Contextualizing Cave Maps as Geospatial Information: Case Study of Indonesia

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Abstract. Caves are the result of solution processes. Because they are happened from geochemical and tectonic activity, they can be considered as geosphere phenomena. As one of the geosphere phenomena, especially at karst landform, caves have spatial dimensions and aspects. Cave’s utilizations and developments are increasing in many sectors such as hydrology, earth science, and tourism industry. However, spatial aspects of caves are poorly concerned due to the lack of recognition toward cave maps. Many stakeholders have not known significances and importance of cave maps in determining development of a cave. Less information can be considered as the cause. Therefore, it is strongly necessary to put cave maps into the right context in order to make stakeholders realize the significance of it. Also, cave maps will be officially regarded as tools related to policy, development, and conservation act of caves hence they will have regulation in the usages and applications. This paper aims to make the contextualization of cave maps toward legal act. The act which is used is Act Number 4 Year 2011 About Geospatial Information. The contextualization is done by scrutinizing every articles and clauses related to cave maps and seek the contextual elements from both of them. The results are that cave maps can be regarded as geospatial information and classified as thematic geospatial information. The usages of them can be regulated through the Act Number 4 Year 2011. The regulations comprised by data acquisition, database, authorities, surveyor, and the obligation of providing cave maps in planning cave’s development and the environment surrounding.

Keywords: cave, cave maps, geospatial information, regulation

1. Introduction
Caves are one of the typical features of karst region [1]. The definition of caves for the non-scientific purpose is a cavity or void space with enough size which human can enter [2]. That definition is non-scientific because it doesn’t consider the genetic aspect, loose, and contains ambiguity. Scientific definition of caves was defined by White (1988) as “Natural cavity in a rock which acts as a conduit for water flow between input points, such as streamsinks, and output points, such as springs or seeps”. Caves were formed under control of geosphere dynamics and processes such as tectonic activities and solution process involving reactions of water, air, and rocks [3]. Because it is the result of the process and dynamics caves are one of the significance features of earth and geosphere. The significance of caves relies on their values comprised by scientific, economical, to socio-cultural values. Scientific values of caves are related with the new discoveries and their relation with other sciences [4][5].
Utilization of caves to make profit and income is the economic value of caves. Socio-cultural values regard the relation of human and caves.

With its fragile environment and very high values, caves must be protected and managed satisfactorily [6]. However, science solely will not be adequate in management and conservation act. A more formidable and stronger instrument must be put into account. Regulation, institution, and governing aspects as that stronger instruments have to be applied to ensure the preservation of caves.

The management of caves also must be put above the pillars of spatiality as one of the foundations of environmental management. As physical entities on geosphere, caves have all of the location, size, dimension, and boundaries. Those aspects embed caves into spatial dimension. Caves are spatial therefore they contain geographical dimension and thus, can be taken into GIS science [7]. GIS science and the geographical consideration of caves are a fruitful tools and paradigms in establishing a far better understanding of cave itself. The better understanding will yield a more exact and precise management strategies.

The manifestation of amalgamation between geographic-spatial and the managerial aspects of caves values and resources is the cave maps and Cave GIS. Cave maps visualize the cave with geographic-spatial discipline by its exact measurements. Utilization of cave maps into management of caves can be based on ecological and ecosystem [8][9][10], tourism [11], and archaeology [12][13]. Cave GIS is very helpful in assessing and determine the characteristics, fragility, and management strategy in the surface area of karst with its ability to visualize the spatial distribution of cave entrance as the one of the surface features [14][15][16]. Cave maps and Cave GIS both are the speleo-spatial aspect of speleology.

Scientific application must be entailed by regulation. Practices of karst management in Indonesia frequently do not involve the speleo-spatial elements, whereas the speleo-spatial element is crucial. The lack of knowledge and information of cave cartography and GIS can be considered as the cause. Another reason is because of the karst management has not included geospatial aspects into its elements. To formulate an exact management system, speleo-spatial elements must be contextualized into geospatial aspect. To contextualize the speleo-spatial aspect means to put its scientific result in the regulation and juridical context. It is essential to examine regulations of karst and management and the geospatial one then merge them into more contextual. A comparison also needed to be made between what is written on the regulation and what science has provided. The comparison will enrich both side of management.
2. Geospatial Information

