Use of Physical Characteristic Data for Landuse Planning in Agriculture Activities: Conceptual Design

Ahmad Priyo Sambodo[1*], Yoesep Budianto[2], Rusma Prima Rokhmaningtyas[3], Muhammad Geyn Noveberian[4]

[1] Earth System Science and Andaman Natural Disaster, Prince of Songkla University, Phuket Campus, 83120, Thailand

[2] Research and Development Harian *KOMPAS*, Jakarta, 10270, Indonesia

[3] Geoinformation for Spatial Planning and Disaster Risk Management, Graduate School of Universitas Gadjah Mada, Yogyakarta, 55281, Indonesia

[4] Faculty of Geography, Universitas Gadjah Mada, Yogyakarta, 55281, Indonesia

***Corresponding author, ahmedpriyos@gmail.com**

Abstract

The absence of standard parameters in land use planning threaten the quality of land resources and leads to a decline in agricultural productivity, especially in Indonesia. Identification of erosion process, productivity index, and slope conditions could be considered for land use planning, especially for agriculture. Since 2018, the Indonesian government has provided a national seamless Digital Elevation Model, called DEMNAS, which has 8,5 meters resolution for development planning purposes, including environmental research. This paper aims to design a conceptual framework for utilizing the physiographic conditions, erosion identification, and projecting the productivity with productivity index values as a basis for land-use planning. The concept is formulated by using available data and literature studies, related to land resource management. The conceptual design from this study can be helpful for land use planning purposes, especially if the good quality of data provided.

Keywords: *Land Resources, Soil, Erosion, Landslide, Landuse Planning*

1. Introduction

As a country with the fourth-largest population in the world, the need for food continues to increase from year to year. However, in Indonesia, land clearing for agriculture is carried out, mostly, without good planning. Land use is carried out spontaneously and only based on actual needs, without considering sustainability. The long-term negative impact is the occurrence of land degradation in the form of accelerated erosion, landslides, and decreased productivity (Duan, Xie, Ou, & Lu, 2011; Pierce, Larson, Dowdy, & Graham, 1983). The absence of good data sources, standard parameters, and integrated work models for planning challenges experienced by the Indonesian government.

In 2018, the Indonesian government launched a digital elevation model (DEM) with a resolution of 8.5 meters under the name DEMNAS or national seamless DEM (Badan Informasi Geospasial, 2018). The main purpose of the launch of this DEM is to support the development process, especially in terms of planning. In addition, Unmanned Aerial Vehicle (UAV) or drones with a high-resolution camera, multiple sensors, but with affordable prices are also growing in the market. The UAV technology could provide even detail remote sensing data. High-resolution, detail, and precise data could be used to model land characteristics for land-use planning.

2. Methods

2.1. Research Area

Designing the framework for land management planning is carried out in volcanic areas, more specifically the transition area between quarter volcanic and tertiary volcanic. This region has unique characteristics, mainly super thick soils that have very high clay content. Soil from volcanic materials is very suitable for agricultural activities because of its fertility, but due to rainfall intensity, high clay content, and super thick layers the threat of erosion and large landslides are the challenges that must be considered in land management. Although under the specific conditions, the transition landforms are commonly found around the volcanic belt of the island of Java which has a high population and is majority an agricultural area.

2.2. Methodology

This paper was prepared using a literature review from the research that has been carried out in the volcanic transition area, namely the Bompon Watershed, Magelang District, Central Java. The study was carried out from 2015 to 2016 under the natural laboratory and the Transbulent study group. On this study, the soil-landscape relationship, soil productivity index, landslide, soil erosion, and tolerable soil loss terminology is an important key factor for a land use planning for agriculture.

a. Soil – landscape relationship

To understand the relationship between soil and landscape, it is important to know first the basic soil formation formula which is

$$S = f(cl, o, p, r, t)$$

S is for *soil*, *cl* stands for *climate*, *o* is for an *organism*, *p* for *parent material*, *r* from *relief* and *t* for *time* (Jenny, 1994). Because topography so strongly affects pedogenic processes, either directly or indirectly, and is relatively easy to measure, there is considerable interest in using it as the basis for modeling the spatial distribution and behavior of soils (Dobos & Hengl, 2009; Hengl & MacMillan, 2009; Scalenghe, Certini, & Ugolini, 2006).

