Using GIS for Integrated Assessment of Agriculture Land Suitability and Food Security in Small Islands

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Abstract. Food security has recently become one of important issues in Indonesia’s small islands, since increasing human populations and declining land quality have continued to occur in such areas. With limited new agricultural land in small islands to develop, meeting the food needs of future populations in such areas will require an increase of crop yields, through appropriate decisions on land use and land management. The principal aim of this paper is to construct a spatial decision making mechanism using Geographic Information Systems (GIS) to perform land suitability analysis and to assess food security in a very limited agricultural land of a small island. We use spatially integrated method in GIS and Analytical Hierarchy Process (AHP) to generate priority of food crop development that may give insights into some important criteria of food security. In our analysis, we use five types of food crops (dryland rice, maize, sweet potato, taro plant, and cassava), with five generic criteria: land potential (LAND), economic aspect (ECON), culture aspect (CULT), infrastructure availability (INFR), and local government policy (POLY). Our preliminary findings show that maize was the most important food crop to be developed in this area, followed by cassava, dryland rice, sweet potato, and taro plant, although each criterion selected gives a different rank for the five crop types. The results of this analysis could provide the basis for local government to strengthen its decision making in the allocation of food crops from the perspectives of the small island’s food security.

Key words: agricultural land suitability, food security, GIS, small islands

Introduction

The main problem that is often faced even failure in agricultural land development is that the selected commodities are less or even not in accordance with the local soil and climate conditions. Thus, the genetic potential of cultivated plants cannot be optimized due to a mismatch between the requirements for plant growth and the characteristics of the soil and the local climate. Young (1988) argues that, based on many experiences, there is a risk level of 30-50 percent for a large-scale agricultural enterprise if it is not based on detailed information about the nature of the soil and climate. In the long-term perspective, these non-conformities not only have an impact on risks such as low productivity of plants, but also pose a threat to damage to land resources.
Indonesia is an archipelago with thousands of large islands and small islands. Each region, especially in areas with small islands, will vary in terms of the success of responding to the implementation of the self-sufficiency program mentioned above. Food needs and approaches to fulfillment will differ from one another, depending on geographical typology, land area and quality, climate, level of vulnerability to natural disasters, and community culture. Generally, the small islands in Indonesia face the problem of limited agricultural land and/or at the same time the limited infrastructure that connects the region with the enclaves of agricultural food production.

Evaluation of agroecological suitability (land suitability) will emphasize the analysis of the diversity of land characteristics, because it will determine the type of commodity that can be cultivated, which in its sequence determines the level of land productivity (Baja, 2001). Meanwhile, socio-economic studies can provide direction on the economic feasibility of developing certain commodities (Rossiter, 1995), including the ability of farmers to manage land within a particular region (Webb and Thiha, 2002). The development of agricultural commodities in areas that are in accordance with the requirements of plant propaganda (climate, soil, and topography) and socio-economic conditions, coupled with management based on land characteristics, will provide optimal and sustainable results (Doran et al, 2002). This requires continuous and integrated research.

Research objectives
The purpose of this study is to know and solve the problems of developing food commodities in small island areas, from the aspects of quality and availability of land (biophysics), public interest and preferences, and policies implemented.

Methodology
This research was conducted at Kaledupa Island, Wakatobi Regency, Southeast Sulawesi Province Indonesia from May to August 2018 (Fig. 1). Analysis of soil samples in the laboratory of the Department of Soil Science, Faculty of Agriculture, Hasanuddin University, Makassar, Indonesia.
system map, 19 land units were built for field observation and soil sampling. Soil observation in the field was conducted by transect [2,4]. Soil classification was determined according to Soil Survey Staff [5]. Field observation and soil sampling were conducted on the 19 land units. The field survey to identification of land characteristics such as soil depth, soil drainage, slope, soil surface rock, flood hazard, and others. In this stage included analysis of climate data. Soil sample analysis was conducted primarily for land evaluation. Soil characteristics analysis consist of: a). soil texture, b). drainage, c). soil depth, d). rock surface, and e). inundation (flooding). Properties of soil chemical are: a). soil acidity (pH), b). base saturation, c). organic matter, d). cation exchange capacity (CEC), and e). salinity. For land suitability classification using GIS software ArcGIS 10.2 (licensed by ESRI Indonesia). Land suitability classification was analyzed based on FAO system with simple limitations method [6, 7] for 5 crops consist of dryland rice, maize, sweet potato, taro plant, and cassava.

