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DETERMINATION OF ATTRACTIVENESS INDEX AND CARRYING CAPACITY OF THE GEOSITES FOR SUSTAINABLE GEOTOURISM DEVELOPMENT IN THE CYCLOOPS MOUNTAINS OF PAPUA, INDONESIA

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Abstract: The Cycloops Mountains are geologically and ecologically important conservation area, but are disturbed by degradation and deforestation. Geotourism is applied as an activity that supports sustainable use of the area. The aims of this research is to analyze the attractiveness and carrying capacity of the geosite for the development of sustainable geotourism. This research uses expert judgment in determining attractiveness based on the index value method and the suitability of carrying capacity with physical, real and effective geosite method.

Key words: Attractiveness, Carrying Capacity, Cycloops, Sustainability

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INTRODUCTION

The tourists are motivated in a place because of its natural beauty and unique culture of the community. Natural elements inherent in all living beings and numerous natural formations. Whereas culture is the way humans adapt to the natural and inherited to the following generation. The elements of tourism environment to be part of the point of interest of a destination (Hermawan and Brahmanto, 2018). The built tourism environment is a community creation area that was built by man-made structures that formed the balanced interaction between biotic to abiotic components, thus supporting the tourist activity. A mutual relationship between human and nature to ecologically produce distinctive cultural community behavior. A combination of nature, society and results of fostered to attract the tourists and specifically developed which is known as the special interest tourist attraction. Law of the Republic of Indonesia No. 10/2009 concerning tourism defines a tourist attraction as the object that has uniqueness, beauty and value resulting the diversity of nature and culture, as well as man-made outcomes into tourist destination. The diverse, original, unique and vintage geological objects can be attractive if they are developed as a special interest nature tourism and are combined with a specific theme and challenging adventurous activities. Geotourism is a geology and landscape themed with special interest nature tourism (Farsani et al., 2011; Hose, 2012) which is applied to conservation areas as a tool for sustainable development if managed effectively (Newsome et al., 2012). Cycloop mountains is natural reserve territory that serves as forest conservation, protection of water sources and landslides, as well as the natural laboratory. The existence of a conservation area is not only important because of ecological aspect, but also to improve economic and social culture of society. The main threat of forest areas in mountains are deforestation and land degradation due to high population growth and natural resources exploitation, in form of shifting cultivation and illegal excavation, hunting and trade of endemic plant and animal species. The sustainability issue of natural resources utilization into strategic issues of the Cycloop mountains management. Geotourism development in Cycloops mountains is based on geosite as a unit of site analysis of potential geodiversity by considering the sensitivity aspect of the nature reserve caused by tourists, such as noise, movement and garbage. The influence of tourists is not only reduce the value of attraction, but also reduce the ability of existing carrying capacity of geosite. The ability of carrying capacity according to amount and activity of tourists can keep environment quality and tourist attractions (Yulisa et al., 2016). Geotourism research not only focuses on geology, but takes into account scientific, ecological, aesthetic and economic value (Fassaulas et al., 2012). This research aims to analyze the attractiveness based on index value and to determine the physical, real and effective carrying capacity of the geosite. It is hoped that potential and superior geosites can be obtained that can be developed as sustainable geotourism in Papua.

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STUDY AREA

Study area is located in Cycloops mountains in between Jayapura Regency, Papua Province, Indonesia. The mountains occupy position coordinates of 140° 22′ – 145°43′ East longitude and 2°25′ – 2° 33′ South Latitude. Geographically, location of study is limited by Pacific Ocean in Northern part, Humbold Bay in Eastern part, Sentani Lake in Southern part and Tanah Merah Gulf in Western part. The area is about 35,000 Ha and about 80% are located in territory of Jayapura Regency administrative area (Figure 1). These mountains are located on Northern coastal of Papua Island, separated from Central highlands of Papua. Name of Cycloops was given by Dutch sailors who sailed in Northern of Port Numbay, due to its resemblance to the Greek god-eyed. Local people call this mountain with the name of the Dafonsoro or Rohong Hollo or Ravenirara, meaning forest where has the source of water. Surrounding mountains, there are 5 settled major tribes who have customary rights to land, consist of Enggros-Tobatí (Jayapura City), Sentani, Moy, Tepera and Ormu (Jayapura Regency). The existence of culture can add to tourist experience that describes interaction between human activities and their environment (Pica et al., 2014). Cycloop mountains have a vital function in ecologically and geologically. These mountains is a conservation area with status of a Nature Reserve based on the Minister of Forestry Decree (SK Menhut) Number: 365/kpts-II/1987-defined as forest area with function as protected areas, particularly for: (a) water management (hydrology) and micro-climate; (b) prevention of erosion, landslides and floods; (c) forest ecosystem and wild animals habitat, and; (d) significance of education and culture. Geologically, these mountains represent condition of floor of ocean and arc of volcanic islands that was Paleogene aged, as well as being part of a complex ophiolite of Papua (Ishlah, 2012) consisting of a group of metamorphic Cycloops and igneous mafic-ultramafic formed in pre-Tertiary (Suwarna and Noya, 1995).