b. Soil Productivity Index

Productivity index (PI) is a method to assess the potency of land productivity for agricultural activities (Pierce et al., 1983). The formulation to estimate the productivity index using the so-called Modified Productivity Index (MPI) method is as follows

$$PI = \sum_{i=1}^{n} A_i \ x \ CL_i \ x \ O_i \ x \ D_i \ x \ WF_i$$

A is the Available Water Content, CL is clay content, O is organic matter, D is soil pH, and WF is a Weight Factors (Duan, Xie, Feng, & Yin, 2009; Duan et al., 2012; Duan, Xie, Ou, & Lu, 2011)

c. Soil erosion

Soil erosion is the movement and transportation of various agents, especially water, wind, mass movements and hence the climate is a key factor (Blanco & Lal, 2010; Renard & Service, 1997). It is a slow dynamic natural process that involves detachment, transportation, and accumulation of productive surface soil across the earth's surface (Jain, Kumar, & Varghese, 2001). Soil loss from erosion has exceeded the rate of new soil formation as much as 10 and 20 times in the last decade (Montgomery, 2007).

d. Landslide

Landslide is one of the Natural Disasters that can cause massive both casualties and economic losses in distant mountainous regions (Dai, Lee, & Ngai, 2002). It is sad yet inevitable, therefore in order to ease both massive casualties and economic losses, a better understanding is required. Essentially, a landslide is downwards or outwards movement of earth-forming materials. Soil is not the only thing in the earth-forming materials, there are bedrock, natural rock, and artificial materials or a combination of these. There are also factors that make an unfavorable change of conditions like stress condition and strength of the materials (Varnes, 1984).

e. Tolerable soil loss

Tolerable soil loss is a rate of soil erosion that still allowed without having a negative impact on land cultivation (Arsyad, 2010; Boardman & Poesen, 2006; Li, Du, Wu, & Liu, 2009). The tolerable soil loss is very important because the soil erosion is a part of natural processes on soil that also has some benefits, and cannot be eliminated (Montgomery, 2007). The tolerable soil loss value has the potential to be used as a reference because it considers the recovery rate of the soil, and also the natural productivity ability of the soil based on its natural composition (Soil Science Division Staff, 2017).

3. Discussions

Agricultural planning requires several main parameters related to the physical characteristics of the land. Collaboration between physical characteristics of soil and detailed mapping using UAV and DEMNAS technology is the key to successful land management. Precision agriculture is the main goal of all parameters used. The concept of this framework is based on the conditions of the transitional volcanic landform, which has unique and specific soil characteristics. This framework also accommodates planning up to a detailed scale, which is 1: 10,000. The concept that has been compiled consists of three stages, (1) Data acquisition, (2) designing soil mapping units, and (3) identifying potential uses and problems (**fig.1**).

Four studies underlie the design of agricultural land planning. The method used is the meeting point of precision agriculture. Each research method produces studies that are following general characteristics to detailed land resources at the research site.

Budianto's (2016) study of clay content in the soil reveals the detailed characteristics of land resource units composed of soil. The method used is the test of the physical properties of the soil and analysis of soil behavior on land processing carried out. The physical properties of soil include basic conditions for agriculture to the sensitivity and strength of the soil. As a result, the clay content in the volcanic transition region reaches more than 60 percent with the type of kaolinite mineral. While the strength of the soil is in the soft category with sensitive properties to changes in water content. The results of this study can offer a clear picture of the processing of clay soil which must control water content. So that the carrying capacity of the soil is maintained for agriculture.

