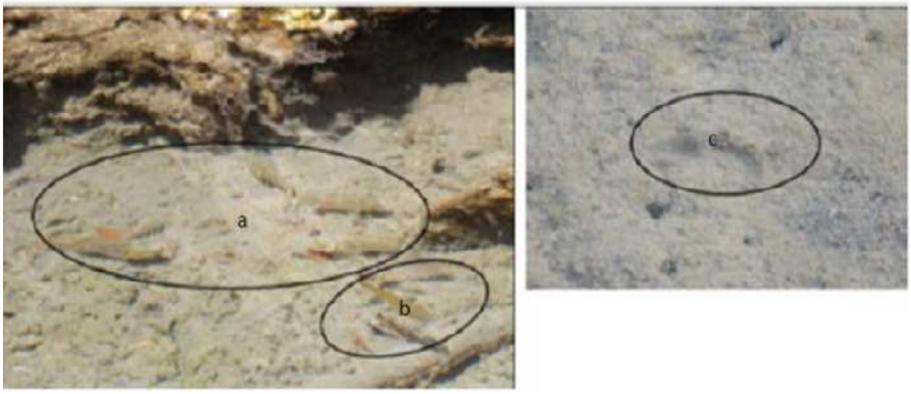


Figure 10. (a) Nila fish, (b) Betok, (c) Glodok

Observations on Lake Oendui found the potential for feeding Rote snake-necked turtles in the form of fish fauna that usually lives in freshwater namely tilapia (*Oreochromis niloticus*), mas, and cork. There is no protective vegetation in the lake water body, and there are only a few types of aquatic plants like hydrilla and water jug. Around the lake, many livestock is owned by people who graze and drink water from the lake, such as sheep, goats, horses and cows. In the southern part of the lake, there is space utilization for agricultural activities.

Observations on Lake Lendeoen found fish fauna that usually lives in fresh water, namely tilapia (*Oreochromis niloticus*), correct, and shrimp. In addition to the water fauna in Lake Lendeoen also found aves water birds namely grouse ducks (*Dendrocygna javanica*). Observation results at Lake Hela Lake are located in the area Sedeoen Village West Rote District. During the dry season has an area of 28.39 ha, with a depth of 1.5 m and during the rainy season can reach 4 m. This lake has the potential of carp, tilapia, eel, shrimp, sun, cork, and catfish. There is no dominant cover, and there are only a few palm trees. Around the lake, there are cattle and goats. Other community activities on this lake are fishing.

Observations in all of the inland waters on Rote Island, which are still feasible as Rote snake-necked turtle's habitats are only three, namely Lake Ledulu, Lake Lendeoen, and Lake Peto (Kayat et al., 2015). Lake Ledulu is located in Daiama Village and Lake Lendeoen in Deaurendale Village, Landu Leko District, while Lake Peto is in Maubesi Village, Rote Tengah District.

Kayat et al. (2012) survey result showed that Lake Ledulu has an area of about 7.6 ha. Lake Ledulu is surrounded by secondary forests, and in the western part is bordered by quite high cliffs along the west side of the lake (Figure 11). In the Ledulu Lake body, many plants are tolerant to standing water (Figure 12). The water has a pH of around 6-7. While the water is clear, so there is no measurement of turbidity. Water plants in Lake Ledulu are dominated by 3 types, namely hydrilla (*Hydrilla verticillata*), anabaena (*Lemna sp.*), and tunjung (*Nymphaea lotus* L.) with INP values of 92.0%, 89.9%, and 33, respectively. 5%, while tifa (*Typha angustifolia*) although overall does not dominate the Lake Ledulu area but in some places clustered quite a lot so that it seems dominant in certain regions. The potential of turtle feed in Lake Ledulu is cork fish, frog, tilapia, bro, and catfish. However, if it is already large, cork fish is a severe threat to turtles because of its potential as a predator.

Figure 11. Lake Ledulu from satellite imagery 2017

Figure 12. Habitat conditions of Rote snake-necked turtles in Lake Ledulu (Kayat et al., 2010)

The next natural habitat is Lake Peto. Eastern of Peto Lake is bounded by rice fields and mamar, and the northern part is bounded by paddy fields and secondary forests, the western part is bounded by rice fields and land shrubs, and the southern part is bounded by rice fields (Figure 13).

Figure 13. Lake Peto from satellite imagery 2017

During the rainy season, Lake Peto has a surface area of about 77.48 ha. Lake Peto has clear water and pH 7. The potential for turtle feed is beunteur, catfish, botok, impun, cork, and frog. Cover in Lake Peto area is woody plants which are dominated by eucalyptus species (*Melaleuca cajuputi*) with INP 300 values and aquatic plants such as tifa (*Typha latifolia*), hydrilla, tunjung, and others (Figure 14). The space around Lake Peto is rice fields in the west, south and east, while the northern part is land.