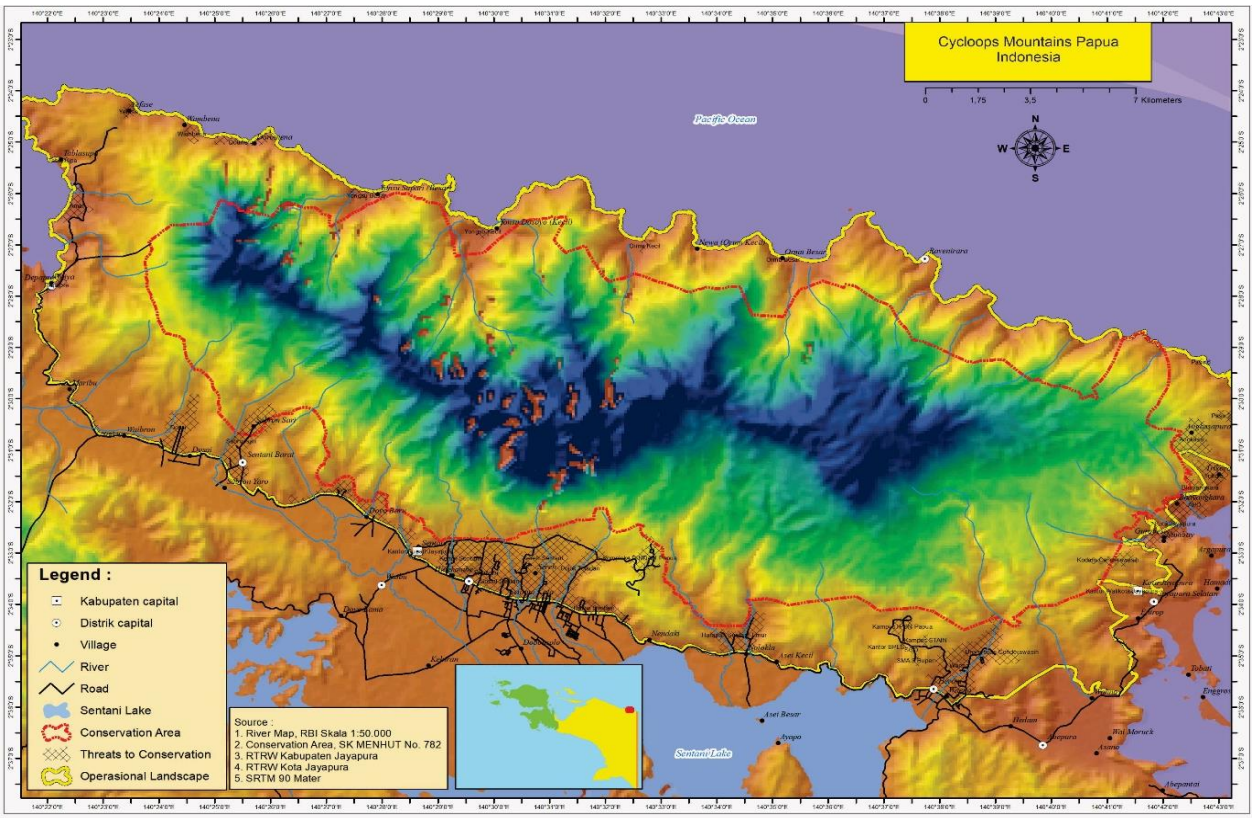


Figure 1. Location map of study in Cycloops Mountains, Papua, Indonesia (Source: Digital Elevation Model, 2018)

MATERIALS AND METHODS

The term of geotourism became popular in Indonesia around 2003, which National Seminar on Earth was held by the Center for Research and Development of Geology Bandung (Today is known as Geological Agency). Geotourism is defined as the tourism based on the geological and landscape (Sunkar and Brahmantyo, 2013; Hurtado et al., 2013; Farsani et al., 2014). Geotourism activity is different from other natural attractions. Thus it is categorized as special interest tours. This tourism applies the conservation principles in accordance with ecotourism rules, so that geotourism is seen as both environmentally insightful or sustainable tourism. Geosite assessment was obtained from survey results and expert opinions. Following the scheme of applied research methodology (Figure 2).

