Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol. 3, No.5, 2013

An Agro-ecological Approach for Sustainable Farming in Langge Sub-watershed, Bolango Watershed, Gorontalo, Indonesia

R.H. Anasiru[1,2*], M.L. Rayes[3], Budi Setiawan[4] dan Soemarno[3]

1. Agriculture Science Graduate Program, Faculty of Agriculture, Univ. of Brawijaya,Malang, East Java.
2. Gorontalo Assessment Institute for Agricultural Technology, IAARD, Gorontalo, Indonesia
3. Soil Departemen, Faculty of Agriculture, Univ. of Brawijaya, Malang, East Java. Indonesia.
4. Agroeconomy Departemen, Faculty of Agriculture, Univ. of Brawijaya, East Java. Indonesia

* E-mail of the corresponding author: anasiru.rh@gmail.com

Abstract

Sustainable farming is an integral part of sustainable development, a farming system which preserves water resources, land resources, and plant resources in acceptable and suitable ways economically, socially, and environmentally. The effects of rapid population growth and increasing natural resources exploitation will not only lead to increasing deforestation as human needs more areas for farming, but also lead to decreasing quality in our environmental resources, such as river pollution, erosion and sedimentation. The study aims at examining the development of sustainable farming in dry land areas of Langge sub-watershed through an agro-ecological approach. In this present study, land unit was derived from overlaid of geological, geomorphological, topography, and land-use maps of the area. There were 12 land units found in the study area. In General, the suitability of land for food crops and vegetables in Langge sub-watershed which is highly suitable (S1) was 58 ha (0.9%). Then, 1,957 ha (33%) of the land belongs to moderately suitable (S2) and marginally suitable (S3) with oxygen availability, rooting condition, and erosion hazard as the limiting factors. The rest 4,307 ha (68%) of the land were not suitable (N) with erosion hazard as the limiting factor. The areas which can be optimized for planting food crops and vegetables are 740.23 ha, consisting of (1) 650.52 ha for food crops and (2) 89.71 for vegetables. The value of R/C ratio on paddy field, maize, and peanuts was 1.81, 1.16 and 1.29 respectively. For vegetables, the value of R/C ratio was 1.79; 1,28, 1,33; 1,42 and 1,21 for onion, chili, mungbean, pickpea, and eggplants. The commodities having highest revenue for food crops category was paddy field as much as 7,163,000 IDR /ha/season, while for vegetables was onion as much as 22,470,000 IDR/ha/season. However, considering the optimal land area and land suitability, then the commodity having highest potential to develop and economically feasible are paddy field and maize.

Keyword : Agro-ecology, land suitability, sustainable farming.

1. Introduction

The vision of Indonesian agricultural programs in 2020 is to develop a modern and efficient agriculture system; one of the characteristics is the optimal and sustainable use of resources, especially the water, soil, germplasm, human resources, capital, and technology (Kasryono *et al.,* 1997). According to FAO (Kwaschik *et al.*,1996), sustainable farming is an integral part of sustainable development, a farming system which preserves water resources, land resources, and plant resources in acceptable and suitable ways economically, socially, and environmentally.

Meanwhile, the dynamics of development programs in an area are as the starting point of the process of land-use conversion. Land use conversion brings both advantages and disadvantages for human beings; the disadvantages deal with the increase of critical land, pollution, flood, and drought. Therefore, development programs must be planned carefully in advanced, especially in terms of land use management based on the ecological, social, and economy of the areas as to avoid environmental degradation

According to Mahmoudi *et al.*, (2010), the effects of rapid population growth and increasing natural resources exploitation will not only lead to increasing deforestation as human needs more areas for farming, but also lead to decreasing quality in our environmental resources, such as river pollution, erosion and sedimentation, which finally will damage dams due to intensive sedimentation. Changes in forest into agricultural land are not normally accompanied with the use of suitable agro-technology, which finally results in decreasing environment quality (Sthiannopkao.*et al*., 2007). In addition, Xiana and Crane (2007), as well as Milesi *et al*. (2003), state similar ideas—that changing forests into agricultural land will cause changes in hydrological condition of watershed areas, especially on the structures and functions of ecosystem.

Natural resources and environment development programs create such causal relationship in which the utility of natural resources and the environment to which they belong are considered an ecological unity. Human beings in the ecosystem not only act as consumers, but also take a role as active producers. Their wish to improve their economy and well-being must not be interpreted as an excuse for human beings to damage the environment and its resources. Thus, natural resources must be managed and used wisely and sustainably, so that the benefit can be enjoyed optimally in such harmonious and balance ways.

