SUSTAINABLE CAVE TOURISM ENVIRONMENT USING CAVE ECOSYSTEM PROFILE: CASE STUDY OF COKRO CAVE, GEOPARK GUNUNG SEWU

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Abstract

With their high value and various features, caves can be easily overexploited by mismanagement of caves. One of the utilization of caves are to be used as tourism sites. Cokro cave is one of the cave in Geopark Gunung Sewu which had been a tourism site. Initiated by local people, it had developed and become one of the favorite site to be visited. With its unique and fragile ecosystem, it is very important to assess and recognizing features and the characteristics of caves. One of the methods used is Cave Ecosystem Profile. This method is chosen because its simplicity and interdisciplinary in assessing the cave and the visual result. It uses ecosystem by inventorying physical and biotical features and building correlation among them. The inventory then will be visualized in a cave map to show the spatial distribution of those features along the cave passage. From the inventory, management will be able to choose the right strategy in keeping all of those features.

The inventory of the physical features are including the speleothems, speleogens, sediments, passages form and all of the geomorphological process and aspects. Speleothems found are stalactites, flowstones including gourdam. The passage forms consists of chamber and collapse. These physical features become attraction and habitat for the microchiropteras, arachnids, rhaphidophoridae, and swallows. In every single habitat, disturbance from the tourist will affect the biota and the geological features. To minimizing the impacts, some behavioral protocols and modifications are necessary to be made as conservation strategies. All of these are summarized and visualized using Cave Ecosystem Map.

K e y w o r d s : Cave, Maps, Ecosystem, Tourism

Introduction

Background

With its uniqueness and potencies, karst area has a very high and numerous values. Those values are comprised by scientific, socio-cultural and economic value (Samodra, 2011) .With the right and good management, values of karst can be used to develop scientific understanding on earth science and encourage community development. However, particularly on the community development, karst –especially on Indonesia is famously known with its chalkstone characteristics and identic with arid, famine, and even acute poverty thus the people of karst must adjust their livelihood strategy by following the water cycle. (Baiquni, 2011). That identification is related with the glimpse of karst characteristics. With its hilly topographic, thin soils and absence of river, living in karst is a difficult. It will lead to a high environmental preesure (Lestariningsih, Cahyadi, et al., 2013)

Therefore, it is urgent to develop alternative strategies to overcome those difficulties. Tourism is, recently, considered as one of the alternative solution for the people in karst area. The landscape and landform of karst is unique. With reef coastal, typical landscape with hills and valley.This landform can be promoted as interesting tourism site with the most unique features of which only karst landscape would have: the cave. Cave's become the most unique karst's characteristics (White, 1988; Ford & Williams, 2007). With the presence of the cave, thus, karst can be divided into the exokarst which comprised by all the elements in the surface and the endokarst which is comprised by all the elements in the subsurface. Caves provide more values to karst area with its value and ecosystem service from its biodiversity (Medellin, Wiederholt, et al., 2017) and its own morphology and features. Those elements can be used to be tourism attractions.

Strives to develop karst and its cave into promising tourism site had been done through the time. In Gunung Sewu karst, since its recognition as the world heritage in 2004 by President of the Indonesia developments were constantly done by registered it as National Geopark of Gunung Sewu on 2013. The pinnacle of the effort was the acceptance of National Geopark of Gunung Sewu into Global Geopark Network under auspices of UNESCO on 2015 and recognized as Gunung Sewu UNESCO Global Geopark. This acceptance can be considered as official admittance of the effort and the intrinsic uniqueness and values of Gunung Sewu karst. Another karst area will be following this effort such as Maros Karst in South Sulawesi and Sangkulirang-Mangkalihat Karst in East Borneo.

Gunung Sewu UNESCO Global Geopark contains 33 geosites. Those geosites are sites with representation of the characteristics and geological process which become the main aspects of geopark (Koh, et al. 2014).