The last lake that is still suitable as a habitat for Rote snake-necked turtles is Lake Lendeoen. Kayat et al. (2015) survey result showed that Lake Lendeoen has an area of about 30.5 ha. Lake Lendeoen has clear water and pH 7. The lake is surrounded by secondary forests, community gardens, and in the western part bordered by cliffs (Figure 15). Just like Lake Peto, Lake Lendeoen is dominated by woody plants such as eucalyptus and on the edge of the lake is overgrown with aquatic plants, such as tifa, hydrilla, tunjung, and others (Figure 16). The potential for feed in Lake Lendoen is tilapia, right, and shrimp. Observations by Kayat et al. (2015) from some Rote snake-necked turtle's habitat in the form of lakes, springs, and rivers in the Rote Island region from the West to the East showed that a large part of the Rote snake-necked turtle's habitat has decreased in size according to suitability habitat components in each of these habitats.

Figure 14. Habitat conditions of Rote snake-necked turtles in Lake Peto (Kayat et al., 2012)

Figure 15. Lake Lendeon from satellite imagery 2017

Figure 16. Habitat conditions of Rote snake-necked turtles in Lake Lendeon

Only the three lakes above still have opportunities as natural habitats that are still good. However, it is necessary to develop habitat on two lakes, namely Ledulu and Peto. Habitat development that is needed is to eliminate predatory fish species, namely cork fish.

Water resources aspect

Rote Island in a climate zone including dry climate conditions with very limited water resources potential. However, based on a study conducted by Hatmoko et al. (2018), irrigation security in this region is included in the medium category, better than Banten, Bali and Lombok. One of the causes is the water usage index which is relatively lower than in other regions. The density and activity of the population on this island has not been too intensive. This also shows that there are still high opportunities to harmonize efforts to improve the welfare of the population with natural conservation. Based on the results of a field survey, the main water source on Rote Island comes from rain collected both in shallow aquifers (springs) or lakes, reservoirs and ponds. With a limited amount of rainfall and catchment area, no large river can flow water continuously in the dry season.

Agricultural activities are generally carried out during the rainy season at the beginning of the year. However, in certain areas where there is a supply of irrigation for springs, agricultural cultivation can almost be done throughout the year. One of these areas is land that is irrigated from the Oemau spring (Figure 17). Irrigation water is still available in the dry months even after most of the water discharge is pumped for local water agency water supply. This is in stark contrast to the condition of other lands that do not get irrigation water supply other than springs (Figure 18).

Figure 17. The condition of Oemau Spring (left) and irrigated land (Right)

The land and most of the reservoirs and reservoirs were observed in dry conditions at the time of the survey. Based on data from the Central Bureau of Statistics of Rote Ndao Regency (2018), the area of irrigated (semi-technical and simple) rice fields on Rote Island is 5022 ha and the harvest area in 2017 is 7952 ha. Thus, the cropping index is 1.58 (100% of the land can be planted in the rainy season, and 58% of the land can be planted in the dry season). This value is quite good when compared to data from the Ministry for general work and public housing in 2014 where the cropping index on surface irrigated land in Indonesia is 1.4 - 2.3. The discharge of a large enough spring even in the dry season is of course not free from the condition of the land and catchment areas which are still preserved. Preservation of water catchment areas is needed not only for irrigation but also for maintaining the condition of the ecosystem, especially the lake.

Figure 18. Land conditions that do not get irrigation supplies from springs

In addition, there are also freshwater lakes that can become endemic wildlife habitat of Rote Island, which is the Rote snake-necked turtle. The lake is a natural habitat that is currently degraded, both due to pollution and grazing (Endarwin et al., 2005). The Ministry of Environment and Forestry is now carrying out conservation efforts in the form of breeding and release back to nature.

The success of efforts to make tourism and conservation destinations are of course highly dependent on the sustainability of the lake ecosystem. From the aspect of water resources, the study of the potential of water resources is needed to understand the phenomena that occur and formulate water resources management policies needed to ensure ecosystem sustainability. The study can be done through measurements in the field or modelling to formulate Best Management Practices in the management of water resources.

