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Realizing the Dead Sea Lakes Region in Rote Islands to be a geopark using multidisciplinary spatial information approach

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Abstract. Rote Ndao Regency is the southernmost region of Indonesia bordering Australia and Timor Leste. This regency has varieties of unique and endemic geology, biodiversity and inland waters. The regency has some 80 lakes where around 20 are saltwater lakes. The salinity of these lakes exceeds the salinity of seawater. The majority of these saltwater lakes are located in the Dead Sea Lake Region of Rote islands. Geologically, the islands have mixed deformations that move vertically and horizontally and are lifted partially from the Australian continent. The biodiversity in this region is also unique as there is a Roti snake-necked turtle that enters endangered animals. There are also unique mangroves conditions that live far from water sources due to vertical deformation. Rote Ndao also has areas of peat coal that are mixed with saltwater areas, freshwater areas, and brackish water areas. Remote sensing can be used to help effectively and efficiently in geological, biodiversity and inland waters mapping. This study aims to inform the related spatial information of the frontier region of Rote Ndao with the use of multidisciplinary remote sensing to realize Geopark. This multidisciplinary approach in remote sensing applications is used to obtain spatial information based on geo-biophysical and classification parameters. Data used in the form of ~ 65-70% remote sensing data and ~30-35% non-remote sensing data. Remote sensing data in the form of Landsat, Sentinel, WorldView-2, Planet, Grace, Goce, Champ, and others. This multidisciplinary approach includes remote sensing, geodesy, geology, limnology, biodiversity, water resources, forest conservation, and geo-informatics. The uniqueness of geology and biodiversity in the Dead Sea Lake Region of Rote is expected to make this region become a Geopark.
Keywords: Rote Ndao, Remote Sensing, Multidisciplinary, Spatial Information, Geopark

1. Introduction

Geopark is an area that has geological elements in which local people are invited to participate to protect and enhance the function of natural heritage, including the archeological, ecological and cultural values that it contains [1]. The initial purpose of Geopark was to protect the geological heritage in European countries by a non-governmental organization called Europe Geopark Network (EGN) in 2001. The existence of Geopark by the United Nations Educational, Scientific and Cultural Organization (UNESCO) was developed and facilitated by forming the Global Geopark Network (GGN) organization in 2004 to be able to accommodate more members from countries in the world [2]. Besides, the purpose of the Geopark is to be further developed, not just to protect geological heritage [3]. According to UNESCO [1], Geopark aims to benefit, explore, appreciate and develop the geological heritage as well as Biome Preservation [4].

According to UNESCO, the main elements in Geopark have divided into 3 namely geodiversity, biodiversity and cultural diversity [2]. The concept of Geopark according to UNESCO is economic development in an established manner through geological heritage or geo-tourism [4]. Geoparks aim to protect the diversity of the Earth (geodiversity) and the conservation of the environment, education and broad geography [5].

As a region, Geopark must have firm and real boundaries. Geopark surface area must also be sufficient, in the sense that it can support the implementation of the action plan development activities. Geopark contains several geological sites (geo-site) that have meaning in terms of science, scarcity, beauty (aesthetics), and education [1].

Geopark activities are not limited to geological aspects, but also other aspects such as archeology, ecology, history, and culture. The geological site making up the Geopark is part of the Earth's heritage. Based on the meaning, function and opportunity of the utilization of the existence and sustainability of these sites need to be maintained and protected. The objects of inheritance of the Earth in Geopark have the opportunity to create economic value. The development of local economies through nature-based tourism activities (geology) or geo-tourism is one option. The implementation of Geopark tourism activities in a sustainable way is interpreted as activities and efforts to balance economic development with conservation efforts [2]. Geopark development in an area will have a direct impact on humans who live in and around the region. The concept of Geopark allows people to remain in the area, namely to reconnect the values of the Earth's heritage to them. The community can actively participate in the revitalization of the region as a whole. In the activity of protecting natural heritage objects from damage or deterioration in environmental quality, the Geopark area becomes a testing ground for the methods of protection that are put in place [4]. Besides, the Geopark area is also fully open to various scientific and technological research and research activities.