Attraction

Geotourism activities were conducted at tourist destination that displays uniquely and authentic geological objects to become a tourist attraction, which is known as geosite. Geosite is vital element of region in geotourism planning because it contains education, research, tourism, conservation, and other aspects. Geosite that contains elements and records of geological history in a particular region can be a legacy of the earth (geoheritage) which its existence can be witnessed, studied, documented and preserved (geoconservation). A large number of geosites can compete with each other and

affect directly or indirectly. The ability to compete determines success of a geosite as a superior destination (Pavolova et al., 2014). A indicator that affects competition between geosites is element of geological attractiveness.

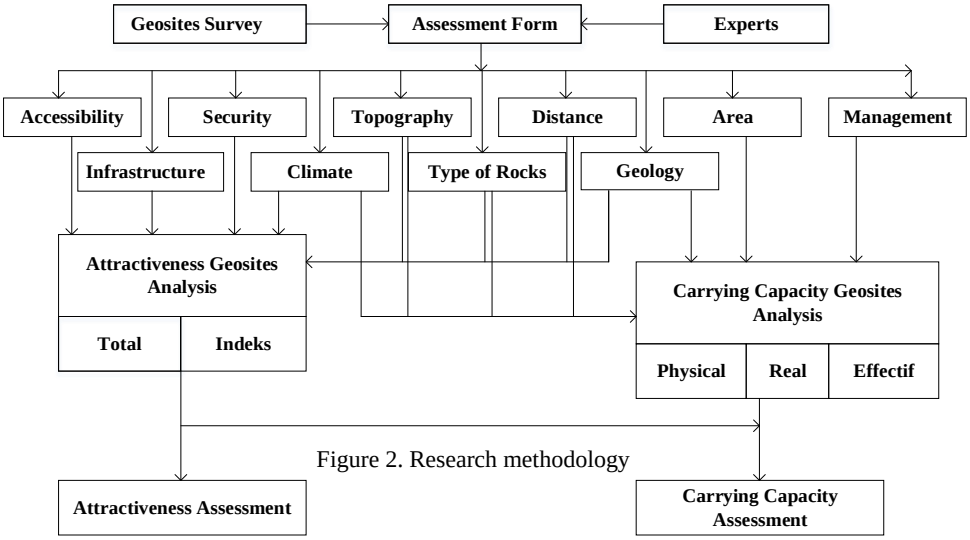


Figure 2. Research methodology

Elements of geology which became attraction of a) materials (soil, rocks and minerals, including dairy), b) process (result of tectonics, volcanism, weathering dissolution, including fossilization, and c) period (history of geology and fossils of living creatures). The geosite attraction can also be determined from principles application aspect of geology and visualization of landforms evolution process (landscape). The attractiveness of geosite is determined by aesthetics value of geology and quality of environment. Hassan et al., (2012) suggested the geosite attractiveness assignment by index approach. This method has been developed in Razavi Khorasan Province in Iran towards 5 elected geosite. The geosite attractiveness assessment is determined by 9 criterias and weights (Table 1).: The determination of score (1 – 5) is carried out by experts who understand the geology objects and context of nature tourism. Experts who consist of the academicians, the professionals, and the government officials of tourism. The index is calculated by comparing scores and weights against maximum score of each criterion (Equation 1). The result of index summation of all criteria are then determined by geosite categories, ranging from less attractive to very attractive (Table 2). In this research, we will look for geosites that are categorized as attractive to very attractive expressed as a potential geosites that are worthy of further development.

Equation 1: $I_{DT} = \frac{S*B}{S_{max}}$ where I_{DT} = Attractiveness index, S = Score (1 – 5, 1 for lowest score and 5 for highest score), B = Weight of each criterion, and S_{max} = The maximum score that has been set on each criteria.