One method that can be used to communicate the results of the study of water resources is Water Budget. Water Budget is used to evaluate the availability and sustainability of water resources by presenting inflow and outflow values in an area, including evapotranspiration, rain, surface flow, and groundwater flow (Healy et al., 2007). In very limited data conditions, the formulation of components in a Water Budget can be done using integrated remote sensing data and hydrological modelling (Gao et al., 2010; Sheffield et al., 2009; Smith and Pavelsky, 2009; Srinivasan et al., 2010). Based on available climatological data, rain components and evapotranspiration are now being formulated. Data of air humidity, temperature, wind speed, and irradiation time are processed into reference evapotranspiration (ETo) values using the Penman-Monteith method (Allen et al., 1998; Gao et al., 2010). ETo is converted to evaporation (evaporation from the surface of the water) using a coefficient (kc) of 1.1 (Jensen, 2010). The results obtained are as in Figure 19. Based on these data, it appears that rain exceeds evaporation only in wet months (December, January, February, and March). In other months, evaporation far exceeds rain. The total rainfall for one year is 1748 mm, and evaporation is 1623 mm. In general, it can be estimated that there will be a reservoir filling in the wet month and a reduction in the reservoir in addition to wet months. However, there is a tendency for an annual surplus of 125 mm. Comprehensive analysis needs to be carried out further by estimating other components (hydrology flow) through the process in according to the characteristics of each lake.

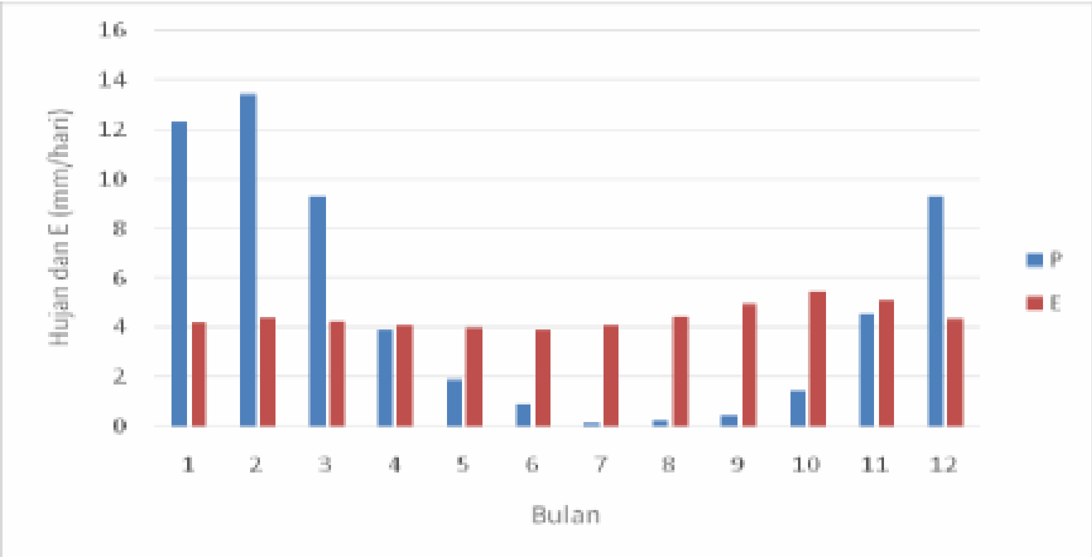


Figure 19. the average of rain (P) and evaporation (E)

Geology and geodynamics aspect

The unique combination of geologic activities, rock formation and many other variables resulted in a one-of-its-kind condition as a saltwater lake. In addition, due to saltiness and warm climate on Rote Island, this lake has several unique and endemic flora and fauna. Figure 20 describes the related high model made from remote sensing satellite data processing. This high model includes Digital Terrain Model (DTM) and bathymetry. DTM is made using ALOS PALSAR and DEMNAS Interferometry integration. Vertical accuracy of ~ 1m after high difference test in the field. Bathymetry is made from Geodetic satellite integration. This bathymetry has not been tested for the height difference.

The real geological uniqueness that seen in Rote island are high salinity in dead sea lakes, live freshwater fish in salt lakes, the geological environment in those lakes is ocean waters (rocks, shells, etc.), mangrove in a hill that located far from water, and very dominant geological process. In Figure 21 there is a mudflow that dries around the dead sea lake area. The mud forms a vast expanse so that it is overgrown with grass and thickets. This is one of the effects of deformation that forms new land.