Caves and coastal areas are the most dominant geosites followed by forest and valley which indicates that Gunung Sewu UNESCO Global Geopark is uniquely represented by its caves and coastal areas. One of the fascinating and spectacular geosite is Cokro Cave. Before its recognition as geosite, Cokro Cave had been initiated to be tourism site by local community with assistance and guidance of Acintyacunyata Speleological Club since 2004. Through the times, Cokro Cave attracts attention from tourist and outdoor club because its beauty and uniqueness.

Continuous visitations with dense activities inside the cave will affect the cave environment (Russel & McLean, 2008), change its microclimate (Fernandez-Cortes, Callafora, et al., 2006; Novaz, Gazquez, et al., 2017), disturb the biotas (Biswas et al., 2011; Sari et al., 2015), decrease its ecosystem function and ultimately degrade its environmental quality. The deterioration of environmental quality will make the environment component of physical (including speleothem, soil, and climate), biotic (biotas and its biodiversity), and cultural (tourism activities) will disturbed and inconvenience to stay in the recent habitat. At the most severe impact, the ecosystem will collapse and terminate the ecosystems services it provides. To overcome the situation, a sustainable paradigm, concept, and management is strongly obligated to be prevailed.

Researches and efforts had been done in order to formulate the most appropriate management system. First thing to do is to invent and know the cave characteristics and its ecosystem dynamics. Inventory is comprised by abiotic inventory and biotas inventory.

Methodology

Habitats of the biotas depend on some properties of the landform. Morphology, as one othe properties will affect other environment properties and the cave's geoecosystem which operates under "brash" equation dynamics (Hugget, 1995). From the "brash" element, relief or morphology is included as one of the components in the geoecosystem. On cave, morphology consists of passage section (Bogli, 1980; Palmer, 2003, Surawan, 2010, Labib, 2015), speleothem, and speleogen. Those morphologies are then considered as the habitat of biotas. Vandel, (1965) mentions some of the habitats or analogues with biotopes as an "area with uniform physical and chemical characteristics". Those biotopes are: entrance, endogenous, guano, wall with stalagmites, liquid medium, and interstitial medium (Vandel, 1965: 287).

However, to simplify the observation and data collection, the biotopes will be relied toward morphology. Uniform morphology, according the "brash" equation (Hugget, 1995) may lead to the similar climate and physical characteristics. Morphology also can be easily visualized using diagram or cave maps. Therefore, a speleomorphology approaching is used to analyze

habitats as the unit. Speleomorphology is a science deals with the morphology of the cave passages, classifies it and explains the process within (Bogli, 1980). For the biotic components inventory of biota is the method. After the inventory of biotas is done, spatial distribution of them are provided. The spatial distribution shall help the manager to create management plan spatially.

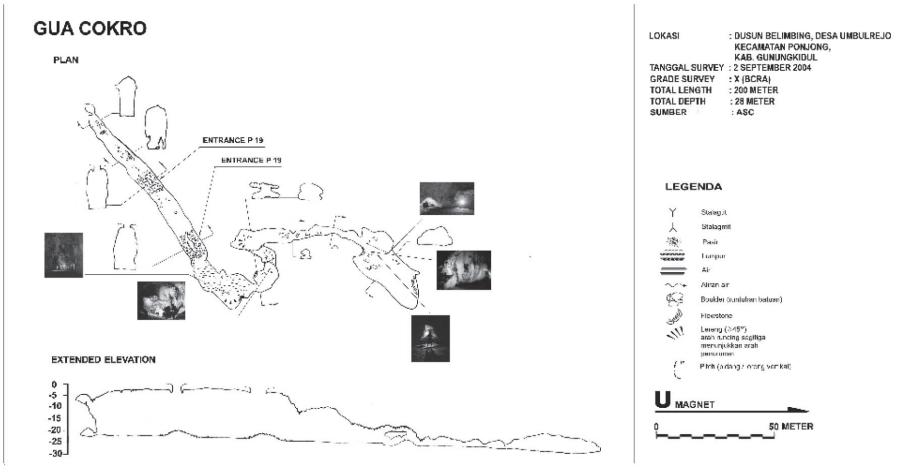

Figure 1. Map of Cokro Cave (source: Acintyacunyata Speleological Club, 2004)

Environment management cannot be unattached from its spatial dimension. Environment, however, must take place somewhere. Its spatial dimension can be expressed by geographical information. The geographical information, when they are visualized becomes a layer of information. With geographical information, the analyst can stack the information and make the overlay. From the data overlay, the relation between information with the other can be constructed.

