Ecological spatial modeling for land use optimization for *Zea mays* L. in Patilangio Sub district, Randangan District, Pohuwato Regency, Gorontalo Province

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Abstract. This research was conducted at Pohuwato District in Randangan Sub District. The aims of this study are to assess the physical characteristic of ecological, land cover, land use, and land capacity to support the maize cultivation; to analyze the land capability, land sustainability, and the carrying capacity of land to support the system of maize cultivation; lastly is to spatial analyzes the ecology for maize land use optimization. The method for land evaluation was analyzed based on a land unit basis. Samples for the study site stratified with random sampling that determined by considering the land units (slope, landform, and land use). The samples of respondents was carried out for economics and social data that performed by the accidental method. The data of optimization land use was obtained from the map of RBI, map of administration, the map of land unit, and product LCLP analysis. The land carrying capacity and the land population pressure data was carried out based on the map of RBI, the map of administration, and the secondary data. The soil sampling was conducted at 3 locations. Land cover, land capability, land sustainability, land carrying capacity, and production was analyzed by using spatial analysis through GIS. Descriptive analysis was done for the social economic and stakeholder population data. The results show that the existing land (OPT) in the one Randangan Sub District of Pohuwato is classified as low category optimization (L). Where the OPT (L) = f (KL(III, IV) + KS (S3,N1) + DDL (L) + P (L) + TP (L). A strategy that can be done to optimize this low classified region are by converting some land of plant oil palm plantations that have categorizing in a high (H) and medium (M) class land capability for maize.

1. Introduction

Law of the Republic of Indonesia No: 32 of 2004 regarding Regional Government states that regions are given the authority to manage national resources available in their territory and are responsible for maintaining environmental sustainability in accordance with applicable laws and regulations. Land use is a tangible manifestation of the influence of human activities on a part of the earth's physical surface.

Pohuwato Regency is a maize development center in Gorontalo Province. This is based on the characteristics in the form of land area for cultivation of the largest maize plant found in the Pohuwato Regency. Besides that, the highest maize production was in the area, followed by Boalemo and Gorontalo districts. Maize cultivation actually becomes superior Gorontalo in improving the welfare of its people.

Based on BPS data [1], the area planted with maize in Pohuwato Regency is 82,432 ha (63%, 36%). In addition, of the total area planted with maize in 2010 (82,432 ha or 63.36%), there were still 47,661
ha of land or 36.64% which had not been optimized for maize cultivation. In table 1 is the planting area of Pohuwato district, but in this study the study material is specifically for one of the districts namely Randangan District covering an area of 9,954 ha.

| No | Sub-district   | Planted Area (ha) |
|----|----------------|-------------------|
| 1  | Popayato       | 4,873             |
| 2  | Western Popayato | 6,082           |
| 3  | Eastern Popayato | 4,269           |
| 4  | Lemito         | 6,041             |
| 5  | Wanggarasi     | 5,251             |
| 6  | Marisa         | 2,751             |
| 7  | Patilangio     | 19,893            |
| 8  | Buntulia       | 3,225             |
| 9  | Duhiadaa       | 1,252             |
| 10 | Randangan     | 9,954             |
| 11 | Taluditi       | 8,178             |
| 12 | Paguat         | 5,045             |
| 13 | Dengilo        | 5,618             |

Source: BPS of Pohuwato Regency (2010)

Randangan District is an area in Pohuwato district which has an area of 9,954 ha of maize cultivation. Of the total area of maize in Pohuwato Regency 82,432 ha. Changes in land use in this region have been rapid in the last seven years from agricultural land to residential land.

In connection with the above description, we need a model for optimize the land use of agriculture for maize plants ecologically. A comprehensive study is needed to determining the optimization of land use for a particular purpose in the ecological approach. It means that information between land cover, land use, and land physical character, capability and suitability of land, carrying capacity and population pressure is needed to run this model. This information is useful due to the maize cropping patterns regulations.

2. Methods

2.1. Location and time
This research was carried out only in one sub-district namely Randangan District, Pohuwato Regency. Randangan district is a maize base district in Pohuwato Regency. Patilangio Sub-district was chosen as a research location because (1) it is located in Pohuwato Regency and this area is one of the 13 largest maize center districts where the total maize production in Pohuwato Regency in 2010 is 397,237.56 tons. In other words, Pohuwato supports 44.93%, (2) the typology of the Randangan District area is quite diverse both in terms of geographical, natural resources, administration, population, land ownership, income and human resources (education level), (3) the land in the sub-district is located in a strategic maize development area known as the maize base area of Pohuwato Regency in accordance with the Pohuwato Regency spatial plan, (4) the sub-district can represent 13 sub-districts in Pohuwato Regency both in terms of landform, slope and land use, thus the land units in the three sub-districts vary so that they can represent the totality of existing land units in Pohuwato Regency, (5) Randangan District has land characteristics that meet the minimum criteria for maize growth.
Table 2. Territory base maize based on potential production