Changes in land cover will affect the existing order of spatial ecological patterns, which finally will lead into evolution in ecosystem functions (Wang *et al*., 2006). The effects of land usage and changes in land cover, especially on environmental resources, and sustainable development have become scientific issues (Potter 1991; Vörösmarty *et al*., 2000).

Ibrahim (2008) conducted a study on Bolango watershed in Gorontalo, Indonesia. The results of the study reveal that based on the calculation of erosion rate prediction on the existing condition of the watershed, using maximum daily rainfall in five years, the erosion rate was as many as 4,636,448 tons/year in an area of 39,783 hectares, which means that the average erosion rate per hectare 116.54 tons/hectare/year. This erosion rate belongs to Erosion Rate Class III (very heavy rate of erosion).

"Agropolitan" is one of the priority program of the Government of Gorontalo Province that it focus to the main crop is maize. This led to the use of land for agriculture especially growing maize. In the year 2009 the agricultural land in the province of Gorontalo maize is 124,798 ha and in the year 2010 increased to 143,833 ha (BPS Gorontalo, 2011). The phenomenon of growing crops especially maize farming without conservation techniques. This leads to land degradation, especially in watershed Bolango in Bone Bolango District.

One of the ways to solve problems related to environment is through the land-use management approach, which refers to the availability of land through evaluation on land-use suitability in order to gain optimal land use. With the optimal land use management, it is expected that economic advantages be gained maximally and environment degradation be decreased to its lowest possible level.

Based on afore-presented information, the study aims at examining the development of sustainable farming in dry areas of Langge sub-watershed through an agro-ecological approach such as climate, land suitability, farming feasibility and land optimization.

2. Research Method.

The study was conducted in Langge sub-watershed, in Bolango, Tapa sub-district, Bone Bolango regency, Gorontalo province, Indonesia, from January 2012 until December 2012. Langge sub-watershed is located geographically at 0° 34' 40"- 0° 39' 05" North Latitude and 123° - 03 '59" - 123° 13 '16" East Longitude.

2.1 Research Procedure

2.1.1 Land Mapping Unit

The study started with land unit mapping. The basic map used was the digital topographic map of Indonesia with a scale of 1:50,000 page 2316-13, 14, 23, 41, 42, 43, 44 and 51 from Badan Koordinasi Survei dan Pemetaan Nasional year 1991; an Indonesian geological map with a scale of 1:250,000 on page about Kotamobagu (2316), from Pusat Penelitian dan Pengembangan Geologi Bandung, year 1997; and digital contour map of Indonesia from *Shuttle Radar Topography Mission* (NASA, 2004), satellite imagery of Econos *path* /*row* 112/060, 113/059 and 113/060. Land unit map is a unit of land that is bounded in the field based on the appearance of the landscape (land scape). Soil map unit arranged to accommodate critical information from an area (polygon) on matters relating to land surveys. Soil map unit or units of the map consists of a collection of all the delineation of land marked by symbols, colors, distinctive name or symbol on a map. Delineation of land is an area bounded by a boundary on a map (Rayes, 2006).

2.1.2 Land Suitability Analysis

Land Suitability analysis was conducted using matching system approach, in which it aims at finding out the suitability of land qualities/land characteristics with land class criteria arranged based on the requirement on land-based growing crops. Analysis was conducted in two stages (Sitorus, 2004). The first was assessment on the requirement of potential growing crops or finding out the characteristics of land and location having negative effects toward crops. The second stage was identifying and limiting land having characteristics required without the unwanted characteristics.

According to Djaenuddin *et al*., (2000), land evaluation is a process of estimating the classes of land-use suitability which is potential for certain uses, such as farming and non-farming activities. The potential of farming areas is developed based on physical characteristics and plant growth requirement approaches. Physical suitability and commodity developed represent information on the level of potential development of the land. Thus, land uses in commodity development have taken into account the expected input and output factors.

Van Niekerk (2010) states that land evaluation is an integral part of land-use planning and has been established as one of the methods in supporting management of sustainable land-use. In short, land evaluation aims at comparing and matching the uses of potential land with individual characteristics of land, or land units.

Availability of continuous spatial data can bring such great effects on choices of land units for conservation programs. Suitability of ecological condition to preserve land units as a conservation target becomes important consideration in evaluating possible conservation areas (Humphries *et al*., 2010).