Result and discussion

Biotas

Observed biotas at Cokro Cave are the arachnids, diplopods, rhaphidophoridaes, chiropteras and the swallows. Those biotas construct two communities which are the ceiling community and the floor-wall community. Each community inhabits habitats at certain morphologies. The ceiling and the floor-wall community are crucial to be distinct because it will be impacted differently. Each categorize of biota will react differently on different disturbance. It depends on their niche at certain habitat and their behavior including the adaptation toward cave's environment characteristics.

The Chiropteras or bats are quite sensitive and will easily be stressed out by disturbance from light and noise from the visitors (Sari, et al., 2015).

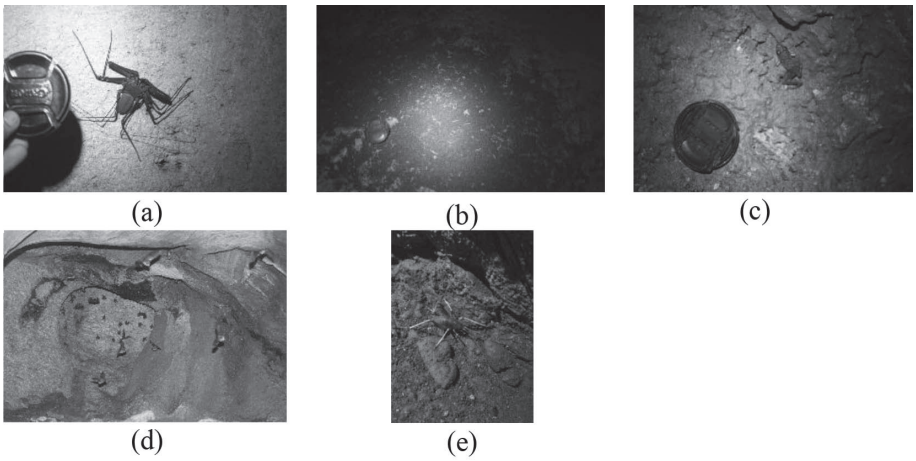

Figure 2. Biotas of Cokro Cave (a) Arachnid (b) Myriapod, (c) Frog (d) Chiroptera (Bats) (d) Rhaphidophoridae

They also will be affected by the alteration of microclimate parameter such as temperature and humidity (Biswas et al., 2011; Saroni, 2005). Bats are the most crucial and important biotas for they are one of the energy and food providers (Wynne & Pleytez, 2005). With their dungs known as guano, biotas in the floor-wall community obtain their nutrient. Thus, conservation of the bats is one of the backbones to the conservation guidelines. In addition, bats also provide ecosystem service as the pollinator (Acharya, Bumrungsri et al., 2011) and pest controller.

The arachnid, rhaphidophoridae, and diplopods can be included into the arthropod. The arthropod has important role as the biodiversity (Rahmadi, 2011). The arthropods also act as scavenger. They accelerate decomposition of organic material into nutrients and help to maintain nutrient in the soil. Rhaphidophoridae for a particular example, can be used as the indicator for the soil compaction as they must stay at the soft soil in order to lay their eggs. Compact soil will make them barely lay eggs which induce them to leave and looking for softer soil.