[3] Results and Discussion
There are 2 quite broad sub-districts, namely Wangi-Wangi and South Wangi-Wangi sub-districts covering 54, 43% of the total area of Wakatobi Regency. Whereas Kaledupa District is only 5.53% and South Kaledupa is only 7.11% of Wakatobi Regency. However, Kaledupa and South Kaledupa Subdistricts are two sub-districts that have a extensive land area, so the development of agricultural commodities on Kaledupa Island was very potential to be carried out.

The result of land suitability analysis showed the level of suitability of the land unit for specific crops. The class of suitability consists of; S1 = highly suitable; S2 = moderately suitable; S3 = marginally suitable, N1 = currently not suitable and N2 = not suitable permanently, and the most potential crops to be developed were dryland rice (S2) 2182.7 ha, maize (S2) 2.067,4 ha, and taro plant (S2) 2.067,4 ha.

| Crops         | S1 | S2     | S3     | Land potency (ha) | Development potency (ha) |
|---------------|----|--------|--------|-------------------|--------------------------|
| 1. Dryland rice| -  | 2.182,7| 2.250,1| 4.432,8           | 4.432,8                  |
| 2. Maize      | -  | 2.067,4| 2.365,4| 4.432,8           | 4.432,8                  |
| 3. Cassava    | -  | 1.906,0| 2.526,0| 4.432,8           | 4.432,8                  |
| 4. Sweet potato| -  | 1.906,0| 2.018,0| 3.924,0           | 3.924,0                  |
| 5. Taro plant | -  | 2.067,4| 2.365,4| 4.432,8           | 4.432,8                  |

Soil analysis results also showed that soil characteristics mainly soil chemistry and fertility classified as quite good. Soil acidity, cation exchange capacity, C-organic and base saturation were generally moderate while potassium and nitrogen were at medium to high level. The level of limiting factor of soil chemical was relatively mild, while the degree of limiting factors from soil physics was classified moderate to severe and it’s needed more efforts to overcome the limitations such as soil depth, percentage of surface stoniness, coral, drainage of land unit. The mild constraints of soil fertility (pH, CEC, C-organic,) could be improved by fertilization and calcification [12, 13]. Dryland rice is the most prospective commodity, followed by maize and taro plant based on the land suitability class and land potency for every crop. The limiting factors that should be considered in land development were the soil depth and stoniness in the surface.

Based on land suitability analysis, dryland rice classified as moderately suitable (S2) and marginally suitable (S3) in area 4.432,8 ha, which consist of 2.182,7 ha in S2 and 2.250,1 ha in S3. Maize classified as
S2 located at 2.067,4 ha, S3 2.365,4 Ha and potentially to be developed become 4.432,8 ha. Cassava was suitable to be cultivated at 1.906 ha (S2) and 2.526 ha (S3). Sweet potato has potentially to be cultivated toward 4.432,8 ha which consist of 1.906 ha as S2 and 2.018 ha (S3). The suitable area for taro plant located class S2 was 2.067,4 ha, class S3 2.365,4 ha. The examples of land suitability distribution in Kaledupa showed in the Fig. 2 for dryland rice and sweet potato.

![Figure 2. Map of land suitability of dryland rice (a) and (b) sweet potato in the research area](image)

### Conclusion

The preliminary findings show that dryland rice was the most important food crop to be developed in this area, followed by maize, cassava, dryland rice, sweet potato, and taro plant, although each criterion selected gives a different rank for the five crop types. The results of this analysis could provide the basis for local government to strengthen its decision making in the allocation of food crops from the perspectives of the small island’s food security. The main limiting factors to the development of food crops in this area are soil fertility, rock outcrops, and topography.

### Acknowledgments

The authors deeply thankful to The Ministry of Research, Technology, and Higher Education, Republic of Indonesia, through an BMIS research scheme and the Department of Soil Science, Faculty of Agriculture, Hasanuddin University, for supporting data and facilities for this research.

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