Methodologies for mapping abandoned wetland in tropical region

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Abstract. Wetland development for food crops relies upon the good management related to the condition of canals, ditches, and water-gate, which determine the crop productivity and prosperity. Abandoned wetlands will create shrubs and bush. Revitalizing abandoned land means rebuilding infrastructure and re-clear wetland and requires valid spatial data to provide its proper planning. This study proposes a method to map abandoned wetland to gain sufficient information in supporting inventory and revitalization program in various scale. The methods include (1) dataset preparation by collecting historical satellite imageries, historical land use map, the boundary of previous wetland usages; (2) preliminary map preparation covering digital image processing, satellite image interpretation, overlying analyses of previous maps with infrastructure map, base, and land tenure map; (3) ground sampling survey to evaluate preliminary map and collecting biophysical and socio-economic data; (4) validation using accuracy test and statistical analysis; and (5) geo-visualization and tabulation for improving preliminary map and calculating abandoned map distribution. The activity will produce the vegetation indices and land use map by various methods and will be analysed using statistical analysis after ground sampling survey. The result showed that map of biophysical and socio-economic characteristic were prominent to provide basic spatial data for abandoned wetland revitalization.

1. Introduction
Suitable water management provides both ecological and economic functions which balancing the need of sustainable future for the community in tropical wetland environment. The utilization of wetland by developing canal, ditches, and water-gate have been productive in term of sufficiently satisfying the need of community. Nevertheless, increasing crop productivity by optimizing the use of wetland including swampland without proper management become the main issues in swamp farming \cite{1}. Water management monitoring have not been conducted well and leading to lowering water table, the acid oxidation, and lowering water and soil qualities. This wetland degradation decreases the swamp farming productivity, resulting in the abandonment of the land for relatively a long time by the owner. Thus, the terminology of abandoned wetland establishes which is referring to a wetland that is not used by its owner for a long time. Currently, this land has been covered by various grasses and shrubs or shrubs with the dominance of long-leaved paperbark (\textit{Melaleuca leucadendra}).

Some facts in the field show that abandoned wetland occur after more than 10 years of not being worked on \cite{2}. In fact, re-opening of abandoned wetland is important for saving the environment.
because it is prone to burning, optimizing land use and increasing value of investment, as well as providing new planting land to increase production and productivity. The restoration of abandoned wetland in the world, such as in Spain and Panama, is generally directed to recover swampland to swamp forest again. The abandoned wetland area is directed as a buffer zone as well as a remediation zone for aquatic pollutants caused by environmental activities. Some researchers also direct it for the development of agricultural crops, including for bioenergy [3,4,5]. Therefore, abandoned wetland reopening through revitalization is prominent to increase the environment value and community empowerment.

Farmers leave their land and let the land become abandoned due to several reasons, which include aspects of water, land, socio-economic, and labour. Knowing of the causes of abandoned wetland will determines the approach and efforts to restore it, whether it will be returned as natural swampland or revitalized into agricultural land again [2]. In the Indonesian context, optimizing swampland into agricultural land is a difficult choice that must be made because it is faced with fertile land reduction in dry land [1,6]. The revitalization of abandoned wetland has prevented the re-opening of forest swampland for agricultural activities. On the other hand, the spatial data information of abandoned wetland is needed to provide sufficient data to develop accurate revitalization planning and deliver a direct impact to the community. The spatial data of the distribution of abandoned wetland by name by address is not yet available. Land survey approaches and socio-economic surveys can be implemented but require a long time and are expensive because the locations of abandoned wetland are generally in remote area. Meanwhile, the advance of remote sensing, data analysis technology, and computing allow us to accelerate spatial identification activities which are then combined with field checking and socio-economic surveys [7,8].

The advance of remote sensing such as high and medium resolution satellite data are now increasingly accessible. Likewise, processing spectral index and machine learning-based classification methods using computer software is getting easier. On the other hand, the advancement of the internet and cloud storage technology allows data processing to be carried out virtually so that it does not consume a lot of data storage media and computer memory [9,10,11]. Local and expert knowledge are compulsory to justify the study areas representation and the use of this technology analysis especially in determining the robust methods for the best result.

This paper aims to discuss about 3 methods for identifying the spatial distribution of abandoned wetland with the goal is to provide an effective methods of utilizing an advanced high and medium resolution remote sensing data; spectral index processing and machine learning; and the use of internet technology for cloud-based data processing. These methods are new for identifying the spatial distribution of abandoned wetland. Without ignoring the existing shortcomings, the strengths of these methods are covering a wider and remote area; cost-effective, time, and human resources.

2. Methodology
This study conducts multi-temporal and multi-scale satellite image analyses applied into three methods based on remote sensing and geographic information system analyses. It includes (1) visual interpretation analysis; (2) spatial modelling using transformation index analysis; and (3) classification automatization using Google Earth Engine ®(GEE®). Mapping validation for ground survey, utilizes field sampling determination and statistical analysis, based on mapping analysis units generated from these three methods.
2.1. Method 1: Sentinel satellite image-based spatial modelling

![Diagram](image)

**Figure 1.** Flow chart for mapping abandoned wetland with Sentinel satellite image-based spatial modelling.

In the first method, an index transformation is used, namely the Normalized Difference Water Index (NDWI) to identify water bodies and soil surfaces that have higher water content. The NDWI transformation is used to distinguish land and water areas [12]. The NDWI algorithm uses the green band and infrared band according to the formula:

\[
NDWI = \text{Green} - \text{NIR}/(\text{Green} + \text{NIR})
\]  \(1\)

While the other index is the extraction of the Normalized Difference Vegetation Index (NDVI), which was originally called the Transformed Vegetation Index (TVI), to identify vegetation based on its greenery level [13]. The NDVI algorithm uses the infrared band and the red band with the formula:

\[
NDVI = \text{NIR} - \text{Red}/(\text{NIR} + \text{Red})
\]  \(2\)

Both index are processed from Sentinel 2A satellite data with a resolution of 20 m. The combination of the two index is expected to be able to be used to distinguish high-density vegetation and low-density vegetation in wetland areas and non-wetland areas. NDWI and NDVI values range from -1 to 1, each of which indicates the degree of wetness and greenness of the earth's surface.