Carrying Capacity

Potential geosite tend to have more tourists compared to other geosite. The behavior of tourists could give a significant impact on environment around geosite, particularly in areas that have sensitive plants or wild animals. The ability of geosite to accommodate tourists and their activities not to disturb or damage ecosystem is highly dependent on the carrying capacity of a tourist location. Carrying capacity is capacity of a location to receive tourists or maximum number of tourists that can visit without causing a decline in environment quality. Carrying capacity can be determined based on physical, biological, and regional management condition by considering 3 capacity, a) physical capacity, b) real capacity, and c) effective capacity (Zacarias et al., 2011; Lucyanti et al., 2013). The third capacity are also pay attention to movement or tourist flows, size or area, amount of space available for each tourists and visiting time in tourist destination.

Geosite carrying capacity is one of tools determining geological conservattion by evaluating geoheritage using geomorphosite assessment (Kirchner and Kubalikova, 2011). Carrying capacity assessment of geosite is using some assumptions so that applied comparison will be more consistent. Assumptions were obtained from general survey results and consideration of comfort and security of tourists. Assumptions used are:

1. Area for tourists is 10 m^2 per person (water tours) and 15m^2 per person (mountain tours);
2. Operating time of tourist location is 8 hours per day maximum;
3. A minimum distance of tourist attractions to nature reserve boundary is 100 m;
4. Maximum precipitation is 30 mm/day;
5. Maximum slope is 40^o

The method of analysis of carrying capacity using Cufuentes formula as proposed by Lucyanti et al. (2013), which is based on maximum number of tourists in one day, to observe correction factor of local biophysical characteristics, as well as management area capacity. Carrying capacity formula of environment based on Cufuentes method (1992), equation 2-4 modified by Muhammad (2013), as follows:

Physical Carrying Capacity (PCC) Equation 2: $PCC = A * \frac{1}{B} * Rf$ where A = area provided and used for tourism; B = area needed by every tourist for tourist activities; and Rf = rotation factor

Table 1. Attractivenes Assessment Form for Geosite (Source: Hassan et al., 2012)

No.	Indicators (Weight)	Parameters (level1)	Sub Parameters (level2)	Score	Description
1	Distance from the geosite (10%)	a. Long (>30km); b. Medium (10-30km) c. Short (<10km)		1 3 5	
2	Accessibility (10%)	a. Good (roadway/highway) b. Poor (unpaved/Limited road) c. No access (baling/hiking)		1 3 5	
3	Climate (5%)	a. Rainfall b. Temperature c. Humadity d. Windy	i. High (>20mm/day) ii. Medium (10-20mm/day) iii. Low (<10mm/day) i. Hot (>25°C) ii. Normal (20-25°C) iii. Cool (<20°C) i. Dry (<80%) ii. Moderate (80-90%) iii. Humid (>90%) i. Strong windu (>10knots) ii. Moderate (7-10knots) iii. Breeze (<7knots)	1 3 5 1 3 5 1 3 5 1 3 5	
4	Type of Rock Formation (5%)	a. Igneous; b. Sedimentary c. Metamorphic; d. Melange			If found 1 then 1 score; 2 then 3 scores; more 2 then 5 score
5	Historical Geology (5%)	a. Stratigraphic relation; b. Age of formation c. Fossil content or beo-stratigraphy			If found 1 then 1 score; 2 then 3 scores; more 2 then 5 score
6	Topography or Slope (5%)	a. Highland b. Lowland	i. Mountaneous Streep (>40°) ii. Rugged terrain/Cliff (>40°) i. Rolling Hill (10-40°) ii. Undulating Hill (10-40°) iii. Flat (<10°)	1 2 3 4 5	
7	Geology/Geomorphology (25%)	a. Weathering forms b. Caves; c. Lake or Swamp d. Spring; e. Waterfall; f. Fold or Fault ofset g. River/Gully Erosion; h. Xeonolith/Vein/Enclave i. Underground River; j. Mine	i. Physical ii. Chemical iii. Combine		If found les 2 the 1 score; 2-4 then 2 scores; 5-7 then 3 scores; 8-9 then 4 scores; and more 9 then 5 scores
8	Security (10%)	a. Ranger/Officer; b. Police Patrol c. Police Station; d. Protection against Wilde animals ; e. Rescuer			If found 1 then 1 score; 2-3 then 3 scores; more 3 then 5 score
9	Tourist's Infrastructures (25%)	a. Appropriate Gide signs; b. Accommodation c. Drinking Water; d. Telephone/Mobile Network e. Emergency Service; f. Restaurants/Bars g. Gas Stations or Repairing Service h. Shops or Traditional Market i. Sanitary Service; j. Tourist Protection (sair, railing, pavement, Life jaket, teh) k. Electricity; l. Banks or Money Change m. Health Center or Drugstore n. Parking or Car rental			If found les 3 the 1 score; 3-5 then 2 scores; 6-8 then 3 scores; 9-11 then 4 scores; and more 12 then 5 scores