Remote sensing is the science, art, and technique for obtaining information on an object, area, and/or phenomenon through the analysis of data obtained with a device without having direct contact with the object, area, or phenomenon being studied [6]. In principle, every object and natural phenomenon in the earth's surface can be detected from satellite imagery [7]; [8]. The ability of satellite images to detect objects and natural phenomena that occur is very dependent on the resolution, both spatial, spectral, radiometric, and temporal [7]; [9]. This study is used to create a multidisciplinary integration system of inland water. It is also useful for the benefit of local residents, the Rote Ndao Regency government, and the central government. In this research, we will be discussed related to the ideals to realize the Geopark Rote with the approach of Geodesy, Geology, Limnology, Biodiversity, and Geo-informatics (Geomatics). This study aims to inform the related spatial information of the frontier region of Rote Ndao with the use of multidisciplinary remote sensing to realize Geopark.

2. Methods
This multidisciplinary approach includes remote sensing, geodesy, geology, limnology, biodiversity, water resources, forest conservation, and geo-informatics. Multidisciplinary implies that an issue is reviewed from several disciplines without being integrated.

2.1. Study area
Rote Ndao is an archipelago in the Province of East Nusa Tenggara, located in the southernmost part of Indonesia. Since 2002, the archipelago has the status of a regency and was named Rote Ndao Regency with the Capital in Baa, an area of around 1,731 km².

Rote Ndao Regency is the southernmost region of Indonesia bordering Australia and Timor Leste. This regency has varieties of unique and endemic geology, biodiversity and inland waters. The regency has ~80 lakes, around 20 are saltwater lakes [10]. The salinity of these lakes exceeds the salinity of seawater. The majority of these saltwater lakes are located in the Dead Sea Lake Region of Rote islands.

The name Rote Ndao comes from the names of two main islands that are part of this region, namely: Rote island and Ndao island. There are 96 islands in this regency, but only six islands are inhabited, namely: Rote, Usu, Nuse, Ndao, Landu, and Do'o islands. Rote Ndao Regency is well-known for its inhabitants, the people of Rote, along with lontar cultivation, beach tourism, Sasando music, and traditional Ti'i langga hats.

Figure 1. Rote islands, August 2019. Imagery from Planet [11]**.**

The rote dead sea lake region is located on the Rote islands. In detail, the location of this area can be seen in figure 1. Rote islands have many lakes that have unique characteristics [12]. Lake Oemasapoka is the largest lake in the whole Rote islands, with an estimated total area of 1005 ha. In the eastern part of the Rote islands, several saltwater lakes have very similar ecosystems to the sea, such as Lake Oemasapoka, Lake Oeinalaen, Lake Oeduli, Lake Oeapa, Lake Bisaolifoe, Lake Bisafoh, Lake Oeina, Lake Tutui, Lake Oekukura, and others. These lakes are also saltwater, meaning that the salinity of this lake is higher than a normal freshwater lake, or even higher than sea-saltiness. These lakes have higher salt content than seawater and inhabited by endemic biota.

2.2. Data
Data used are in the form of about 65-70% remote sensing data and about 30-35% non-remote sensing data. Remote sensing data are in the form of Landsat, Sentinel, WorldView-2, PlanetScope, and Geodesy Satellite. Landsat is an optical image that has a spatial resolution of 15 and 30 m. It belongs to the United States of Geological Survey (USGS). There are three types of sentinel satellites namely Sentinel 1, Sentinel 2, and Sentinel 3. Sentinel 1 is Synthetic Aperture Radar (SAR) satellite with a spatial resolution of 10 m. Sentinel 2 produces optical imageries with spatial resolutions of 10 and 20

m. Sentinel 3 is a microwave satellite. WorldView-2 is Maxar satellite imagery with a spatial resolution of 50 cm. PlanetScope imagery is daily imagery with a spatial resolution of 3 m. Geodetic satellites consist of The Gravity Recovery and Climate Experiment (GRACE), The Gravity Field and Steady-State Ocean Circulation Explorer (GOCE), Challenging Mini-satellite Payload (Champ), and SWARM is microwave satellites used for sub-surface mapping. All of these satellites are used in mapping the Rote islands. Geodetics satellites can be used to detect the sub-surface potency, such as gravity disturbance, magnetic field, Bouguer, geodynamics, etc. Non-remote sensing data used include field measurements for geology, deformation, limnology, biodiversity, and others.