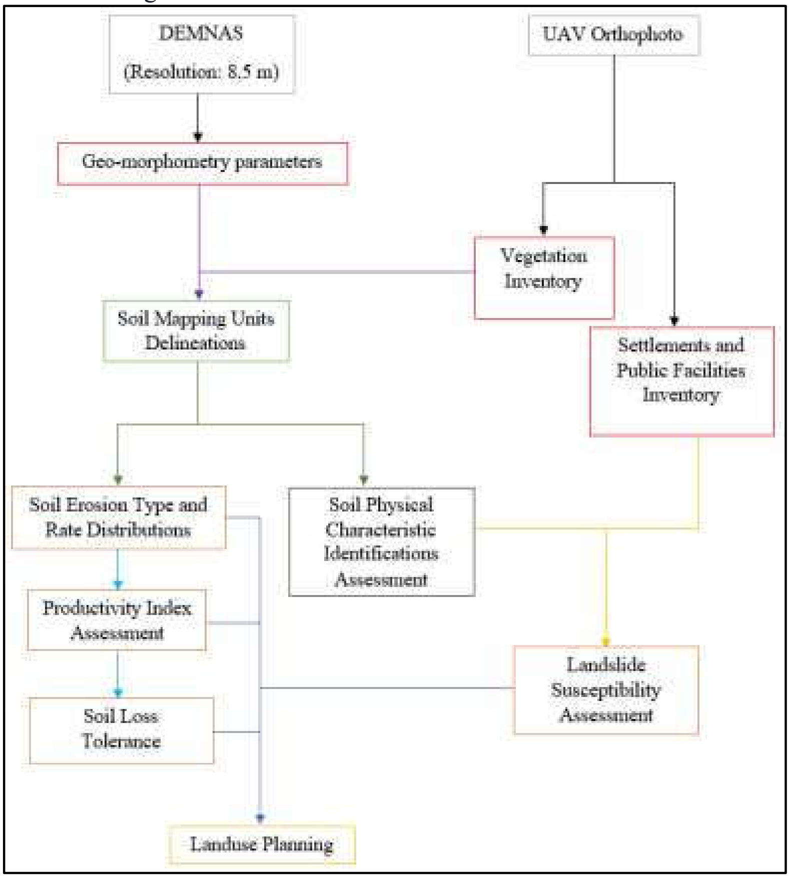

Figure 1. Framework for Landuse Planning

Detailed slope analysis was carried out by Noveberian (2017) by utilizing slope attributes, such as the inclination angle of the slope to the direction of the slope. The use of the results of this study is for residential land use associated with other land uses, such as plantations and agriculture. As a result, a broad type of land use is not affected by slope conditions on a macro basis. The detailed inventory of slope characteristics is the key to the sustainability of land resources in a region. The picture on a broad scale is increasingly irrelevant to use to ensure the quality of land, especially the productivity of agricultural land.

The application of land characteristics combined with detailed mapping technology is measuring the sustainability of land resources. Rokhmaningtyas (2017) calculates the estimated loss of land. The method used is the interpretation of DEM data combined with an inventory of vegetation and land conditions. As a result, the type of vegetation has a significant role in the high rate of land loss. Agricultural planning does not only rely on one type of vegetation. The more types of vegetation planted in one area of land, the potential for loss of land decreases. The type of intercropping agriculture is one of the best ways to meet needs and keep up the environmental quality.

Another application of detailed land characteristic data is to estimate the productivity index and tolerable soil loss. Sambodo (2016) calculated the tolerable soil loss in the volcanic transition area based on the soil productivity index. Physical and chemical characteristics of soil are used to calculate productivity index values which are then used to measure tolerable soil loss. The results of this study indicate that soil in the volcanic transition region has a very low productivity index. The high clay content and low organic matter on the soil contribute to the low productivity index value. This resulted in a low tolerable soil loss in the transition volcanic region. To maintain the quality of the land, land use planning should be done precisely, conservation method, as well as the selection of suitable commodities, need to be done so the sustainability of land can be maintained.

4. Conclusions

The availability of high-resolution digital elevation model can be used to make detailed planning through identifying the physical characteristics of the land. Data with detailed resolution can be transformed into morphometric data with fine accuracy. Combined with other data such as aerial photographs of UAVs, and primary data collection, key information such as soil characteristics, landslide vulnerability, erosion rates, potential productivity, and tolerable soil loss can be added to land use planning.

5. Acknowledgement

The authors are very grateful for worthwhile assistance and guidance from Prof. Dr. Junun Sartohadi, M.Sc, and Dr. Muhammad Anggri Setiawan, M.Sc as Supervisor Faculty at Universitas Gadjah Mada, Special Region of Yogyakarta. The authors would like to thank Doctor Guruh Samodra from Environmental Geography, Universitas Gadjah Mada, for his valuable discussion during research. This article is composed of every research from 2015 to 2017 by the authors, at Transbulent Natural Laboratory, Bompon Watershed, Magelang, Central Java. The entire data legally belong to the Transbulent Study Group.

6. References

Arsyad, S. (2010). Konservasi Tanah & Air. Retrieved from https://books.google.co.id/books?id=g52mtQEACAAJ

Badan Informasi Geospasial. (2018). DEMNAS: Seamless Digital Elevation Model (DEM) dan Batimetri Nasional. Retrieved April 27, 2019, from http://tides.big.go.id/DEMNAS/

Blanco, H., & Lal, R. (2010). Principles of soil conservation and management (1. softcover print). Dordrecht: Springer.

Boardman, J., & Poesen, J. (Eds.). (2006). Soil erosion in Europe. Chichester, England ; Hoboken, NJ: Wiley.