The two index maps are then overlaid with more detailed SPOT satellite data, 6 m, [14,15] to determine the estimated pixel values of the abandoned wetland with other areas. Next, the observation points are randomly assigned to obtain a threshold value for each abandoned wetland. The threshold value becomes a benchmark for building a model so that a temporary map can be obtained which is followed by conducting ground checked.
2.2. Method 2: GEE based automatic classification

![Flow chart for mapping abandoned wetland with GEE based automatic classification.](image)

Second method uses Google Earth Engine Editor with visible light bands, namely the red band, green band, and blue band from Sentinel 2A satellite data [11]. These three bands are also known as RGB or true colour bands. In this method, classification relies on differences in features such as patterns, textures, and associations that automatically appear in the visible light band using the segmentation method. Next, 13 points of abandoned wetland are determined as training data. Likewise, other areas around the abandoned wetland such as rice fields, settlements, and forests.

2.3. Method 3: Analog/visual interpretation analysis

![Flow chart for mapping abandoned wetland with analog/visual interpretation analysis.](image)
Third method uses QGIS software with visible light bands, namely the red band, green band, and blue band known as RGB band or true color on SPOT data which is a high resolution image [15]. This third method is a frequently used method, which is basically a desktop-based interpretation of satellite imagery or online-based via Google Earth. In this method, RGB or true colour satellite imagery on SPOT data which is a high resolution image becomes the basis. The classification of abandoned wetland cover is determined by comparing differences in features such as patterns, textures, and associations that appear in the visible light band. This method works well on a narrow area but takes longer if it covers a large area. Satellite imagery archives as a basis are widely available so that it is possible to monitor and limit land cover changes. For example, Google Earth provides time series images that can be used to monitor changes in abandoned wetland.

![Figure 4. Archived imagery on Google Earth Pro 2012-2019 to monitor abandoned wetland changes in the Dadahup A5 block, Kapuas, Indonesia.](image)

3. Result and Discussions
This research includes the satellite image processing and visual interpretation analysis, and sampling methods determination for ground surveys. The results of these processing will have 3 different types of mapping unit analysis. Therefore, each method will have different sampling methods and numbers, as well as their accuracy test.
Using analog/visual interpretation analysis, abandoned wetland areas are showed in polygons (figure 5). By using a different method, abandoned wetlands are showed in blue color in figure 6 (sentinel satellite image-based spatial modelling method) and figure 7 (GEE based automatic classification method). Comparison methods will be undertaken to perceive the level of accuracy and effectiveness of each abandoned wetland mapping methods. The current research results present a descriptive hypothesis of the methods comparison analysis. Table 1 compares the performance of the three methods based on selected parameters. From the aspect of speed and coverage area, method 1 and method 2 tend to be fast. However, in terms of the chance of misinterpretation of method 2, it is classified as moderate.
| Parameter                  | Method 1 | Method 2 | Method 3 |
|---------------------------|----------|----------|----------|
| Speed                     | Fast     | Fast     | Slow     |
| Input availability        | Available| Available| Available|
| Modelling                 | Yes      | No       | No       |
| Programming               | Yes      | Yes      | No       |
| Scripts availability      | No       | Yes      | No       |
| Software                  | QGIS, R  | GEE      | QGIS     |
| Computer ability          | High     | Moderate | Low      |
| Coverage effectiveness    | Wide     | Wide     | Narrow   |
| Automatic updates         | Yes      | Yes      | No       |
| Possibility for misinterpretation | Low     | Moderate | Low      |
| Ground checking           | Yes      | Yes      | Yes      |
| Platform                  | Offline  | Online   | Offline/online |
| Open source support       | High     | High     | Moderate |
| Technician availability   | Limited  | Moderate | Abundance|
| Data models               | Raster   | Raster   | Vector   |

Table 1 data can be taken into consideration in selecting approaches and procedures in identifying abandoned wetland in the tropical region. The chosen method is determined by data availability, technician, and coverage area. Applying all the methods then compare the consistent results as the final result is also a better approach. From the table 1, it appears that method 1 is promising because the raster-based results can be integrated with other environmental modelling activities. However, limited human resources will make this method less popular. Raster-based data processing such as method 1 and method 2 requires good hardware support, such as random access memory and high storage. The database also needs to be developed so that the results can be easily retrieved for updates or for integration with other models.

4. Conclusion
This paper discussed 3 methods that might be applied in Indonesia for abandoned wetland mapping. Which method might be applied is adapted to the availability of human resources who understand concepts and procedures, data availability, and hardware support. By looking at the advantages and disadvantages of the three methods, method 1 and 2 looks more promising. Lack of human resources that hinders the implementation of method 1 can be anticipated by conducting regular trainings and dissemination, to make sure that this method will be recognized and implemented widely. In the future, a lot of training and preparation of data in the database is very much needed to accelerate the provision of spatial data by adding the availability of detailed sensory data.

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