In Indonesia, geospatial information can be divided into two: Base Geospatial Information (Informasi Geospasial Dasar (IGD)) and Thematic Geospatial Information (Informasi Geospasial Tematik(IGT)). The primary regulation on these geospatial information is the Act Number 4/2011 (Undang-undang Nomor 4/2011) Concerning Geospatial Information. This juridical paper regulates and becomes the main reference on the following and derivative regulation. Geospatial information is defined at Article 1. Geospatial itself is defined as “spatial aspects points to locations, lies, and positions an object or phenomena below, on, or above earth surface and represented in particular coordinate system.” Geospatial aspect is expressed on geospatial data.

![Figure 2. Basic Management System](image)

![Figure 3. Schema of Geospatial Information](image)
Geospatial information is derived from geospatial data. Article 1 defines geospatial information as “geospatial data which have been processed thus can be used as tools in formulating policies, taking decisions, and/or executing actions which are related with geospatial”. Geospatial information is divided into Base Geospatial Information which is a Geospatial Information containing object which is directly visible or measured by physical appearance on earth surface and steady in a relatively long-time. Another Geospatial Information is the Thematic Geospatial Information which is “Geospatial Information which represents one or more certain theme which is created refers to Base Geospatial Information”. A more complete elaboration of Base Geospatial Information can be found on the Part 2 of Act Article 5-18. Article 5 states that Base Geospatial Information consists of Geodetic Control Network and Base map which is comprised by three maps of Indonesia’s Topographic Maps (Peta Rupabumi Indonesia), Indonesia Coastal Environment Maps (Peta Lingkungan Laut Indonesia), and National Marine Environment Maps (Peta Lingkungan Laut Nasional).

It can be extracted from the definition above that geospatial aspect has these characteristics: (i) location and position (ii) positioned below, on, or above earth surface, and (iii) has particular coordinate system. These three elements are the path to understand the context of caves as geospatial data and information.

3. Karst Management

The national regulation about the management of karst is the Minister of Energy and Mineral Resources of the Republic of Indonesia Decree Number 17/2012 (Keputusan Menteri Energi dan Sumber Daya Mineral Republik Indonesia Nomor 17 Tahun 2012) about Establishment of Karst Landscape Area. This decree regulates the definition of karst and its status of conservation or preservation. Karst, according to this decree must have permanent spring, karst hill, doline, uvala, polje and/or lake as exokarst features (Article 4 (5)) and Underground River and speleothem as endokarst features (Article 4(6)). Caves do not have their own regulation. They are still clung to the Decree Number 17/2012 and considered as endokarst features. Cave maps are not even included in the decree.

![Figure 4. Maps of Established Karst Landscape Area’s Status. Source: Decree of Energy and Mineral Resources Number 3045 Year 2014.](image-url)
To establish a status of karst landscape area, all of those features must be inventoried and reported completed with the explanation and elaboration (Article 9(2)). This report is obliged to have maps on it (Article 9(1)). The authority to establish the status is on the minister of energy and mineral resources with motion and consideration of the status are given by the regency government and the Head of National Board of Geology (Article 11). The status of karst area is very crucial because area of karst is the geological reserve as written on Government Decree Number 26/2008 About National Land Use Plan (Article 60(2)). As geological reserve, it has a strict zoning and very limited activities. Activities which are allowed limited only due to the research and scientific purpose and tourism development (Article 104).

4. Cave Maps and Geospatial Information

Cave maps had gone through a very long period of time and history since 14th century where the first cave map was created [17][18]. Cave map contains cartographic elements on its layout and drawn using terrestrial survey on cave. The survey is done to measure the dimension and size of the cave thus it can be projected on a media [19].

As it contains cartographic elements, cave maps are presenting the situation inside the cave by graphic. Caves, as a geosphere feature, have precise location and position which makes them geospatially be. Without the element of location and position, caves will be difficultly understood. To contextualize this in juridical context, cave maps must be analysed and compared by the geospatial aspects at Act 4/2011.