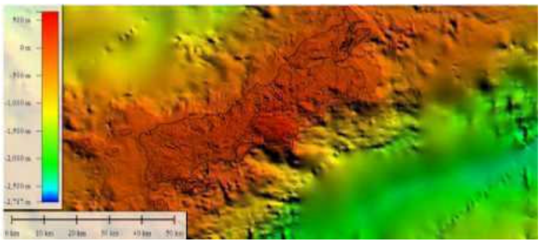


Figure 20. Height model (DTM and bathymetry) of Rote islands from satellite data processing

In Figure 22, there are mangroves on the hill far from water sources. This is the impact of vertical deformation due to rising seabed. This causes new land to form; flora and fauna will evolve due to adjusting environmental conditions. In Figure 23, the seabed will appear to close and be ready with a new trap in the inland sea. If new landforms and closes the inland sea, new dead sea lakes will form and have the potential to have a higher salinity than seawater.

Figure 21. Mudflow (dried) around of Dead Sea Lakes.

Figure 22. The mangrove is elevated to the hill (vertical deformation)

Figure 23. Seabed is being raised to land (vertical deformation)

In Figure 24, the seabed appears to have increased, and a fault occurred due to the deformation of the mixture between horizontal and vertical. One of the impacts of cracks on the seabed being lifted is mangroves and other water vegetation being lifted into new land. Figure 25 describes the rise of the seabed, causing mangroves to be lifted up and away from water sources. This increase is caused by vertical deformation. If vertical deformation continues to occur in Figure 25, then it can cause the evolution of mangroves far from water sources as shown in Figure 22.

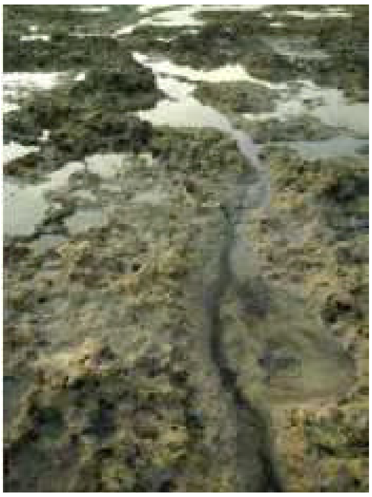


Figure 24. Seabed suffered cracks (mix deformation)

Figure 25. Mangrove in the seabed is elevated

Geodesy and geomatic engineering aspect

This aspect was focused in Web Based Geographic Information System (WebGIS) and storytelling maps. The integration system (geovisualization) created includes WebGIS and storytelling maps. This integration system is dynamic so that it can update its latest spatial information. WebGIS Rote Island is compiled on the online ArcGIS platform and contains various layers that have been created previously. This WebGIS serves as a foundation when developing storytelling maps. WebGIS created has a simple interface and several functions of analysis and visualization. Some functions that can be used on the Rote Island WebGISinclude measurement, layer filter, layer depiction, time slider and swipe. In addition, the additional data function can be used to add data from various sources connected to Indonesia's spatial data infrastructure. For example, regional planning data from East Nusa Tenggara Province can be added from the http://gistaru.atrbpn.go.id/ network as guardians of spatial data in the area. Figure 26 describes WebGIS Rote with active slide time function. This function is useful for viewing region changes with multitemporal satellite imagery. Besides the analysis function, this Rote Island WebGIScan also is used as a spatial data source for use by various relevant agencies and stakeholders. Layer availability with verified information, such as lake toponimi, can be used as a reference in decision-making. Another function of the Rote Island webgis is as an information centre for research and tourism. By using functions such as swipe, web users can make comparisons between topographic data from DEM with satellite imagery so that a variety of information can be obtained. This website can be accessed via the *geopark4rote.com/webgis* address. Figure 27 describes WebGIS Rote with swipe function. This function is useful for comparing two different parameters in the same region at the same time.