| Sub-district     | Production (tons) | Production level |
|------------------|-------------------|-----------------|
| Popayato         | 27,002.88         | Low             |
| Western Popayato | 24,272.12         | Low             |
| Eastern Popayato | 20,615.48         | Low             |
| Lemito           | 24,549.12         | Low             |
| **Wangarasi**    | 25,492.32         | Low             |
| Marisa           | 11,019.61         | Low             |
| **Patilangio**   | 89,441.18         | High            |
| Buntulia         | 11,160.82         | Low             |
| Duhiaadaa        | 5,643.17          | Is              |
| **Randangan**    | 57,574.5          | Is              |
| Taluditi         | 50,993.72         | Is              |
| Paguat           | 23,212.8          | Low             |
| Dengilo          | 26,259.84         | Low             |

Amount 397,237.56

Source: Pohuwato Regency Agriculture Office, 2010

Based on the table 2, the maize production area with medium production is found out in Randangan District. However, the aspect of the number of residents used as a material consideration so that the Location Quotient (LQ) analysis is used [2]. The results of the LQ analysis are presented in table 3.

Table 3. Maize base area selection based on LQ analysis

| No. | Sub-district     | Production (tons) | Population | LQ   | Ranking |
|-----|------------------|-------------------|------------|------|---------|
| 1   | Dengilo          | 26,259.84         | 5,353      | 1.58 | IV      |
| 2   | Paguat           | 23,212.8          | 15,389     | 0.48 | -       |
| 3   | Marisa           | 11,019.61         | 16,962     | 0.20 | -       |
| 4   | Duhiaadaa        | 5,643.17          | 10,960     | .16  | -       |
| 5   | Buntulia         | 11,160.82         | 10,424     | 0.35 | -       |
| 6   | Patilanggio      | 89,441.18         | 8,736      | 3.30 | I *)    |
| 7   | Randangan        | 57,574.5          | 13,752     | 1.34 | V       |
| 8   | Taluditi         | 50,993.72         | 6,836      | 2.40 | II      |
| 9   | Wanggarasi       | 25,492.32         | 4,720      | 1.74 | III     |
| 10  | Lemito           | 24,549.12         | 11,164     | 0.70 | -       |
| 11  | Popayato         | 27,002.88         | 9,855      | .91  | -       |
| 12  | Popayato Barat   | 20,615.48         | 7,586      | .87  | -       |

Source: Results of Analysis, (2010).

Note: *) is a research location

Based on table 3 from the 13 sub-districts in Pohuwato Regency, the sub-districts which are the maize bases based on LQ analysis are: LQ > 1: Patilangio, Taluditi, Wanggarasi, Dengilo, Randangan and Popayato Barat. Based on the 6 sub-districts that constitute the maize base region, the selected sub-districts which are the location of the study are those that are ranked LQ V (is). In table 4 is presented the comparison area bases maize based production and based on the analysis of LQ (production and population).
Table 4. Basis maize district areas

| Maize Production Class | Maize Maize Base Districts Based on Production Potential | Maize Seed Subdistrict Area Based on LQ Analysis (production and population) |
|------------------------|---------------------------------------------------------|--------------------------------------------------------------------------------|
| High                   | Patilangio                                              | Patilangio * ) Taluditi                                                       |
| Medium                 | Duhiadaa Randangan Taluditi                             | Wanggarasi Dengilo                                                            |
| Low                    | Popayato, Western Popayato, Eastern Popayato, Lemito, Wanggarasi, Marisa, Buntulia, Paguat, Dengilo | Randangan Western Popayato                                                     |

Source: Results of analysis, 2010.
information: *) is the location of the study

2.2. Method of data collecting
Analysis of social and economic data from both the community and the stakeholder is qualitative descriptive, which is trying to describe or describe precisely the facts and the relationship between the phenomena studied. Retrieval of samples was conducted by Survey, a method that aims to ask respondents. The approach used in this research is a combination of bottom-up (demand-driven) and top-down (supply driven) approaches. The bottom-up approach is carried out with questionnaire material conducted on the stakeholder, to get information about:

1) Perception of planning,
2) Problems associated with the use of spatial data -ekologis use maps cover land / land use (land-cover / land- use),
3) Parameters of land capability, land suitability and carrying capacity of land needed to support the analysis of research data for the optimization of land for maize.