Budianto, Y. (2016). Keterdapatan Sensitive Clay Pada Lokasi Longsorlahan di DAS Bompon, Kabupaten Magelang, Jawa Tengah (Universitas Gadjah Mada). Retrieved from http://new.etd.repository.ugm.ac.id/home/detail_pencarian/104056

Dai, F. C., Lee, C. F., & Ngai, Y. Y. (2002). Landslide risk assessment and management: An overview. Engineering Geology, 64(1), 65–87. https://doi.org/10.1016/S0013-7952(01)00093-X

Dobos, E., & Hengl, T. (2009). Chapter 20 Soil Mapping Applications. In Developments in Soil Science (Vol. 33, pp. 461–479). https://doi.org/10.1016/S0166-2481(08)00020-2

Duan, X., Xie, Y., Feng, Y., & Yin, S. (2009). Study on the Method of Soil Productivity Assessment in Black Soil Region of Northeast China. Agricultural Sciences in China, 8(4), 472–481. https://doi.org/10.1016/S1671-2927(08)60234-5

Duan, X., Xie, Y., Liu, B., Liu, G., Feng, Y., & Gao, X. (2012). Soil loss tolerance in the black soil region of Northeast China. Journal of Geographical Sciences, 22(4), 737–751. https://doi.org/10.1007/s11442-012-0959-5

Duan, X., Xie, Y., Ou, T., & Lu, H. (2011). Effects of soil erosion on long-term soil productivity in the black soil region of northeastern China. CATENA, 87(2), 268–275. https://doi.org/10.1016/j.catena.2011.06.012

Hengl, T., & MacMillan, R. A. (2009). Chapter 19 Geomorphometry — A Key to Landscape Mapping and Modelling. In Developments in Soil Science (Vol. 33, pp. 433–460). https://doi.org/10.1016/S0166-2481(08)00019-6

Jain, S. K., Kumar, S., & Varghese, J. (2001). Estimation of Soil Erosion for a Himalayan Watershed Using GIS Technique. Water Resources Management, 15(1), 41–54. https://doi.org/10.1023/A:1012246029263

Jenny, H. (1994). Factors of soil formation: A system of quantitative pedology. New York: Dover.

Li, L., Du, S., Wu, L., & Liu, G. (2009). An overview of soil loss tolerance. CATENA, 78(2), 93–99. https://doi.org/10.1016/j.catena.2009.03.007

Montgomery, D. R. (2007). Soil erosion and agricultural sustainability. Proceedings of the National Academy of Sciences, 104(33), 13268–13272. https://doi.org/10.1073/pnas.0611508104

Noveberian, M. G. (2017). Pemetaan Rumah Rentan Longsor dan Rentan Tertimbu Longsor di Daerah Aliran Sungai (DAS) Bompon, Kabupaten Magelang (Universitas Gadjah Mada). Retrieved from http://new.etd.repository.ugm.ac.id/home/detail_pencarian/111578

Pierce, F. J., Larson, W. E., Dowdy, R. H., & Graham, W. A. P. (1983). Productivity of soils: Assessing long-term changes due to erosion. Journal of Soil and Water Conservation, 38(1), 39–44.

Renard, K. G., & Service, U. S. A. R. (1997). Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE). Retrieved from https://books.google.co.id/books?id=cQEUAAAAYAAJ

Rokhmaningtyas, R. P. (2017). Estimasi Kehilangan Tanah Aktual Terkait Pengaruh Vegetasi di DAS Bompon (Universitas Gadjah Mada). Retrieved from http://new.etd.repository.ugm.ac.id/home/detail_pencarian/111273

Sambodo, A. P. (2016). Perhitungan Nilai Ambang Batas Erosi dengan metode Modified Productivity Index di Daerah Aliran Sungai Bompon, Kabupaten Magelang, Jawa Tengah (Universitas Gadjah Mada). Retrieved from http://new.etd.repository.ugm.ac.id/home/detail_pencarian/104726

Scalenghe, R., Certini, G., & Ugolini, F. C. (2006). Soils: Basic concepts and future challenges. Retrieved from http://public.eblib.com/choice/publicfullrecord.aspx?p=321101

Soil Science Division Staff. (2017). Soil Survey Manual (Craig Ditzler, Kenneth Scheffe, & H. Curtis Monger, Eds.). Washington, D.C: Government Printing Office.

Varnes, D. J. (1984). Landslide hazard zonation: A review of principles and practice. Paris: Unesco.