For the sake of accuracy and quick evaluation process on land-use suitability, an expert system was employed, that was *Automated Land Evaluation System* (ALES) version 4.65d (Rosister and Van Wambeke, 1997). Land-use suitability evaluation was conducted physically and economically by considering the real situation found on the site. Classification on land-use suitability on this present study only covers two classes and sub-classes, as to the fact that evaluation was done in details. Land-use suitability on the class level consists of (1) Class S1 (highly suitable), (2) Class S2 (moderately suitable), (3) Class S3 (marginally suitable), and (4) Class N (not suitable). Sub-class classification is based on quality and characteristics of land which becomes the toughest limiting factors.

Criteria on land-use suitability used in the present study were based on the criteria developed by Pusat Penelitian Tanah dan Agroklimat (Djaenuddin *et al*., 2003), as many as 13 factors, namely (1) temperature, (2) rainfall, (3) drainage, (4) texture, (5) coarse material, (6) soil depth, (7) clay CEC, (8) alkalinity, (9) pH (H_2O), (10) organic C, (11) slope, (12) erosion, and (13) surface stoniness.

2.1.3. Land Optimalization

Linear Programming (LP) method is used in modeling of land optimization for food crops and vegetables, which should be optimized in land as wide as regulated in land-use suitability of S1, S2, and S3 classes.

Linear Programming (LP) is a mathematical technique used in allocating the areas of limited land used for planting food crops and vegetables among the competing factors (oxygen availability and has no meaning on S1, hazard erosion on S2, and hazard erosion on S3) in order to maximize objective function (areas for food crops and vegetables). The common model representing LP is as follows (Thie and Keough, 2010):

$$\text{Maximize}: \quad G = \sum_{j=1}^{n} C_j X_j$$

$$\text{Subject to} \quad : \quad \sum_{j=1}^{n} a_j X_j \; \begin{matrix} > \\ = \\ < \end{matrix} \; b_i; \; i=1,2,\ldots, m$$

$$\text{and} \qquad X_j \geq 0$$

in which: G is *objective function* or the function to be maximized (areas for food crops and vegetables); x_j refers to *activities* or decision variables, that is food crops (maize, paddy field, and peanuts) and vegetables (onion, chili, mungbean, pickpea, and eggplant); c_j refers to contribution of activity number j on objective function (existing areas of food crops and vegetables); a_{ij} is the average value (areas of oxygen availability and has no meaning on S1, hazard erosion on S2, and hazard erosion on S3) of limiting factors or requirements number b_i by an activity unit number j; and b_i refers to resources or requirements.

The equation of limiting factors and non-negative condition having to be fulfilled in order to optimize land use can be illustrated as follows:

$$\text{Optimization: } G = c_1x_1 + \ldots + c_jx_j + \ldots + c_nx_n$$

Limiting factors:

$$a_{11}x_1 + \ldots + a_{1j}x_j + \ldots + a_{1n}x_n \begin{matrix} > \\ = \\ < \end{matrix} b_1$$
$$a_{i1}x_1 + \ldots + a_{ij}x_j + \ldots + a_{in}x_n \begin{matrix} > \\ = \\ < \end{matrix} b_i$$
$$a_{m1}x_1 + \ldots + a_{mj}x_j + \ldots + a_{mn}x_n \begin{matrix} > \\ = \\ < \end{matrix} b_m$$
$$\text{and } x_j \geq 0$$

In which G is objective function; x_j refers to alternating activities; b_i refers to limiting factors: requirements (>), restriction (<), equation (=); a_{ij} refers to addition for (<0) or substraction from (>0) b_i from an x_j unit; c_j refers to addition for (>0) or substraction from (<0) z from an x_j unit; and the first m line under the objective function (z) and the first n colum show conventional LP matrices.

2.1.4. Analysis on Farming Feasibility

The analysis on dry land farming feasibility on Langge sub-watershed was focused on three variables namely production, acceptance, and cost and revenue. Production is the results of farming activities, while net revenue is total revenue minus total cost written by using the following formula PU = TR – TC, in which TR = total revenue, and TC = total cost.

The analysis on determining the feasibility of farming activities can be done using, as an example, R/C Ratio.

$$RC = \frac{TR}{TC}$$

In which RC = Return Cost, TR = Total Revenue, and TC = Total Cost.