Assessment of data against stakeholders who know the problems and conditions of land use taken from various institutions or agencies, Institute of Research (LP)/consultant, University (PT), and the NGO which are related to the planning and optimization of land for maize plant where includes two of the following activities:

1) Identification of physical planning related to specific land use information.
2) Development of land capability classification, land suitability, land carrying capacity, population pressure and production to obtain optimal land for maize at the study site.

2.3. GIS data analysis and synthesis phase
This stage includes:

1) Digitizing on screen, converting analog data from digital data to interpretation maps and thematic maps available (as GIS input data).
2) Doing overlay maps obtained from the tentative interpretation process to produce a map of land units.
3) Data analysis, for land capability and land suitability is carried out using LCLP (land classification and landuse planning) software. The advantages of this LCLP method include
being able to analyze data on the results of land capability analysis and land suitability with the arcview link making it easier for data processors to make a spatial picture of land capability classification results and land suitability[3]. Data pressure of population and land capacity was analyzed by using the formula of land capacity by Soemarwoto [4]. In addition, production data was analyzed quantitatively and qualitatively.

2.4. Preparation of data base
1) Preparation of thematic maps such as landform maps, slope maps, land maps, land use maps, geological maps, climate maps, rainfall maps made based on RBI map 1: 50,000 in 1999, Alos Image June 2008 and July 2010 field survey.
2) Land unit map was produced from overlapping landform maps, slope maps and land use maps.
3) The land capability and suitability map was prepared based on the 1999 RBI map, the Pohuwato Regency administration map in 2010, the Pohuwato Regency land unit map in 2010 and the results of the 2011 LCLP analysis.
4) Land carrying capacity map, population pressure map and maize productivity map were prepared based on the 1999 RBI map, 2010 administration map and Pohuwato Regency in 2010 figures.
5) Map of optimizing maize crop land and map of optimizing land for the application of the maize planting pattern were prepared based on the 1999 RBI map, 2010 administrative map and the land unit map of Randangan District, Pohuwato Regency in 2010.

Figure 1. Land Unit Map
3. Results and discussion

3.1. Ecological spatial model for optimizing land for maize

The ecological spatial model for optimizing land management for maize that can be developed in Randangan District, Pohuwato Regency is based on an integrated approach to several parameters [5], namely:

a. Potential land biogeophysical resources available:
   1) land capability
   2) land suitability
   3) carrying capacity
   4) production potential

b. The social and economic potential of the community in the form: population pressure, income level, land ownership, and;

c. Stakeholder directives and policies on land that can be optimized for maize.

The analysis shows that at the research location there is only one model, which is an integration of the functions of the parameters of land capability, land suitability, carrying capacity, population pressure and production potential:

Model \( OPT \circledast = f (KL \ (III, IV) + KS \ (S3, N1) + DDL \circledast + P \circledast + TP \circledast) \)

where \( OPT \circledast \) map = low land optimization category, \( KL = \) land capability, \( KL (I, II, III, IV) = \) land capability class I, II, III, IV, \( KS = \) land suitability, \( KS (S2, S3, N1) = \) land suitability is appropriate, marginal and not suitable at this time, \( DDL = \) carrying capacity, \( DDL \ (T) = \) high carrying capacity, \( DDL \circledast = \) low carrying capacity, \( P = \) production, \( P \ (T, S, R) = \) high, medium and low production, \( TP = \) population pressure, \( TP \circledast = \) low population pressure.

Based on the results of laboratory analysis and direct observation in the field, there were 18 land units in Randangan District. Based on the results of laboratory analysis on 18 land units the land has the following characteristics and qualities: Slopes range between 0-2% and 2-8%. The effective depth of the soil ranges from 50 to 25 cm, 90 to 50 cm and higher than 90 cm. Erosion hazards are low and some are severe [6]. Soil types is Alluvial brown, Mediterranean, Gley humus, Renzina, Podsolik, Grumusol, Latosol, Alluvial gray. Annual soil erosion ranges from 17.64 tons/ha/year to 395 tons/ha/year. Plant management factors: in addition to maize planted with cocoa, sugar cane, and secondary crops as mixed crops. The length and slope factors range between 0.3 and 0.4. Erodibility or sensitivity of soil against erosion ranges from 0.13 to 0.29. Rainfall ranges between 1,000-1,500 mm per year and 1,500-2,500 mm/year.

Specifically specific to the time Pohuwato Regency experienced an expansion from Boalemo District in 2003, it is deemed necessary to update geospatial information and its contribution through this research, namely the availability of a spatial database in the form of maps so that it can be valuable information for local stakeholders in terms of planning [7] and land use especially for the development of sustainable maize commodity in Pohuwato Regency.