2.3. Methodology

The method used in this research is a multidisciplinary approach. This multidisciplinary includes remote sensing, Geodesy, Geology, Limnology, Biodiversity, and Geomatics. Satellite imagery is used for preliminary surveys and analysis of spatial information. Remote sensing can be used to help geological, biodiversity and inland waters mapping effectively and efficiently. This multidisciplinary approach in remote sensing applications is used to obtain spatial information based on geo-biophysical and classification parameters. Non-satellite data is used at the time of field measurements and validation of mapping results with satellite imagery. Preliminary surveys with satellite imagery can minimize costs and time in field measurements. The geodetic approach is used to make the Digital Terrain Model (DTM) from the integration of various Digital Elevation Model (DEM) [13]. This DTM is used for topographic and bathymetric analysis, utilization in the calculation of vertical deformations, and geological modeling [13]. The Geodesy Approach also focuses on vertical deformation. At the time, the geodetic measurement using the Earth Gravitational Model (EGM) 2008 as the height reference field [14].

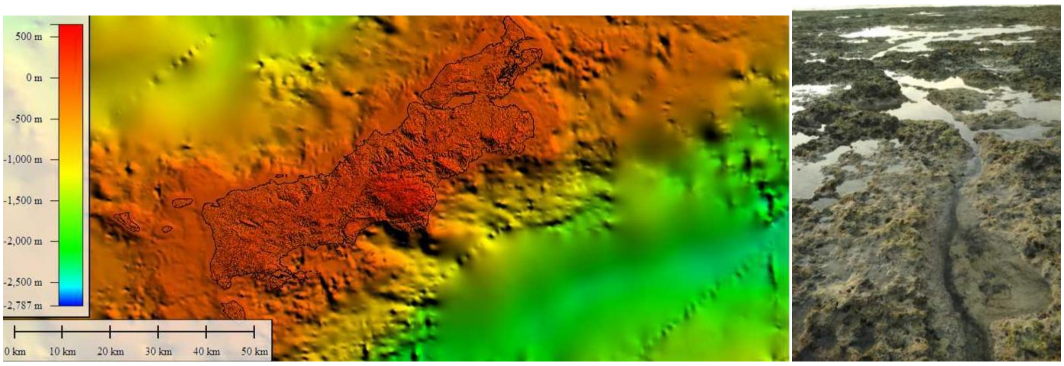
The geological approach discusses the geological formations contained in the study area. This geological formation is influenced by the type of rock and the type of deformation that occurs. The limnology approach discusses more closely the types and characteristics of the lake in the Rote Dead Sea Region. Besides, salinity measurements in the field were also carried out. This biodiversity approach discusses Rote endemic flora and fauna. It also discusses the conservation of flora and fauna due to land changes. The geomatics approach discusses how to display information and integrate all information into one integrated system. This system is in the form of storytelling maps and WebGIS. This system can be accessed online.

General deformation is vertical at a higher speed. An example area that is experiencing mixed deformation is the Tongga beach. In this region, there are many cracks from various directions, rocks that have risen dramatically from the sea and mangroves that have risen due to mounting. This region is used to have unmapped tectonic faults, see figure 2. This deformation detection approach can use height model and geodynamics data extracted from remote sensing data [15]; [16]; [17]. The extraction uses the DEM integration method of SAR and optical images [18]; [19].

