Land suitability evaluation according to agroecological zone information for agricultural commodity development in coastal area of Tegal Central Java Indonesia

Samijan* and S Jauhari

Assessment Institute for Agricultural Technology (AIAT) of Central Java Jl. Soekarno-Hatta Km. 26 No. 10 Bergas Lor, Bergas, Kab. Semarang Jawa Tengah, Indonesia

Corresponding author: samijan_bptpjtg@yahoo.com

Abstract. The Agroecological Zone (AEZ) is an information system to determine the potential of land resources. Based on that, the suitability of plants and their land management technology can be identified. The evaluation of land suitability of coastal areas in Tegal District was carried out using matching method between growing requirements for commodities and land characteristics of AEZ data. AEZ identification results show that the coastal area consists of three zones, namely Zone A, alluvial plains with Typic Endoaquepts and Aeric Endoaquepts soil types; Zone B, Fluvio-marine plains with Tropic Endoaquepts soil types; and Zone C, coastal areas with Typic Udipsamments soil types. Based on the agroecological characteristics, the coastal area is suitable for crops development and fisheries. The suitable agricultural commodities namely rice, water melon, sugar cane and jasmine, which correspond to class 1 (S1) for zones A and B; red chilies and shallots, class 2 (S2) which is suitable for zones A and B. While zone C is identified as less suitable for food crops or horticulture, due to limiting factors such as poor oxygen availability and poor root conditions.

1. Introduction

Optimal agricultural production will be achieved if land and the commodity management system are matched to its potential, capabilities, and suitability class. The decision to make the right choice of land and commodity management requires accurate information about the potential and characteristics of land and resources environment. The Automated Land Evaluation System expert system and the Land Suitability Assessment System [1, 2] could be applied in this regards. The agroecological zone (AEZ) is the simplification and classification concept of variation in agroecosystem for applied and informative classification [3, 4]. According to FAO [5], an AEZ is a map of land resources compiled which based on climatic, land-form, soil, and physiographic data, with a range, potential, and certain limiting factors for certain land use. Using AEZ approach, the use of land potential can be identified quickly, easily, and precisely.

The AEZ information system makes it easy to identify land suitability classes for agricultural commodity development. Abdurachman et al. [6] stated that one of the benefits of AEZ application is its a model for maximizing land management. However, according to [4], the accuracy of AEZ information is highly dependent on the accuracy of the data used in the preparation of AEZ.
Alternative land suitability and agricultural commodities can be determined using AEZ data and information that has been complemented by land resource data from field surveys. By using land suitability evaluation program and agricultural commodities, it could determine the level of suitability of a commodity, and also possible to know the need of land management technology based on the suitability of plant growth requirements with the land limiting factors found in each AEZ. Thus, AEZ information can also be used as tool for evaluating the potential of land resources, which is very useful for land use planning, agricultural development planning and land management planning.

Tegal District is one of the areas in Central Java Province which has coastal area in the north (Kramat, Suradadi and Warureja Sub Districts) which is generally used for agriculture. These three area are around 15,653 ha (18% of the total land area of Tegal District), consist of 10,373 ha (27%) and non-paddy fields of 5,280 ha (11%) [7].

The existing agricultural commodities that are still developed by farmers are rice, corn, chilies, green beans and jasmine [8]. Based on the potential of existing land resources, coastal areas in the northern part of Tegal District have variations in land characteristics, potential, suitability class and land limiting factors [9]. For the purpose of developing agricultural commodities in that area, the identification of potential land resources and assessment of commodity suitability classes and land management need to be studied.

2. Methodology
This study was carried out in northern coastal area of Tegal District, Central Java Province, using 1:50,000 scale of AEZ database compiled by Central Java AIAT [9]. Determination of alternative suitability of agricultural commodities and the need for land management technology is carried out using the expert land system evaluation programs through alignment and matching of data characteristics and quality of the land with data on the optimal requirements of plant growth. The expert system for land suitability evaluation refers to the land suitability evaluation guidelines which is published by FAO and the Agricultural Research and Development Agency [2,5,10–13]. Furthermore, the results produced by the land evaluation program are subject to descriptive discussion and explanation by referring to the technical guidelines for land evaluation [11,13].

3. Results and discussion
3.1. Land characteristics
Based on the AEZ, the coastal area in the northern part of Tegal District is spread over 3 Sub Districts namely Kramat, Suradadi and Warureja, with 3 variations of land units (zones). The land unit variations illustrate the combination of 3 landforms with 4 soil types, and spread over 2 different slopes (Table 1), main material and types of land use [9,14].