When the value of R/C Ratio > 1, farming activities or technology implementation is feasible to conduct; however, when the value of R/C < 1, farming activities or technology implementation is not feasible to conduct (Soekartawi, 1994)

3. Result and Discussion

3.1 Climate

Climate represents average rainfall, temperature, humidity, wind, sunlight intensity, and other factors determining climate. As such, to describe a climate of an area comprehensively and accurately, data on climate factors must be available and complete (Asdak, 2007). However, the data from the climate station are not complete due to its capability in providing data; thus, data on other climate factors such as average temperature needed in classifying land-use suitability and land classes were gained by considering an elevation aspect only. In general, an increase in elevation as much as 100 meters will cause a decrease in temperature as much as 0,55^{o}C (Arsyad, 2010).

Data on monthly rainfall were used in calculating rainfall erosivity index in determining the level of erosion. Data on rainfall used in the analyses involved data on monthly rainfall rate from year 2001 until 2010 in Boidu station which includes Langge sub-watershed (Table 1).

The relationship of the data on monthly rainfall with annual rainfall in the study site is the fact that the site under study has rainfall rate of less than 100 mm during the dry season which happens in July, August, and September. After September, the rainfall rate increases to reach its peak in November.

Based on Oldeman climate classification, it can be seen that the climate in Langge sub-watershed falls to C2 type, whereas based on Schimd-Ferguson classification, the climate in Langge sub-watershed falls to C type. Based on the rainfall data, it can be concluded that the site has rather wet climate with planting probability as long as 9 months (Schimd-Ferguson, 1951; Oldeman, 1975).

Table 1. Monthly Rainfall (mm) in 2001 – 2010 in Boidu Station, Tapa Sub-District, Gorontalo

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	288,0	221,0	48,0	164,0	152,0	191,0	42,0	27,0	121,0	50,0	187,0	91,0
2002	165,0	26,0	197,0	105,0	187,0	121,0	-	-	3,0	54,0	103,0	86,5
2003	161,0	99,0	119,0	203,0	157,0	33,0	121,0	49,0	34,0	36,0	216,0	160,0
2004	174,0	109,0	114,0	67,0	141,0	9,0	92,0	-	6,0	61,0	128,0	114,0
2005	12,0	138,0	208,0	126,0	97,0	129,0	48,0	22,0	6,0	116,0	102,0	155,0
2006	113,0	143,0	136,0	178,0	140,0	250,0	24,0	-	59,0	5,0	145,0	171,0
2007	120,0	176,0	45,0	178,0	78,0	294,0	142,0	112,0	123,0	27,0	157,0	350,0
2008	108,0	97,0	360,0	144,0	48,0	165,0	130,5	102,0	94,5	323,0	198,5	116,0
2009	139,5	64,5	149,0	246,5	137,0	33,0	200,0	39,0	3,5	161,6	409,5	196,0
2010	122,6	45,6	71,6	105,0	163,6	179,0	198,8	173,1	255,3	167,6	120,0	245,3
Total	1.403,1	1.119,1	1.447,6	1.516,5	1.300,6	1.404,0	998,3	524,1	705,3	1.001,2	1.766,0	1.684,8
Average	140,3	111,9	144,8	151,7	130,1	140,4	99,8	52,4	70,5	100,1	176,6	168,5

The Climate, in this case is the even rainfall distribution throughout the year, has also become one of the factors causing instability of hydrology between dry season and rainy season. With the average 3 to 4 dry months (Oldeman, 1975), drought in dry season is unavoidable. Drought in Langge sub-watershed seems to have increased in these recent years, indicated by the difficulty faced by the residents in getting water for irrigation and domestic needs.

3.2. Land Unit

A unit of land is an area, based on some characteristics, different from its surrounding areas, and can be assumed to have homogenous land characteristics (such as climate, soil, and land cover). Components of land (elements of land shape is also called as units of areas or segments of surface land) are frequently used as a land unit, especially because the border of environment condition (Van Niekerk, 2010).

In this present study, land unit was derived from overlaid of geological, geomorphological, topography, and land-use maps of the area. There were 12 land units found in the study area which presented in Table 2, and presented as maps on Figure 1. The numbering on land units was based on areas, type of soils, soil depth, texture, cation exchanged value, pH and organic maters.