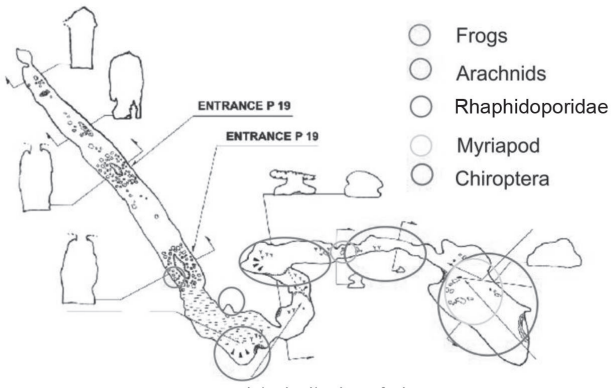

Figure 3. Spatial Distribution of Biotas

Speleomorphology and Habitat

Cokro Cave's morphologies are the result of genetic process of. Genetic or geologic or geomorphological process of karst is the solution process karst (Santosa, 2015). From the visualization of the cave, it tells us that the process of solution is regulated by structural control and the solution control. The structural control can be seen from the lineament of the passage while the solution control can be seen from the cross section of the passage. There is also an incasion or breakdown control which can be seen from the collapsed material in the floor. From the control observed, Cokro Cave can be considered as mature cave because it has incasion control (Bogli, 1980).

Speleothem or cave ornaments in Cokro Cave are various. There are flowstone like microgourdam and draperies and dripstone like stalactites, stalacmites, and column. Speleogens in Cokro Cave are cupolas, notches, and pockets. The speleogens are used by the biotas as the preferential habitats. Bats tend to roost on the cupolas or in the pockets. The arthropods prefer to segregate under the bats habitat because they need the guano to live and obtain nutrients. Arachnids tend to hide from the predator in the cracks or fissures in the wall. In some section, incasion creates endogenous habitat (Vandel, 1965).

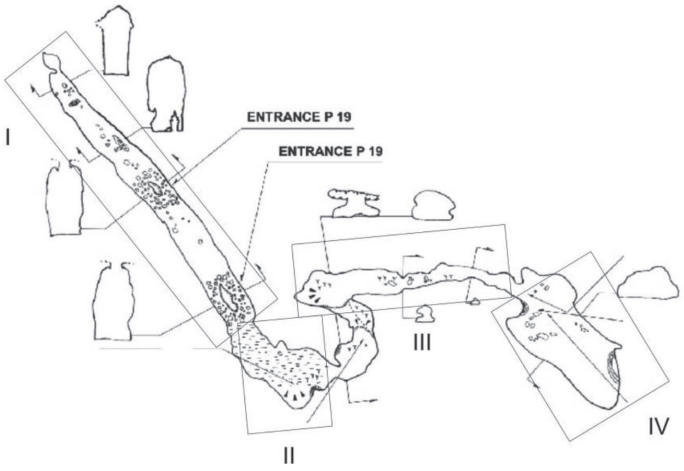

Figure 4. Morphology of Cokro Cave

Tourism Attraction and Activities

Tourism is initiated by motivation of humans to seek pleasure, leisure, identity and escapism (McIntosh et al., 1995). In order to fulfill the motivation, tourist will do activities and gain experiences. Those activities will be affected by the place setting at where the activities are done (Haryadi & Setiawan, 2010). Thus, certain activity is the result of the space surrounding or the environment. In the cave, spatial experiences are related with cave's characteristics. Dark

Table 1. Physical Properties at Each Morphology's Section

Section	Physical Properties				
	Passage	Light	Air	Sediment	Speleogen
I	High and narrow passage with entrances	Presence	Well circulated	Incasion, clay	-
II	Wide passage with small chambers	Twilight to absolute darkness	Well circulated	Mud	-
III	Narrow and low passage with chamber	Absolute darkness	Well circulated	Guano and clay	Cupola
IV	Big chamber	Absolute darkness	Well circulated	Incasion, clay, guano	Cupola, pocket

and narrow with physical boundaries, cave can be perceived as threatening and discomfort. However, beyond those threats, cave provides beauty and aesthetic element from its uniqueness and typical features. Ornament with certain form, interaction of light, and color of certain mineral are some of the cave's beauty.

Cokro Cave provides most of the cave's sensation. Tourist will have descending process using rope and lowered by lowering system. This descending process is basically an attraction because it gives tourist challenges. After reach the bottom, tourist will see attraction of ray of light where sunray penetrates through the entrance. Inside Cokro Cave, tourist can enjoy attraction like ornaments and experience of entering peculiar universe of subterranean. Absolute darkness and the space experience will give sensation to the tourist.