The integration system (geo-visualization) created includes WebGIS and storytelling maps. This integration system is dynamic so that it can update its latest spatial information. WebGIS is developed on the ArcGIS Online platform. In June 2019, a field survey by this inland waters team was conducted in the field of measurement in the Dead Sea Lake area. field measurements carried out in the form of measurements of deformation, geology, salinity, brightness, turbidity, types of fauna and flora, aquatic plant samples, mangrove identification, fauna identification, simple toponymy, area mapping, and others. The measurements were taken at Lake Oemasapoka, Lake Oesotimori, Lake Oeduli, Lake Kaleon, Lake Bisaina, Mulut Seribu, Lake Merah, Lake Putih, and Lake Ndana. Storytelling maps were selected using the Storytelling Cascade format [10]. The narrative for the storytelling map was compiled based on the results of interviews with local residents and was supplemented by research results obtained during the survey.

3. Results and Discussion

The uniqueness of geology and biodiversity in the Dead Sea Lake Region of Rote is expected to make this region become a Geopark. Geologically, the Rote islands have mixed deformations that move vertically and horizontally and are lifted partially from the Australian Continent. The oldest rock exposed on Rote Ndao islands is the Aitutu Formation, consisting of thin interlaces of colorful silt (red, brown, gray, greenish) with marl and limestone. The upper part of this formation consists of a layer of white-yellowish calcilutite, containing calcite veins with gray flakes. Quartz sandstones, micaan sandstones, chert, and crystal limestone, are thin inserts contained in them. Based on the fossils of *Halobia* sp. and *Monotis salinaria* fossils found in reddish-brown siltstone, the age of the Aitutu Formation in the Late Triassic (between 235-208 million years ago). The Aiututu Formation revealed around Namodale is comparable to the formation revealed in East Timor. The thickness of this formation is estimated at 1,000 m.



(a) (b)

Figure 2.(a). Height model and geodynamics on Rote islands; (b) cracking the mix deformation in Tongga beach.

Rote islands have more than 80 inland water bodies in the form of lakes, reservoirs, and swamps. There are about 20 lakes that are salty due to tectonic uplift and high deformation. As a result, these lakes have higher salinity than seawater salinity. Many freshwater springs are located around these saltwater lakes. Lake Kaleon is an example of a saltwater lake located at elevation >100 m (figure 3). Other lakes such as Oemasapoka are located at elevations >50 m.

Figure 3. Lake Kaleon, one of the saltwater lake in elevation >100 m in Rote Dead Sea region.

The Wailuli Formation is above the Aitutu Formation, consisting of calcarenite, silt flakes, napal, grewak, which are generally gray to greenish. This formation contains the fossil *Belemnopsis* sp., which shows the age of the Late Jurassic (157-145 million years ago). The rock layers are generally good stratification and have not yet experienced strong deformation. In the Oitbolan area, west of Kolbano, West Timor, the thickness reaches 450 m. Previously, the spread of this formation in the Rote Ndao islands was uncharted, except in East Timor.

The Nakfunu Formation overlaps the Wailuli Formation, consisting of siltstone, containing radiolaria fossils, flakes with radiolaria, silt napal, radiolaria flint, and calcilutite. This formation thickness reaches 600 m. All of these rock formations are covered by younger rocks, which generally consist of coral reefs. Radiolaria types found include *Dictiomitra* sp., which shows the age of Early Cretaceous (Albian, or 112 - 97 million years ago).

Tectonically, Rote Ndao islands tectonics is the same as that experienced by Timor island. Based on paleontological data, it can be concluded that the Aitutu Formation has experienced a reversal caused by the pile of the formation to its present place through a process of petals (nappe, downslide) from other places. Such rock outcrops can be seen on the Tulandale coast, Lobalain District. The Rote Ndao islands can be better understood with evidence of fossil content. It is the position of the Halobian fossil stratigraphy above the Monotid fossils, whereas biostratigraphically, it should be the opposite. Examples of this tectonic uplift can be seen at Lokodamon Beach, Mulut Seribu. Mangroves that live on these rocks are far from water sources, see figure 4. As a result, mangroves in this region experienced an evolution compared to mangroves in other regions in Indonesia. Figure 4 is the evolution that the mangrove is moving to the hill. Most of the mangrove in this area is located far from the sea or river. The mangrove grows in the top hill and dry land condition.