Geospatial, according to the act must fulfil these criteria: (i) position and location, (ii) below, on, and above, earth surface and (iii) has particular coordinate system. Caves, therefore, has geospatial aspects because they have certain position and location. They are also on the earth surface and below the earth surface. Caves, in the cave maps or Cave GIS, when they are overlaid with some base maps in the drawing, will be set on certain coordinate system. If the caves are inventoried and recorded, they are transformed from phenomena into raw data. It brings caves as geospatial data because every data which satisfies the geospatial criteria will be considered as geospatial data.

Caves as geospatial data are a series of record and inventories. This data are spatial data because they have both location and position and the attribute. If the spatial data were projected on the media with cartographic elements and disciplines, then a map will be created. Position of certain points or data must be terrestrially measured by their length and direction. Inside the cave, passages are measured by this method because passages are invisible from earth surface. In cave cartography, those points on the passed are called as stations. Every station is related and locked to another station and eventually attached with the ground reference point (GCP). The GCP is usually the cave entrances because the cave entrances are the only connection between the surface and the sub-surface features.

Next process is to advance the data into information. Caves have a very significance role on providing ecosystem services [20]. They keep the water as one of the the karst aquifers [21] and are the habitat of bats which act as pollinator or pest control. From the ecosystem services they provide, it is urged and very relevant to put them in the consideration on karst management. Thus, data of the caves can be used to help formulating relevance regulation and directing the management of karst.

In case of Indonesia, presence of cave entrances obviously and boldly signifies area of karst. Not only has the entrance, the passage also indicated the presence of karst. It is stated at decree 17/2012 where the Underground River can be categorized as the passages for the passages are formed due to the activity of Underground River. As the data, the entrances and the passages must be included into the report in establishing karst’s status. Activity report on karst inventory must attach maps with coordinate of the exokarst and endokarst elements (Article 9(2)). To achieve that, spatial data must be considered. By using the data as the consideration of karst status, it means the data has been used in implementing regulation and making the decision. Caves maps and Cave GIS are now geospatial information.

Advancing again, cave maps as the geospatial information must be derived and categorized whether it is base geospatial information or thematic geospatial information. From the Part 2 Act 4/2011, base geospatial information is limited only to the Geodetic Control Network and the Base Maps with their derivations. It is clear then, that cave maps cannot be classified as the base geospatial information. Thus,
the only possibility is to classify the cave maps as the thematic geospatial information. Thematic geospatial information must have these two conditions which are: (i) has certain theme and (ii) refers to base geospatial information. Certain theme is very loose concept. The theme of cave maps is relative due to its usage whether it is tourism, scientific, or ecological. To satisfy the second condition, a cave maps must be referred or overlaid with the base maps. At this case, to make it is easier, is referred to topographic maps rather than Geodetic Control Network. Nevertheless, joining the cave survey to Geodetic Control Network is highly recommended.

![Figure 5. Overlaid Topographic Maps as Base Geospatial Information with Cave Passages](image)

5. Management of Data and Challenges

After categorizing cave maps and Cave GIS as the thematic geospatial information, it is important to review how the management of thematic geospatial information is. Thematic geospatial information can be run and organized by Government Institution, local Government, and everybody (Article 23 (1)). Regardless the government, everybody may organize the thematic geospatial information for private purpose (Article 23(4)). It means that institution and body such as speleological club, mapala, or speleological association are legal in organizing and creating cave maps or Cave GIS as the part of thematic geospatial information.

At the Part 5 which regulates the organization of Geospatial Information, it is written at Article 25 that organization of Geospatial Information can be done through: (i) gathering geospatial data, (ii) processing geospatial data and geospatial information, (iii) archiving and securing the geospatial data and geospatial information, (iv) dissemination of geospatial data and geospatial information, (v) usage of geospatial data and geospatial information. This statement must be noticed by every speleologist and caver who runs for geospatial data.

The challenges on organizing and running the geospatial data and information is that cave surveyor has not been considered profession. It will be a violation regarding Article 55 Act 4/2011 which states that geospatial information must be organized by a competent and certified institution. Meanwhile, caver and speleologist in Indonesia are hardly to be certified. Lack of knowledge will lead to the lack of motivation. This can be considered as another challenge where the dissemination of the cave cartography is relatively low. Standardization is also poorly developed since the application and the production of cave maps is small number.
6. Conclusion
It can be concluded that both cave maps and Cave GIS are Geospatial Information regarding the Act Number 4 Year 2011 About Geospatial Information. The organization of them must obey the legal regulation.

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