Table 2. Land units and their physical-chemical properties in Langge sub-watershed, Gorontalo

No Land Unit	Soil Orders	Effective Soil depth (cm)	Soil Texture Classes	Cation Exchange Capacity (cmol/kg)	pH (H_2O)	C-Organic (% C)	Area (ha)
1.	Inceptisol	46	Clay loam	16.08	6.0	0.84	7
2.	Entisol and inceptisol	55	Loam	11,45	6.1	1.01	109
3.	Inceptisol and alfisol	60	Sandy loam	2,97	5.6	0.50	281
4.	Inceptisol	35	Silty clay loam	21.09	6.1	0.72	51
5.	Alfisol and inceptisol	55	Sandy loan	3.38	5.8	0.44	100
6	Alfisol and mollisol	73	Sandy loam	9.27	5.9	0.87	117
7.	Inceptisol, alfisol and entisol	68	Clay loam	9.71	6.0	1.42	228
8.	Inceptisol, alfisol and entisol	62	Clay loam	8.97	6.2	2.01	1.539
9.	Inceptisol and alfisol	65	Sandy loan	6.77	6.0	1.29	1.818
10.	Alfisol and inceptisol	74	Sandy loam	10.34	6.0	1.13	1.241
11.	Alfisol and inceptisol	80	Sandy clay loam	13.35	6.0	1.53	109
12.	Mollisol	100	Sandy loam	6.25	6.2	0.91	722
						Total	6.322

Souce : field research 2012, Bone Bolango agroecological zone 2006.

Land in the study area formed from different parent material, which comes from lake sediments (alluvium and colluvium), volcanic and sedimentary rock material. Soils formed from these materials are classified according to Soil Taxonomy system (Soil Survey Staff, 2006) into several orders, namely Entisols, Inceptisols, Alfisols and Mollisols.

Entisol is land that is still very young in the beginning of the new level of development. Entisols area identified is 128.7 ha (4%). Inceptisol is a young land, but more developed than Entisol. This land has not been developed, so that most of the land is quite fertile. Incptisol area identified is 2356.9 ha (47%). An Alfisol soils are clay accumulation in the lower horizon (argillic horizon) and has a high base saturation of more than 35% at a depth of 180 cm from the soil surface. Alfisol area identified is 1,750,9 ha (35%). Molisoll is a land with a thick epipedon more than 18 cm of black (dark), organic matter content of more than 1%, base saturation of more than 50%. Aggregation breeding ground, so the ground is not hard when dry. Molllisol area identified is 751, ha (15%).