Figure 4. Mangrove in hills in the sea bed and ocean floor shifting.

According to mud volcano, the Rote Ndao islands are geologically easier to learn and then apply to other more complex areas, such as Timor island. Rock outcrops in this area produce unique and interesting landscapes, interesting scenery. Tanjung Termanu is a unique small hill and is geologically composed of the Jurassic Formation Wailuli rocks and the Early Cretaceous Nakfunu Formation. In this area, there are a lot of photons (mud volcano) that often helps to reveal the geology of this area. In one piece, ammonite fossils (*Timorites* sp.) Even more interesting is the presence of photons in the final phase in the village of Bareta. Some areas have clear locations for tourists to visit, such as Tanjung Termanu and the remaining end of the photon activity. This proves that photon activity can push older rocks to the surface in the form of fossils. They were found in Middle Perem age (between 256 - 250 million years ago), even though rock outcrops of the same age have not been found in this area.

In the south Rote islands (Nembrala and Oeseli beach), white sandy beaches with blue sea water are decorated with diverse coral reefs, suitable for resting places while sunbathing and protected by mangrove trees from direct sunlight. The sea around the beach is also a place for people to grow very clean seaweed.

Figure 5. The shifting of the ocean floor in Oeseli Beach.

On Oeseli Beach, there is also rapid deformation and shifting the corals from the sea into a new land, see figure 5. Even the Rote islands in Oeseli Beach has been merged with the small islands in its opposite. This union has become a new land and sandy beach. Based on geological data, especially the Rote Ndao islands need to be made into a Geological Protected Area that is supported by a truly unique cultural diversity. The impact of the title as a Geological Protected Area will not only be a local spatial plan (RTRW), but also it should have begun to improve to become a candidate buffer zone for future industrial development, and also to realize a Geopark for Rote islands.

Dead sea lake area in Rote island can be included in the Faulted Lake type, but it has its uniqueness for its high salinity (above seawater salinity). Salinity measurements in Rote Dead Sea Lake generally refer to value > 40 ppt. While the highest measurements were obtained at Lake Oesotimori. Salinity measurements obtained with value > 100 ppt, see figure 6.

(a) (b)

Figure 6. Sponges, salt foam, and the shifting sea bed in Rote Dead Sea Lake. (a) Lake Oeduli, (b) Lake Oesotimori.

The biodiversity in this region is also unique as there are Roti snake-necked turtle (*Chelodina mccordi Rhodin*). According to the International Union for Conservation of Nature (IUCN), these turtles are critically endangered (red-list) wildlife. The Rote island is famous for its endemic fauna Roti snake-necked turtles (figure 7). At present, there are only five Roti snake-necked turtles on Rote island [10] showing that this wildlife is critically endangered. In the late 2000s, the turtles are included in the IUCN red list as critically endangered due to its changing environment and human activities [10].

Figure 7. Roti snake-necked turtle.

In addition to Roti snake-necked turtle, there are also several other endemic flora and fauna on this island. There are also unique mangroves conditions that live far from water sources due to vertical deformation. Rote Ndao also has areas of peat coal that are mixed with saltwater areas, freshwater areas, and brackish water areas. On this Rote island, many mangrove areas have been elevated due to high vertical deformation, see figure 8.

Figure 8. The shifting of Mangrove in Tongga beach.

Inland water is one of the habitats of wildlife. Some types of wildlife that make terrestrial waters as their habitat are Timor deer (*Rusa timorensis*) and several species of birds. Timor deer makes inland water a place to drink like the one in Ndana Game Park. Timor deer will drink water from the lake and lick the salt on the edge of the lake to meet their mineral needs. The signs of the presence of Timor deer in Ndana Game Park can be seen from the footprints, feces, and traces of male Timor deer markings (figure 9). These signs can be found around Lake Merah, which is in the middle of Ndana island. The existence of three lakes on Ndana island is very useful for wildlife in the region. Three lakes on Ndana island are Lake Merah, Lake Putih, and Lake Ndana. Wildlife on Ndana island, especially Timor deer and various species of birds make the three lakes as a place to drink, find food, and a place to play and other activities.