Space experience depends on the morphology of the passage as the place setting. It means that tourist activities are also related with the passage form. Massive morphology will give releasing sensation while narrow section will give stressful tension. Beauty of ornament will cultivate appreciation and

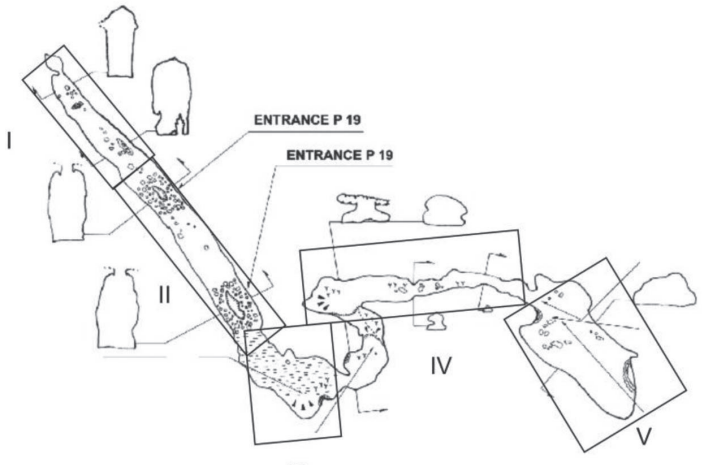

Figure 5. Cokro Cave Attraction's Section

high risk section will raise awareness and build identity. These morphologies can be used as the indicator of how tourist will react and behave at certain section.

Table 2. Attraction at Each Section

Section	Attraction	Behavior	Emotion
I	Speleothem gallery	Careful, observing	awareness, appreciation
II	Ray of Light	Taking picture, Single Rope Technique	Awareness
III	Gradation of light and dark	Observation, enjoyment	Awareness, fear, anxiety
IV	Speleothem and visual feature, narrow passage	Observation, enjoyment, taking picture	Appreciation, fear
V	Chamber and biotas	Observation, enjoyment	Appreciation, anxiety, tension release

Biotas, speleomorphology, and the attraction and behavioral setting of visitor are the component used to construct a sustainable tourist management. Terminology of sustainable is presented because it is the purpose and paradigm of the conservation act in speleology. Sustainable in environmental sense is analogue with long-lasting and achieved by maintaining ecosystem dynamics and preserve the relations among environment components. To create sustainability, every environmental component must be adjusted by the manager. Adjusting the environmental component means put every parameter at exact context, qualitatively and number, quantitatively.

Exact context is including behavioral setting and high quality tourism experience while exact number is related with carrying capacity of the ecosystem. All of these must be considering spatial aspect because

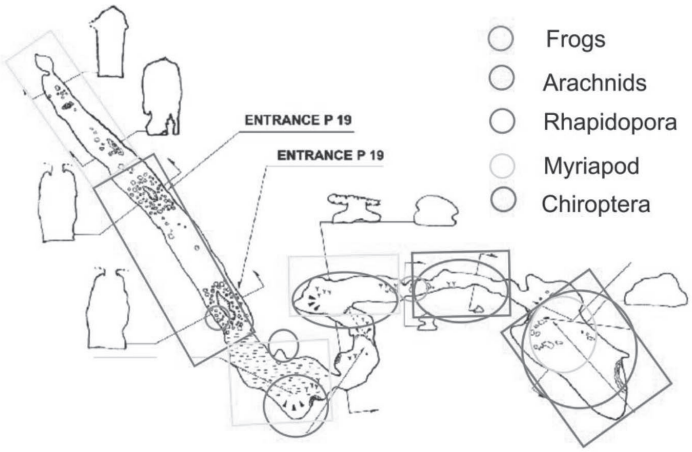

Figure 6. Tourism Ecosystem Profile

environmental is spatial, it must be take place somewhere. In order to have initial guideline, Cokro Cave's ecosystem profile is made using overlay of the component in the cave maps. the overlay can be seen in the Figure 5.