Table 2. Geosite attractiveness category (Source: Director of Nature Tourism and Utilization of Environmental Services, 2003)

Attractiveness category	Index
Less attractive	< 3.0
Quite attractive	3.1 – 5.5
Attractive	5.6 – 8.5
Very attractive	> 8.5

Table 3. Geosite carrying capacity criteria (Source: Lucyanti et al., 2013)

Carrying Capacity	Category
PCC > RCC > ECC	Appropriate
PCC > RCC > ECC	Inappropriate
PCC < RCC > ECC	Inappropriate
PCC < RCC < ECC	Beyond capacity

Real Carrying Capacity (RCC) Equation 3: $RCC = PCC * C_{f1} * C_{f2} * \dots * C_{fn}$ where C_f ... C_{fn} = correction factors of geosite biophysical environment parameters, and C_{fn} = correction factor to -n associated with component data to –n.

Correction factor: $C_{fn} = 1 - (\frac{Mn}{Mt})$ where M_n = real conditions on fn countless variable; and M_t = maximum limit on fn variable

Effective Carrying Capacity (ECC) Equation 4: $ECC = PCC * MC$ where, MC = management capacity area.

Management parameter: $MC = \frac{Rn}{Rt} * 100\%$ where Rn = Number of available officers or manager, and Rt = Number of required officers to manage geosite. The suitability of carrying capacity is determined by comparing results of calculation of PCC, RCC and ECC. The carrying capacity category of sustainable geosite such as Table 3.

RESULTS AND DISCUSSION

Cycloops Mountains Nature Reserve as an ecology conservation area needs to be supported by determination of geology conservation status of which is based on diversity value and geological uniqueness. Cycloops Mountains are isolated mountains that have an important value for scientific, aesthetic or recreational opportunity to be integrated

conservation area that can be developed for limited education and research, conservation and nature tourism purposes. Geotourism activity can be one of alternatives that support management of area that benefits in economically and socially inclusive and environmentally sustainable. The application of geotourism activity can only be conducted on geosite that is stated as attractive and do not give significant impact to ecosystem. The survey results have identified 26 locations as geosite based on classification criteria of geodiversity (Geological Agency, 2017), most of which are in Jayapura Regency. Although study area is located in mountains, some of geosite located on edge of the beach (Figure 3).