3.2. Land optimization strategy for sustainable maize crops

The strategy of optimizing land for sustainable maize in Randangan Subdistrict, Pohuwato Regency is presented in tables 5, 6, and 7.
Table 5. Optimizing Sustainable Land

| Land Optimization Strategy |
|----------------------------|
| 1) Low Optimization (R) Category |
| 2) Limited land management through intensification patterns (efficiency of land resource use) is changed to extensive and sustainable land management |
| 3) The scale of small and limited farming is changed to medium / large scale. |
| 4) Improvement of human resources through training and direct demonstration in the field |
| 5) Increase production through adaptation and utilization of appropriate technology 6) for sustainable land management |
| 6) Restrictions on the number of local farmers and migrants from outside the area. |
| 7) Moderate and severe conservation is carried out. |

Indeed, land conservation is intended to obtain optimum production of a land in a sustainable manner, while trying to make the rate of soil erosion smaller or at least equal to the rate of land formation on the land. Therefore steps or efforts are needed to regulate land use.

Table 6. Soil Type Matrix, Land Capability, Maize Land Suitability, Land Support Capacity and Maize Production Potential

| No | Land Location | Type of soil | Land Capability | Land Suitability | Land carrying capacity | Production |
|----|----------------|--------------|-----------------|-----------------|------------------------|------------|
| 1  | Randangan District (Sari Murni and Sido Rukun Villages) | Chocolate alluvial association, mediterranean (3,796.68 ha), humus gley association, renzina, podsolik (13,023.33 ha), podsolic association, andosol (1,632.33 ha), regosol association, lithosol, organosol (405.19 ha). The most dominant is the podsolic association, | Class III and IV | high | S3 (according to marginal), N1 (not suitable at this time) | high |
4. Conclusions
Based on the results of research and discussion, it can be concluded:
1) The characteristics of land cover or land use in the study location are dominated by forest vegetation while the physical characteristics of the land is vary.
2) The most dominant class for land capability in the study site was found in land capability class III.
3) Land suitability classes for maize at the study site are N1 (not suitable at this time). The limiting factor in the land unit in the study site is a temporary limitation, therefore if land improvement is carried out through conservation measures N1 and class N1 can be turned into potential lands S3 (according to marginal). The land that can be developed for maize is class N1 (not suitable at present) of 66.3 ha (3.41%). The total area of land suitability for maize in the study area is 2121.86 ha.
4) Land carrying capacity is in the moderate range. At the current level the carrying capacity of land can be expressed as carrying capacity of the surplus.
5) The ecological spatial model for optimizing the spatial use of maize plants is realized in the form of a map of optimizing land for low category maize plants (R)
6) Land optimization for maize is an effort to use land units that are currently / not being utilized by integrating land that has the ability, suitability, carrying capacity, population pressure and production in accordance with the aim of realizing sustainable land management.
7) Strategies that can be taken to optimize the land category of medium and low (R) can be done by:
8) Looking for land units with a combination of upland and rainfed lowland that guarantees the availability of land with moderate optimization (S) with a minimum area almost equal to the area of land owned by sub-districts with a low optimization category (R).

| No | Land Location       | Type of soil                           | Tech. Population | Social and economic conditions                      | Stakeholder              | Model Opt. Land          |
|----|---------------------|----------------------------------------|------------------|----------------------------------------------------|--------------------------|-------------------------|
| 1  | Randangan District  | Chocolate alluvial association,        | Low              | 91.89% of farmers, 59.46% have elementary school education, 27% of the land belongs to itself, remaining tenants (peasant), 93.30% b angunan emergency, 25% 1.5 million per harvest, 59.46%> 1.5 million per harvest, 15.54% below 1.5 million per harvest, 91.89% planted maize.78.38% did not rotate. | Opt (R) and Opt (S)       |                         |
|    | (Sari Murni and     | mediterane                            |                  |                                                    |                          |                         |
|    | Sido Rukun Villages | humus gley                             |                  |                                                    |                          |                         |
|    |                     | renzina, podsolik association,         |                  |                                                    |                          |                         |
|    |                     | (13,023.33 ha), podsolic association,  |                  |                                                    |                          |                         |
|    |                     | andosol (1,632.33 ha), regosol         |                  |                                                    |                          |                         |
|    |                     | association, lithosol, organosol       |                  |                                                    |                          |                         |
|    |                     | (405.19 ha). The most dominant is the podsolic association, |                  |                                                    |                          |                         |

Table 7. Tech. population, social and economic conditions and stakeholder.
9) Look for a combination of land uses that are capable of producing production with moderate optimization category (S) by converting part of the coconut plantations that need to be rejuvenated into dry agricultural land for maize.

10) Looking for land use combinations that guarantee the availability of land for the medium optimization category (S) in the form of mixed gardens and dry fields.

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