From the overlay of biotas spatial distribution, speleomorphology, and tourist attraction, now the tourism ecosystem dynamics can be visualized. The cave tourism ecosystem can be divided into three zones depending on the resilience and environment fragility. At Cokro Cave, the green zone located in the area close to the entrance. With the high energy flow through the entrance, this area has high resilience. The yellow zone means there are biotas or cave features with high value. Tourist need to be more careful and behave in this area. The red zone indicates fragility with low resilience. Also, if there is roosting site of chiropteras, the red zone must be applied due to the importance value of the chiropteras and their fragility (Wynne & Pleytez, 2005). Tourist must behave properly under surveillance of cave guide in red zone. The zoning can be seen at Table 3.

Table 3. Zoning of Cokro Cave

Zones	Description	Fragility	Behavior Suggestion
Green	Less speleothem, more circulation or energy flow, no biotas	Low	Free with safety of tourist is considered strict
Yellow	Dried or fossil speleothem, abundance of biota.	Medium	Limited without surveillance from guide
Red	Developing speleothem, rare biota, bats	High	Very limited with obeying instruction from guide.

Cave Passages Morphology as Geoecosystem Significance Element

To understand the dynamics of cave ecosystem, cave must be regarded as geoecosystem at first place. Geoecosystem is defined as a place or an area where relation among each ecosystem components happens (Hugget, 1995). Geoecosystem completes the abstract concept of interrelation coined by ecology with the addition of spatial aspect from geography. It asserts that every interrelation must take place. Expanding this concept, spatial or environmental properties as surrounding condition take a crucial role. Environmental properties which holds significant role in cave ecosystem tourism are the climate, morphology, and soil or sediment. Those three components interrelated with the presence and behavior of cavernicoles which will, ultimately affect tourism activity through space experience.

Morphology, however, is significance in observation because it is the most sensible element. Observers can easily observe it using their eyes and measure it using tape or laser disto. Vandel (1965) assert that the biotopes

which related with ecological niche have physical and chemical properties. Morphology can also be considered as the regulator of other properties since it deals with physical barrier and boundaries.

Moreover, there are two media for biotas to inhabit: the solid and the liquid media. By the solid media, there are cave passages. Cave passages are strongly imposed to the morphological aspect. Passages have dimensions which yields shape and form. Dealing with passages is dealing with morphology and in the cave. Morphology is the key regulator of microclimate properties. Therefore, habitats from ecosystem are much related with morphology of it and the behavior and the ecosystem's dynamic are governed by the morphology.

Management of Cokro Cave

To ensure the sustainability of Cokro Cave, a good management must be applied. Geoecosystem can be damaged by the disturbance from the external factor. In this case, the disturbance comes from tourism and visitation activities. Thus, management must be prevailed to regulate and control the tourism and visitation activities. It can be done using two limitations: first is limitation of activities and second is limitation of number.

Limitation of activities means put the right behavior on the right setting and right place or morphology. Where the fragility is high the behavior must be controlled strictly. No loud voice, no harsh movement, and no blitz are allowed in the high fragility area. The faragility comes from the low resilience or high value component. Bats are the example of it (Wynne & Pleytez, 2005), other example are the ornaments. In the area where the bats and the ornaments are dense, the behavior must be limited.

Limitation is also done by control the number of visitors. Number of visitor will inevitably affect the cave's environment. Cokro Cave, as an isolated system has physical boundaries thus has limitation at its capacity to load the visitors. If the limits are exceeded, then the comfortably of visitor and other environment components will degrade. The number of visitor which still allows the environment's impact to be reversible is the carrying capacity (Buckley, 1999 at Simon, Narajavanga, et al. 2004). Carrying capacity must be obeyed in order to make environment sustainable.

Conclusion

In order to make management guideline, a cave ecosystem profile can be fruitful in visualizing spatial aspect of management and the ecosystem conditions. At Cokro Cave, the cave ecosystem has been explained and visualized using cave ecosystem profile. The management also has been formulated including behavior setting of a place and the importance of limitation.

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