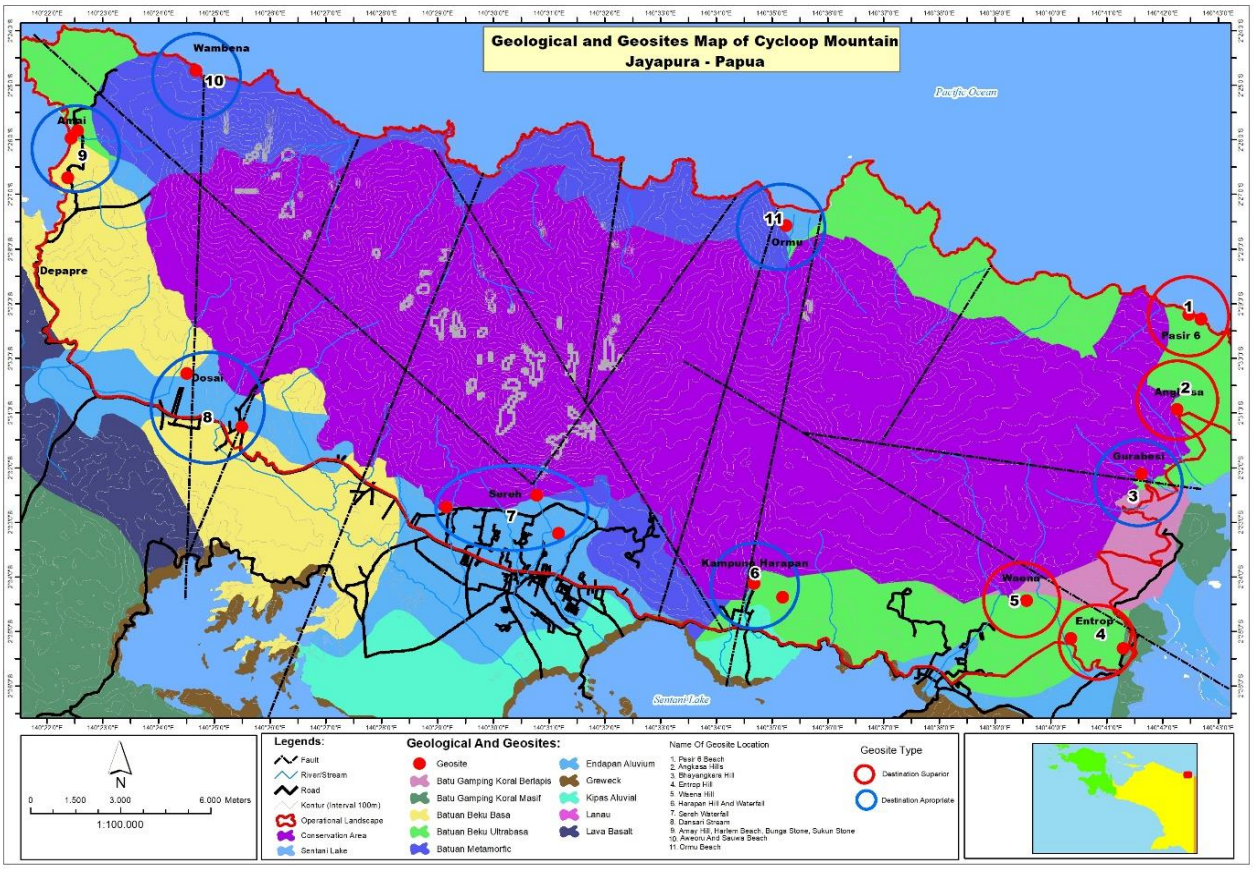


Figure 3. Geological and geosites map of Cycloops Mountains. Suwarna and Noya (1995, revised 2019)

Elements of geodiversity of Cycloops Mountains are including landscapes, rocks, geological processes and tectonics. The landscape is in form of a structural mountain morphology, with constituent rock of ophiolite; gabbro, basalt, peridotite, serpentinite and island arc volcanic rocks, and group of Cycloops metamorphic rock, such as pre-Tertiary schist-phyllite mica. Suwarna and Noya (1995, revised 2019) stated that the Cycloops Mountains contain minerals of economic value, such as nickel, chromite, cobalt, iron sand, talc, garnet, marble and limestone. However, it has not been mapped in detail. The geological process of the formation of the Cycloops Mountains is related to the subduction and uplift of oceanic crust and continental collision with island arcs during the Oligocene (34 – 23 million years ago) which produced aphanitic volcanic rocks (Baldwin et al., 2012). As a result of this tectonic process, it produces beautiful and exotic landscapes in the form of beaches, hills, mountains and highland lakes. The geosite attractiveness can be determined in 2 ways, total score and index (Figure 2). In this study we only used index score, considering sensitivity of final score and category status. With attractiveness index, it is excessively firmly distinguished between quite attractive and attractive category. The considered potential geosites that are categorized as attractive, 1) Pasir6 Beach, 2) Klofkamp's Stream, 3) Bhayangkara Hill, 4) Kodam Hill, 5) Skylane Hill, 6) Entrop Hill, 7) Waena Hill, 8) Buper Swamp, and 9) Harapan river (Figure 4). Most potential geosites locations are residing in Jayapura City territory, due to accessibility is accessible and expeditious. However, many geosites are all managed in a professional manner. Only Pasir6 Beach, Skylane Hill and Harapan river geosite that have been managed by community with guidance from local government. Other geosites are operating on weekends or public holidays and do not have adequate facilities. Evidence of geology diversity at each location shows advantages and charm as a potential geosite. The excellence geosite is determined by the 9 attractiveness parameters index (Hassan et al., 2012).