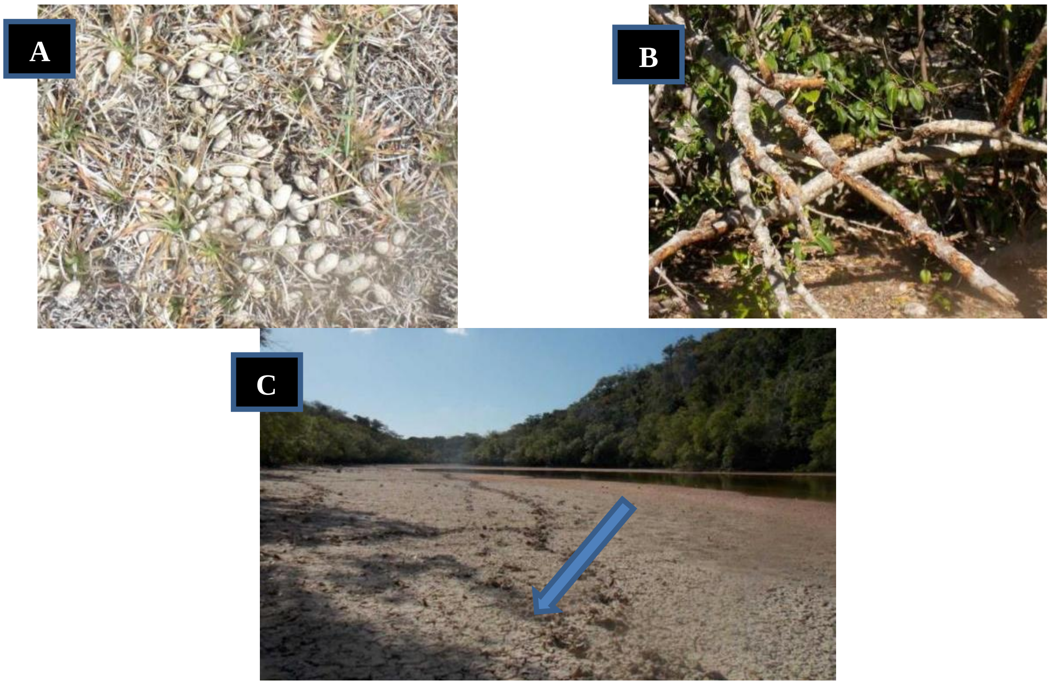


Figure 9. Signs of the presence of Timor deer in Ndana Game Park. (A). Timor deer feces, (B). Former male timor deer heading, (C). Timor deer footprints.

Rote Ndao Regency has two conservation areas, namely the Ndana Game Park and Harlu Wildlife Reserve. Based on field observations, the potential for wildlife in Ndana Game Park was found. In addition, the *Balai Besar Konservasi Sumber Daya Alam* (BBKSDA), East Nusa Tenggara, stated the potential for wildlife in Ndana Game Park is Timor deer (*Rusa timorensis*), Timor Friarbird (*Philemon inornatus*), Timor Imperial Pigeon (*Ducula cineracea*), Rose-crowned Fruit-dove (*Ptilinopus regina*), and migratory birds.

The savanna forest area of Ndana island consists of grasslands and monsoon forest, each covering an area of about 700 ha. The Harlu Wildlife Reserve area is one of the conservation areas located in the northeastern part of Rote island, which is administratively located in Daiama Village, Landu Leko District, Rote Ndao Regency, East Nusa Tenggara Province. Geographically, it is located between 123° 21'-123° 25' East Longitude and 10° 29'-10° 34' South Latitude. In the Harlu BC area, there is Lake Oeinalaen which has the potential for unique flora and fauna. Lake Oeinalaen is one of the saltwater lakes in the Harlu Marga area.