Table 1. Distribution of agro-ecological zone on coastal area in the north part of Tegal District [14,15]

| Zone     | Landform             | Main material | Slope (%) | Soil Types                               | Area (Ha)  | %   |
|----------|----------------------|---------------|-----------|------------------------------------------|------------|-----|
| 1        | Alluvial plains      | Sediment      | 0-1       | Typic Endoaquepts and Aeric Endoaquepts  | 16,769.70  | 94  |
| 2        | Fluvio marine plains | Sediment      | 0-1       | Typic Endoaquepts                        | 171.85     | 1   |
| 3        | Coastal area         | Sediment      | 1-3       | Typic Udipsamments                       | 866.39     | 5   |

Data source: Agroecological zone map of Tegal District, scale 1:50,000 [9]

The variations in land units or agro-ecological zones as referred to above include (1) alluvial plain zone with flat topography at a slope of 0-1%, (2) flat fluvio-marine flat zone with flat topography at a slope of 0-1%, and (3) a coastal zone with a slightly flat topography with a slope of 1-3%. The main material in the zone or land unit is formed from alluvium material to produce 4 types of soil, namely (1) Typic Endoaquepts and Aeric Endoaquepts, (2) Typic Endoaquepts, and (3) Typic Udipsamments
In general, soil types in coastal areas have deep soil depth, neutral pH and poor soil drainage, except for Typic Udipsamments soil types. The annual rainfall at this location is around 2,250 mm per year.

Based on the type of soil, the alluvial and fluvio-marine plains zone has a fine to very fine soil texture with neutral soil acidity (pH). This condition causes soil characteristics in the zone (alluvial plains and fluvio-marine plains) to have poorly soil drained. Whereas the coastal zone with Typic Udipsamments soil type has a neutral soil acidity (pH) with coarse soil texture, so that soil drainage in this zone tends to be excessively drained.

3.2. Land suitability class

The result of land suitability showed in Table 2. The agroecological areas, mostly, still have the opportunity to be used as agricultural development areas. Land suitability classes for agricultural development in the alluvial plain and fluvio-marine zone can be directed to the development of food crops, horticulture and plantations, by prioritizing lowland agricultural commodities. In the alluvial plain zone there are a small number of soil types with dry conditions with several seasons per year, so that in these conditions land can be cultivated by applying a rotation pattern between wetland and dry land. In utilizing the alluvial and fluvio-marine plain zones, it is recommended that farmers pay more attention to and prioritize technological innovations related to improving soil drainage and root conditions. Several agricultural commodities that have good prospects and suitability (S1) in the region namely rice, water melons, sugar cane and jasmine.

**Table 2.** Land suitability class on each agro-ecological zone on the coastal area of Tegal District

| Zone        | Landform [14] | Soil Type [15]                  | Land Suitability                                                                 | Note                                                      |
|-------------|---------------|---------------------------------|----------------------------------------------------------------------------------|------------------------------------------------------------|
| 1           | Alluvial plains | Typic Endoaquepts and Aeric Endoaquepts | - Agricultural system for food crop, horticulture and plantation. Priority for low land agriculture  
- For specific area with soil type 'Aeric' may applied of rotation system between wet and dry agriculture | - Innovation technology priority for improvement of rooting condition and soil drainage  
- Suitable class (S1) commodities : paddy, water melon, jasmine, sugarcane |
| 2           | Fluvio marine plains | Typic Endoaquepts | Agricultural system for food crop, horticulture and plantation. Priority for low land agriculture | - Innovation technology priority for improvement of rooting condition and soil drainage  
- Suitable class (S1) commodities : paddy, water melon, jasmine, sugarcane |
| 3           | Coastal area | Typic Udipsamments | - Limited agricultural system with high input and cost  
- Suitable for fishery | - Innovation technology priority for improvement soil texture by use of high organic fertilizer |

Data source: Map of agroecological zone of Tegal District, scale 1:50,000 [9]

Based on soil characteristics, the coastal zone which is dominated by Typic Udipsamments soil types has a very low agricultural land suitability class. The development of agricultural systems in this zone (coastal sea) requires high production inputs at high costs. Almost all agricultural commodities have a very low suitability class or even an unsuitable suitability class, due to soil texture problems
associated with low water and nutrient capacity. However, this zone actually still has the opportunity to increase its suitability through innovative use of high organic fertilizers and / or by implementing an Oasis farming system. Because the input used to increase land suitability class is quite high and relatively expensive, it is highly recommended to choose commodities that have high economic value, therefore the farming that is practiced is profitable.