Assessment results of index shows that geological history, climate, accessibility and topography/slope to be important parameters in determining potential geosite in Cycloops Mountains. Geological history that is related to the Cycloops complex ophiolite formation process that is very attract tourists to know characteristic of ground floor of ocean are rarely found on surface of earth. The cool and calm mountain climate into tourists' choice to enjoy the atmosphere and geology object of landscape. Climate parameters that have a correlation with altitude and topography, so a lot of tourist sites are in high place or valley. The ease of access and distance to be vital for comfort in journey and the financial factors. Whereas, charm of geosite interpreted from harmony of nature elements composition, culture and built environment is seen

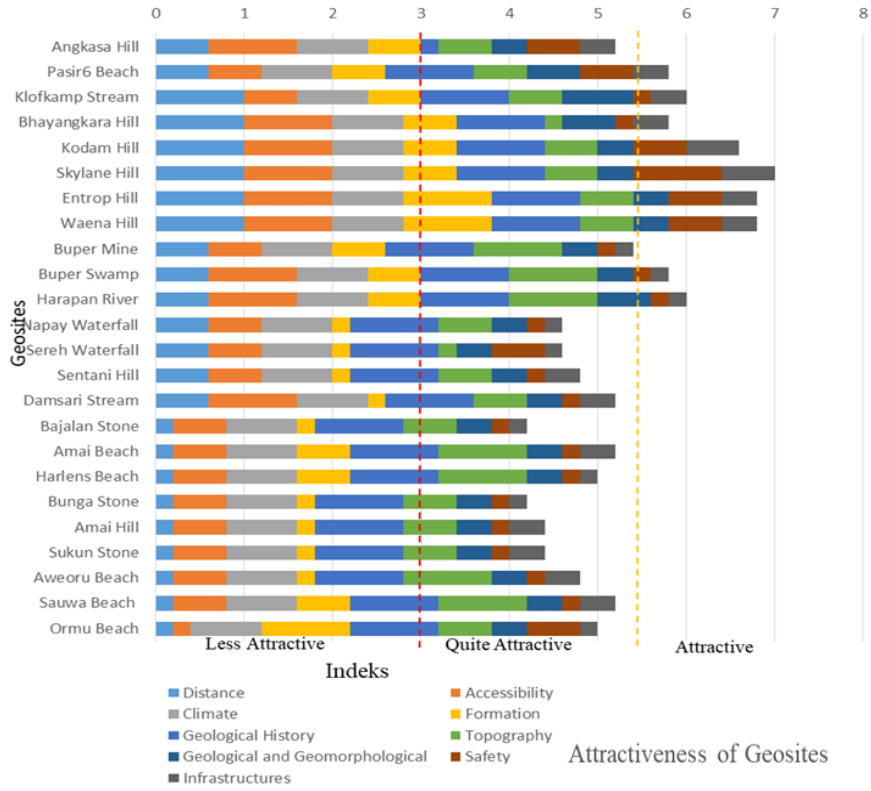


Figure 4. Determination of geosite based on attractiveness index (Source: Analysis results)

as mountainous landscape of ideal into geotourism area. Design and planning of mountains landscape is excessively requisite to support realization of geotourism. The geosites assessed for their carrying capacity are 16 locations based on index, located outside conservation area and managed by individuals or groups. The conservation area or sensitive ecology areas boundaries are used as a limiting factor for bearing real capacity. Geosite located in nature reserve, automatic is not in accordance with real carrying capacity. Similarly, if geosite who do not have a manager or person in charge of location, then effectivity of carrying capacity has no value. Carrying capacity suitability determination in this study is to compare 3 aspects, physical, real and effective. If one aspect is not valuable, then it does not qualify suitability of carrying capacity. That means, location is less feasible to be developed as a sustainable geosite. Results of experts' assessment to elected geosite have determined the 9 locations that meet the criteria in accordance with the carrying capacity for tourism activities, namely a) Angkasa Hill, b) Pasir VI Beach, c) Bhayangkara Hill, d) Skylane Hill, e) Entrop Hill, f) Waena Hill, g) Buper Pond, h) Sentani Hill, and i) Ormu Beach. Although there is a geosite which is not in accordance carrying capacity, but in physically, geosite is not beyond carrying capacity ability. That means, geosite is still worth as a tourist location by considering geophysical factors such as distance of nature reserves boundaries, climate, rock type, topography, and geology diversity. The results of the carrying capacity determination of a physical, real and effective, such as Figure 5. Geosite which has a high carrying capacity and many tourists is Skylane hill with panoramic view of Youtefa bay, then Entrop hill that highlights morphology diversity of the limestone hills, and Waena hill that offers two landscape of beautiful place, Sentani lake and Youtefa bay. The three geosites are located nearby so that the combination of its appeal can support each other forming the geotourism region or the geoarea.