The result of the integration system is WebGIS and storytelling maps. WebGIS Rote island is compiled on the online ArcGIS platform and contains various layers that have been created previously. Storytelling map was chosen because of the effectiveness of delivering messages in the form of map visualization [20]. WebGIS Rote island is created using ArcGIS Online based on spatial data that has been obtained previously, such as administrative boundary data and road networks on Rote island [20]. The toponym was compiled based on the results of interviews with residents and the results of marking lake points in the field. The results of the lake name labeling from this interview were also carried out for verification and correction of lake name data obtained from sources, namely from Google Maps and OpenStreetMap (OSM). In WebGIS of Rote islands, the Living Atlas layer needs to be adjusted in advance so that it can be used as a multitemporal layer (time-enabled layer). The settings are made by activating the time-enabled layer slider or selecting a Landsat image according to criteria using filtering.

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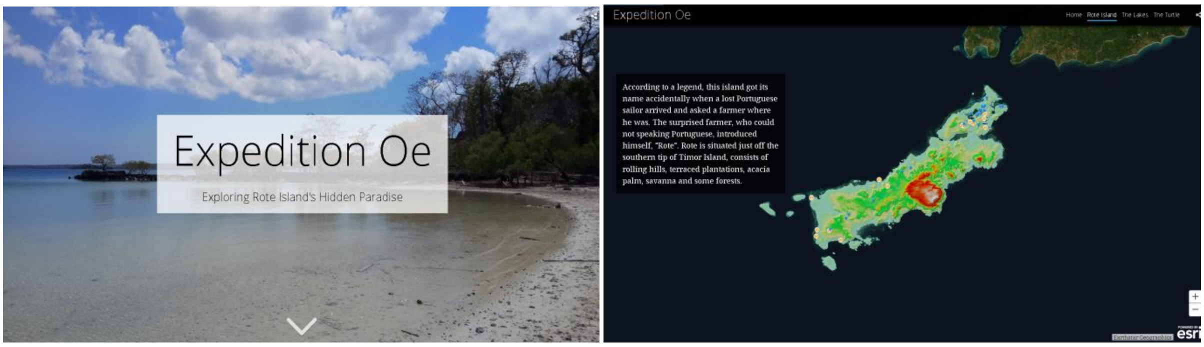
Storytelling maps were built on the previously compiled the WebGIS of Rote island, see figure 10. The final results of the storytelling maps were then uploaded (deployed) on a Github based server. The results of the compilation of storytelling maps and WebGIS were published respectively through the domain address http://geopark4rote.com and subdomain http://geopark4rote.com/webgis [19].



(a) (b)

Figure 10. (a). storytelling maps Oe, (b). WebGIS of Rote

There are many benefits of the Rote dead sea lake region as a geopark. In this region, various regional development strategies can be implemented in a sustainable manner, whose promotion must be supported by government programs.

4.Conclusions

One way to realize Geopark Rote is by a multidisciplinary approach. There are a lot of unique potentials in the Rote Dead Sea Lake region. This region has around 20 saltwater lakes with higher salinity than seawater, high deformation which causes the shifting of the ocean floor and seabed. Various uniqueness is examined from each of these aspects. The uniqueness is its diverse biodiversity, mangrove location far from sea and river, the shifting of the sea bed, high mixed deformation, have endemic flora and fauna, like Rote snake-necked turtle, the high value of salinity on Rote Dead Sea Lake, the higher >100 ppt, etc. The uniqueness becomes the capital in realizing the Rote Dead Sea Lake region to become a Geopark.