3.3. Limitation factor for optimum plant growth

Some of the plant growth requirements considered to identify technology requirements based on AEZ data [1,10,13] are (1) temperature regime, which is interpreted from the mean annual temperature, (2) availability of water, which is interpreted from the average annual rainfall for 10 years, (3) availability of oxygen, interpreted from soil drainage and soil texture, (4) root conditions, interpreted from soil drainage, soil texture, percentage of coarse material, soil depth, (5) erosion hazard, interpreted from topography and conservation techniques, and (6) difficulty / ease of land preparation, interpreted from the percentage of rock on the soil surface.

Based on the characteristics of the land and the requirements for plant growth, several inhibiting factors for the development of agricultural commodities (food crops and horticulture) have been identified in the coastal areas of Tegal District, Central Java Province, as follows:

3.3.1. Limitation factor of temperature conditions (tc). The coastal area has a fairly high (warm) annual temperature (> 26.5°C) which has caused this condition to become an inhibiting factor for the development of several agricultural commodities in some coastal areas in Tegal District. The agricultural commodities which less suitable is due to temperature conditions are soybeans, cayenne pepper, potatoes, cabbage, carrots, garlic, leeks, tangerine, local longan, avocado, apples, and arabica coffee.

3.3.2. Limitation factor of oxygen availability (oa) The problem of soil characteristics found in the alluvial flat and fluvo-marine zone is the very fine soil texture (silty clay). This characteristic has caused the soil types in the 2 agro-ecological zones to have poor soil drainage. This condition causes several agricultural commodities such as corn, peanuts, sweet potatoes, long beans, tomatoes, eggs, green beans, green onions, oranges, durian, duku, bananas, rambutan, mango, mangosteen, salak, pineapple, avocado, grapes, spices, and tobacco have low suitability classes. Meanwhile, another problem in the coastal area is the coarse soil texture so that soil drainage is very fast. This limiting factor also causes most agricultural commodities in the coastal areas of Tegal District to be unsuitable.

3.3.3. Limitation factor of rooting conditions (rc). The coastal zone with Typic Udipsamments soil type has a rough to very coarse soil texture. The nature of this soil greatly affects the less than optimal retention of water and nutrients by soil particles. The result of this limiting factor is that most agricultural commodities become less feasible (S3) in this zone. In fact, this limiting factor has caused some commodities to become unsuitable (N) in the coastal zone. In accordance with the development trend of existing land use, the coastal zone with this condition is gradually being converted into fish ponds.

3.4. Land management technology need and recommendation alternative

Principally, land management technology is a strategy to exploit the potential of land resources and manipulate existing land boundaries. Besides having the potential for the development of a commodity, land characteristics can also be a growth limiting factor for certain agricultural commodities. This means that land characteristics can be a limiting factor for a commodity, but can be a beneficial factor for other commodities. Based on land characteristics and limiting factors in coastal areas, several land management technology which recommended are as follows:

3.4.1. Technology to manipulate of limitation factor of temperature. In principle, the use of potential land resources for agricultural commodity development can be done in 2 ways. First is selecting the
characteristics and quality of the land, based on the commodity to be developed. Second is selecting adaptive commodities, based on the characteristics and quality of the land to be used for development. Temperature conditions is one of factor that unchangeable or to be modified. The technologies to anticipate temperature limiting factors is using and select varieties according to local temperature conditions. In addition, micro temperature manipulation techniques can be carried out by using a simple shade system as protection as well as to reduce the high temperature caused by direct solar radiation (for example cere house or paranet), especially for commodities with high economic value.

3.4.2. Technology to improve of limitation factor of rooting conditions. The limiting factor for rooting conditions in coastal areas is mostly caused by coarse soil texture (sand to sandy loam), so the soil potential from its nutrient supply capacity and water retention is low. So one alternative technology that can be recommended in coastal areas is the use of high organic fertilizers. With the use of organic fertilizers, the ability of the soil to absorb and retain water and nutrients can be improved. In addition, deep and reversed soil cultivation is also highly recommended for coarse soil textures, with the aim of lifting back fine soil particles (clay and loam) and indirectly increasing the soil cation exchange capacity (CEC).

3.4.3. Technology to improve of oxygen availability in the soil. Usually, the decrease in oxygen availability in the soil is caused by poor soil drainage. So, an alternative technology for increasing the available oxygen is done by improving soil drainage conditions. Several alternative technologies recommended in this area include (1) small dike systems (galengan or mounds), (2) raised beds (raised beds) systems, (3) 'surjan' (Javanese) planting systems, which are a combination of plots of wetland planting areas (rice) with plots of dry land (crops and vegetables), (4) use of organic fertilizers to stabilize soil aggregates, and (5) channels construction for better water drainage.