The Sentani Geosite has a low carrying capacity as it is physically relatively narrow and oblique with the attraction that consists of peridotite chunks collection that are hanging on slopes of Sentani Hill (Figure 5). Geosites that are categorized as inappropriate for carrying capacity are influenced by real capacity value (RCC), particularly distance to ecologically sensitive areas, relative humidity and geology diversity. Geosite that is closer to nature reserve and has steep slopes, as well as a few of geology diversity has a lower bound of effective carrying capacity. That visitors are strictly limited so that balance of ecosystem and sustainability of attraction can be maintained.

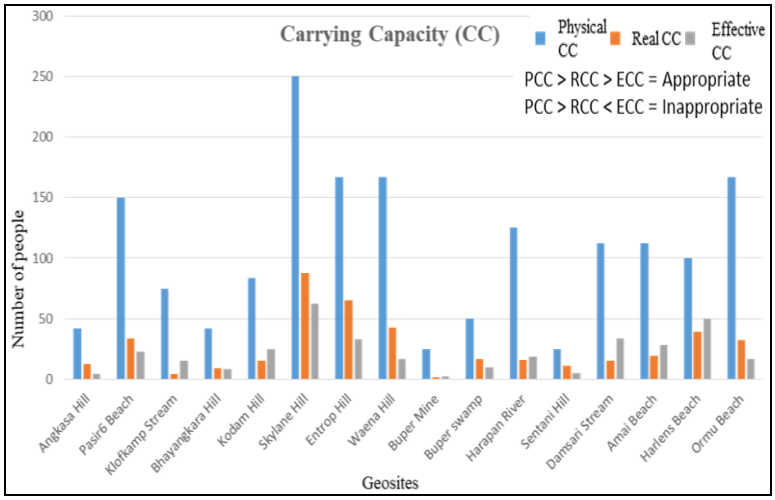
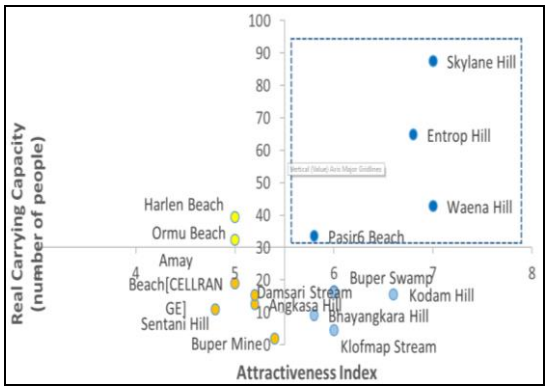


Figure 5. The geosite results of the carrying capacity assessment



Fiture 6. Determination of superior geosites in Cycloops Mountains

Based on attractiveness index and carrying capacity assessment (Figure 6), it is categorized as attractive and appropriate is in accordance owned by 4 geosites, namely Pasir6 Beach, Skylane Hill, Entrop Hill and Waena Hill. Geosite is likely to become a potential tourist destination that developed by community and local government. Pasir6 Beach and Skylane Hill geosites have become popular tourist destinations in Jayapura City. Skylane Hill has already become an icon of Jayapura City and Pasir6 to be the location of the typical ecological support of the Cyclops Mountains.

Geosites that meet attractive and appropriate criteria with carrying capacity potensially become to superior destination. The superior geosite in Cycloops Mountains is highly feasible to be developed as a sustainable geotourism model that has combined economic and socio-cultural benefits of community, and supports environmental conservation. Management of conservation areas through geotourism activities based on geological attractiveness and suitability of geosite's carrying capacity is one of solutions for handling welfare and sustainability issues in Papua.

CONCLUSION

Attraction and carrying capacity in the tourism study into a key parameter in planning the development of the nature tourism. A combination of attractiveness and the matching carrying capacity will determine the sustainability of nature tourism. Attractive Geosite in Cyclops Mountains based on attractiveness index is a Pasir6 beach, Klofkamp river, Bhayangkara hill, Kodam hill, Skylane hill, Entrop hill, Waena hill, Waena lake, and the Harapan river. The geosite attraction elements are influenced by the distance from geosite, accessibility, geology and geomorphology information along with adequate security and infrastructure. Suitability of physical, real and effective carrying capacity determines geosite feasibility as a natural tourist location that maintains balance of ecosystem. Geosite that meet the criteria of carrying capacity is Angkasa Hill, Pasir6 Beach, Bhayangkara Hill, Entrop Hill, Skylane Hill, Waena Hill, Buper Swamp, Sentani Hill and Ormu Beach. The real carrying capacity is very influential on determination of geosite feasibility which is located around sensitive ecology areas and has a high geology diversity.

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