5. References

[1] UNESCO 2016 Geoparks *United Nations Educational, Scientific and Cultural Organization*

[2] Du Y and Girault Y 2018 A Genealogy of UNESCO Global Geopark: Emergence and Evolution *Int. J. Geoheritage Park* **6** (2) pp 1–17

[3] Oktariadi O 2019 *Geopark dan Penataan Ruang* (Badan Geologi Kementerian Energi dan Sumber Daya Mineral)

[4] Henriques M H and Brilha J 2017 UNESCO Global Geoparks: A strategy towards global understanding and sustainability *Episodes* **40** (4) pp 349-355

[5] UNESCO 1972 Statutes of the International Geoscience and Geoparks Programme *Global Geoparks* (United Nations Educational, Scientific and Cultural Organization) p16

[6] Lillesand T M, Kiefer R and Chipman J W 2004 *Remote Sensing and Image Interpretation (Fifth Edition)* **146**

[7] Mokarrama M and Hojati M 2018 Landform classification using a sub-pixel spatial attraction model to increase spatial resolution of digital elevation model (DEM) *Egypt J. Remote Sens. Sp. Sci.* **21** (1) pp 111–120

[8] Strozzi T, Klimeš J, Frey H, Caduff R, Huggel C, Wegmüller U and Alejo Cochachin R 2018 Satellite SAR interferometry for the improved assessment of the state of activity of

landslides: A case study from the Cordilleras of Peru *Remote Sensing of Environment* **217** pp 111-125
[9] Van Der Horst T, Rutten M M, Van De Giesen N C and Hanssen R F 2018 Monitoring land subsidence in Yangon, Myanmar using Sentinel-1 persistent scatterer interferometry and assessment of driving mechanisms *Remote Sens. Environ.* **217** (March) pp 101–110
[10] Julzarika A, Laksono D P, Subehi L, Kayat K, Sofiyuddin H A, Dewi E K and Nugraha M F I 2018 Comprehensive integration system of saltwater environment on Rote Island using a multidisciplinary approach *J. Degrad. Min. L. Manag.* **5** (53) pp 2502–2458
[11] Planet 2019 PlanetScope *Planet.com*
[12] Julzarika A, Anggraini N, Kayat K and Pertiwi M 2018 Land changes detection on Rote Island using harmonic modelling method *J. Degrad. Min. L. Manag.* **5** (53) pp 2502–2458
[13] Maune D F and Nayegandhi A 2018 Digital Elevation Model Technologies and Applications: The DEM Users Manual *American Society for Photogrammetry and Remote Sensing*
[14] Balmino G, Vales N, Bonvalot S and Briais A 2012 Spherical harmonic modelling to ultra-high degree of Bouguer and isostatic anomalies *J. Geod.* **86** (7) pp 499–520
[15] Liu Y, Zhao C, Zhang Q and Yang C 2018 Complex surface deformation monitoring and mechanism inversion over Qingxu-Jiaocheng China with multi-sensor SAR images *J. Geodyn.* **114** (January) pp 41–52
[16] Neelmeijer J, Motagh M and Bookhagen B 2017 High-resolution digital elevation models from single-pass TanDEM-X interferometry over mountainous regions: A case study of Inylchek Glacier, Central Asia *ISPRS J. Photogramm. Remote Sens.* **130**
[17] Ruiz-Armenteros A M 2018 Monitoring continuous subsidence in the Costa del Sol (Málaga province, southern Spanish coast) using ERS-1/2, Envisat, and Sentinel-1A/B SAR interferometry *Procedia Comput. Sci.* **138** pp 354–361
[18] Hoja D and D'Angelo P 2010 Analysis of DEM combination methods using high resolution optical stereo imagery and interferometric SAR data *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci. XXXVIII Part 1*
[19] Julzarika A 2015 Height Model Integration Using ALOS PALSAR, X SAR, SRTM C, and IceSAT/GLAS *Int. J. Remote Sens. Earth Sci.* **12** (2) pp 107–116
[19] Julzarika A, Laksono D P, Subehi L, Kayat K, Sofiyuddin H A, Dewi E K and Nugraha M F I 2018 Comprehensive integration system of saltwater environment on Rote Island using a multidisciplinary approach *J. Degrad. Min. L. Manag.* **5** (53) pp 2502–2458
[20] Laksono D P, Julzarika A, Subehi L, Kayat K, Sofiyuddinh H A, Dewi E K and Mugraha M F I 2018 Expedition Oe: A Visual-storytelling map on Rote Island's Lakes *J. Geospatial Inf. Sci. Eng.* **1** (2) pp. 87–93

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