Figure 26. WebGIS Rote Island with active slider time function

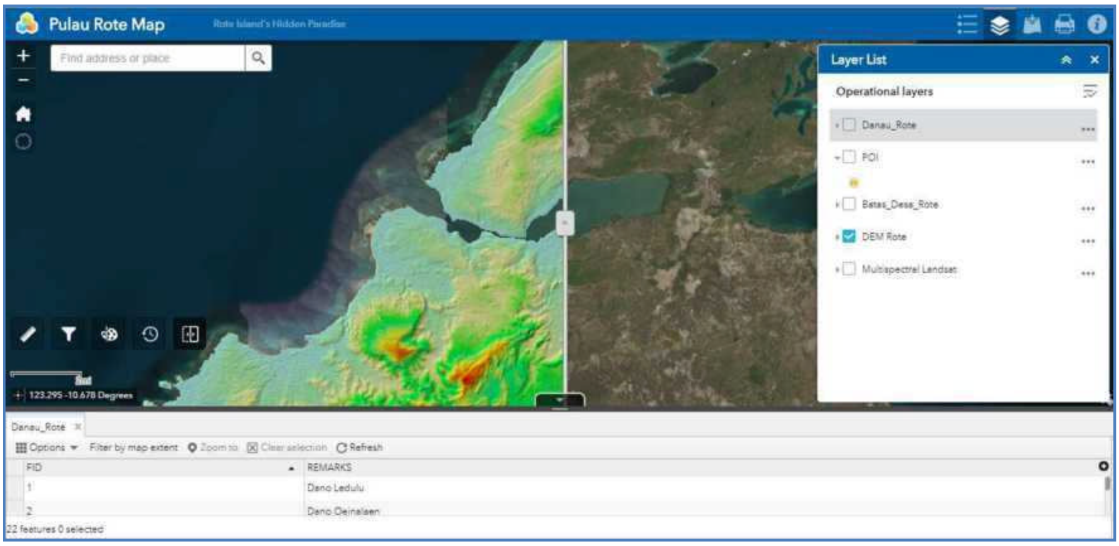


Figure 27. Swipe function in WebGIS of Rote Island

Storytelling maps

Storytelling maps is a story-based or narrative-based visualization method. By displaying research data in a narrative form, website users can more easily understand the message to be delivered. This storytelling maps on research expeditions on Rote Island can be accessed through the geopark4rote.com address. The view of Rote Island's storytelling maps can be seen in Figure 28**.** The storytelling map that has been compiled combines spatial data and non-spatial data that have been obtained through surveys. Narratives in the storytelling map are compiled based on the results of literature studies and interviews with local residents. In addition to highlighting the uniqueness of several lakes on Rote Island, the Storytelling map also provides initial information about Rote snake-necked turtles which are endemic animals on the island. In the narrative storytelling map is given the location of the lake that matches the habitat of the animal to raise awareness to maintain the ecosystem on Rote Island, especially in the lakes that become their habitat (see Figure 29).

Figure 28. Storytelling maps "Expedition Oe"

The storytelling map that has been compiled combines spatial data and non-spatial data that have been obtained through surveys. Narratives in the storytelling map are compiled based on the results of literature studies and interviews with local residents. In addition to highlighting the uniqueness of several lakes on Rote Island, the Storytelling map also provides initial information about Rote snake-necked turtles which are endemic animals on the island. In the narrative storytelling map is given the location of the lake that matches the habitat of the animal to raise awareness to maintain the ecosystem on Rote Island, especially in the lakes that become their habitat (see Figure 29).

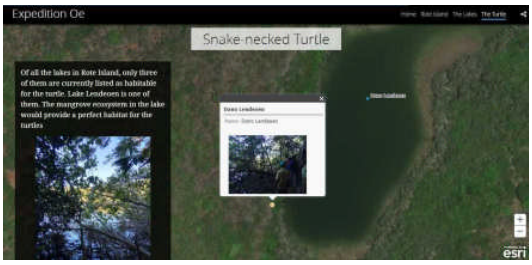


Figure 29. Information of Snack necked turtle of Rote in Storytelling Maps

Rote Island has much uniqueness that has enormous tourism potential. Even so, the magnitude of the tourism potential has not been fully utilized properly. This research was the initial stage in exploring various facts that can attract tourists. The presentation of Rote Island information in the form of maps facilitates spatial analysis carried out by combining information from various agencies. With the development of WebGIS, it will be possible for data obtained from various agencies to be analyzed on a single platform, as well as documentation of future research. The results of the study were also published in the form of storytelling maps sourced from research results that had been obtained and supplemented with information from local residents. In the form of a linear narrative, the storytelling map also contains interactive maps that can be used to get more information about the spatial distribution of various tourist objects and points of interest on Rote Island. Thus, the construction of storytelling maps is expected to have two advantages, namely as a media for disseminating research results as well as a means to attract tourists. This integration system is one example of a system of inland water resources integration in Indonesia. This can also be applied in other regions so reached one map policy and a system for inland water resources will be realized in Indonesia.

Conclusion

The integration system of inland waters resources can be made with a multidisciplinary approach. These approaches included limnology, water quality, conservation of forest resources, water resources, geology, geodynamics, geodesy geomatics engineering and others. All of these multidisciplinary approaches produce geobiophysical information extracted from remote sensing satellites. The integration system (geovisualization) created includes WebGIS and storytelling maps. This integration system is dynamic so that it can update its latest spatial information. This integration system can be used to promote Rote island tourism. This integration system can be accessed via the website geopark4rote.com. This integration system can also be applied in other regions so reached one map policy and a system for inland water resources will be realized in Indonesia.

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