4. Conclusion
The coastal area in the northern part of Tegal District, Central Java Province has 3 agro-ecological zones, namely (a) zone A alluvial plains with Typic Endoaquepts and Aeric Endoaquepts soil types, (b) zone B fluvio-marine plains with Typic Endoaquepts soil types, and (c) coastal zone C with Typic Udipsamments soil types. The results of the land evaluation show that in the coastal areas there are several agricultural commodities that are suitable for zones A and B, namely (a) rice, water melon, sugar cane and jasmine which correspond to class 1 (S1), (b) red chilies and shallots, suitable for class. 2 (S2). Meanwhile, zone C was identified as having less suitability for food crops or horticulture.

There are two main limiting factors in the coastal area of Tegal District, namely (a) poor oxygen availability due to poor soil drainage, and (b) less than ideal root conditions due to a very fine or coarse soil texture. Based on these limiting factors, land management techniques should be focused on (a) improving the unsupportive effect of soil texture with the use of organic fertilizers, (b) improving soil drainage effects by making channels and organic fertilizers, and (c) using tolerant varieties against the limiting factor.

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Appendices

Appendices 1. List of land suitability sub class for several commodities with the limitation factors on coastal area in Tegal District of Central Java Province based on agro-ecological zone (AEZ) analysis.

Table A1

| Unit | Landform                  | Paddy | Maize | Soybean | Peanut | Paddy Upland | Cassava | Sweet Potato | Cayenne pepper | Onion | Long bean | Tomato |
|------|---------------------------|-------|-------|---------|--------|---------------|---------|--------------|----------------|-------|-----------|--------|
| 1    | Alluvial plains           | 1     | 3oa   | 4tc     | 3oa    | 3rc           | 3oa     | 3oa          | 2tc            | 2tc   | 3oa       | 3oa    |
| 2    | Fluvio marine plains      | 1     | 3oa   | 4tc     | 3oa    | 3rc           | 3oa     | 3oa          | 2tc            | 2tc   | 3oa       | 3oa    |
| 3    | Coastal area              | 4oa   | 4ao/rc| 4ao/rc  | 4ao/rc  | 4rc           | 4ao/rc  | 4rc          | 4rc            | 4rc   | 4ao/rc    | 4ao/rc |

Table A2

| Unit | Landform                  | Eggplant | Garlic | Leaf onion | Siem orange | Tangerine | Water melon | Durian | Duku | Banana | Rambutan | Mango |
|------|---------------------------|----------|--------|------------|-------------|-----------|-------------|--------|------|--------|----------|-------|
| 1    | Alluvial plains           | 3oa      | 4tc    | 3oa/ct     | 3oa         | 4tc       | 3oa         | 4oa    | 3oa  | 4oa    | 3oa      | 3oa/wa|
| 2    | Fluvio marine plains      | 3oa      | 4tc    | 3oa/ct     | 3oa         | 4tc       | 3oa         | 4oa    | 3oa  | 4oa    | 3oa      | 3oa/wa|
| 3    | Coastal area              | 4oa/rc   | 4oa/rc | 4oa/rc/ct  | 4oa/rc/ct   | 4rc       | 4oa/rc/ct   | 4oa/rc | 4oa  | 4oa/rc | 4oa/rc   | 4oa/rc|

Table A3

| Unit | Landform                  | Mangosteen | Zalacca | Pineapple | Avocado | Zingiber | Galanga | Turmeric | Kapulaga | Tobacco | Sugarcane | Jasmine |
|------|---------------------------|------------|---------|-----------|---------|----------|---------|----------|----------|---------|-----------|---------|
| 1    | Alluvial plains           | 3oa/wa     | 3oa     | 3oa       | 3oa/tc  | 3oa      | 3oa     | 3oa      | 3oa      | 1       | 1         | 1       |
| 2    | Fluvio marine plains      | 3oa/wa     | 3oa     | 3oa       | 3oa/tc  | 3oa      | 3oa     | 3oa      | 3oa      | 1       | 1         | 1       |
| 3    | Coastal area              | 4oa        | 4oa/rc  | 4oa/rc    | 4oa/rc  | 4oa/rc   | 4oa/rc  | 4oa/rc   | 4oa/rc   | 4oa    | 4rc       | 1       |

Note of limitation factors: temperature conditions (tc), rooting condition (rc), oxygen availability (oa) suitability class 1 (S1), 2 (S2), 3 (S3), 4 (N)

Data source: Map of agro-ecological zone of Tegal District at scale 1:50.000 [9]

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