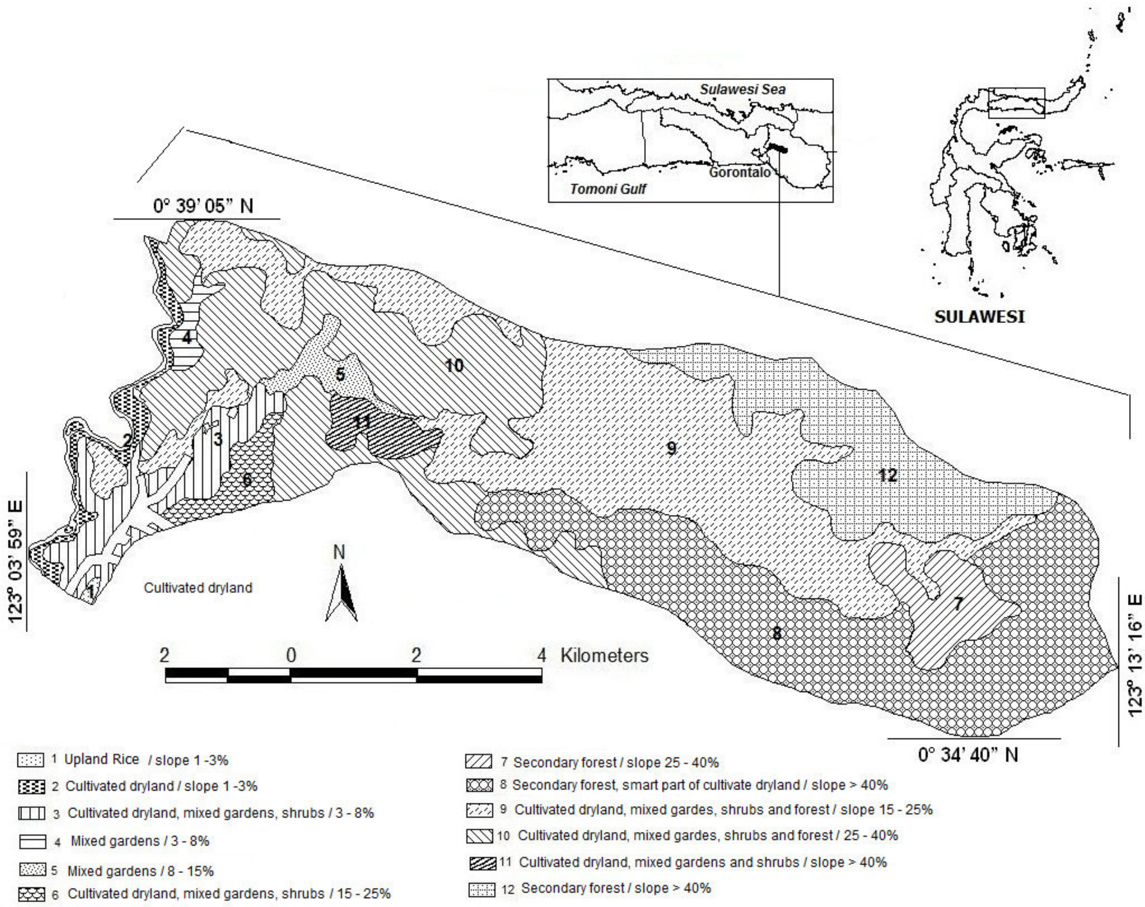

Figure 1. Spatial Distribution of Land Unit, Land Use and Slope in Langge Sub-watershed, Bolango Watershed. Gorontalo

Figure 1 shows that the land use in the sub-watershed Langge consisting of upland rice by 7 ha (12,11%), cultivated dryland 550 ha (8.70%), shrub 921 ha (0.29%), mixed gardens 700 ha (11:07%) and secondary forest 4,144 ha (64.22%)

3.3. Land Suitability

The results of land evaluation, which was conducted by matching and comparing land qualities/land characteristics with class suitability, are arranged based on requirements of plant growth or plant suitability. The evaluation results were then overlaid using the existing land-use maps and resulted in land class suitability. Land class suitability for Food crops and Vegetables are presented in Table 3.

For plants to grow, to have high rate of productivity, and to produce high quality products, plants need to be grown in suitable environment (Amien 1994; Amien *et al*., 1994; Subagio *et al*., 1995). Choices of plants to be grown in certain areas must be based on analyses on slope, texture of soil, acidity, and temperature (Amien 1997).

Table 3 shows the suitability of land for food crops and vegetables in Langge sub-watershed which is highly suitable (S1) was 58 ha (0.9%), without limiting factors. Then, 1,957 ha (33%) of the land belongs to moderately suitable (S2) and marginally suitable (S3) with oxygen availability (oa), rooting condition (rc), and erosion hazard (eh) as the limiting factors. The rest 4,307 ha (68%) of the land belongs to not suitable (N) class with erosion hazard as the limiting factor as well as the land position as secondary forest.

Table 3. Land Suitability Classes in Langge sub-watershed, Bolango watershed. Gorontalo

No Land Unit	Area (ha)	Food Crops			Vegetable				
		Maize	Paddy field	Peanuts	Onion	Chili	Mungbean	Pickpea	Eggplant
1	7	S1	S1	S1	S1	S1	S2oa	S3,rc	S3,rc
2	109	S2,oa	S2,oa	S2,oa	S2, oa	S2,oa	S2,oa	S2,oa	S2,oa
3	281	S3,rc	S3,rc	S3,rc	S3,rc	S3,rc	S3,rc	S3,rc	S3,rc
4	51	S1	S1	S2,rc	S2,oa	S2,oa	S2,oa	S2,oa	S2,oa
5	100	S3,rc	S3,rc	S3,rc	S3,rc	S3,rc	S3,rc	S3,rc	S3,rc
6	117	S2, eh	S3, eh	S2, eh	S3,eh	S3,eh	S3,eh	S3,eh	S3,eh
7	228	N,eh	N,eh	N,eh	N,eh	N eh	N eh	N eh	N eh
8	1,539	N,eh	N,eh	N,eh	N eh	N eh	N eh	N eh	N eh
9	1,818	N,eh	N,eh	N,eh	N eh	N eh	N eh	N eh	N eh
10	1,241	S3, eh/rc	S3, eh/rc	S3, eh/rc	S3, eh/rc	S3, eh/rc	S3,eh/rc	S3,eh/rc	S3,eh/rc
11	109	S3,eh	S3,eh	S3,eh	S3, eh	S3, eh	S3,eh	S3,eh	S3,eh
12	722	N,eh	N,eh	N,eh	N,eh	N, eh	N,eh	N,eh	N,eh

Note : Limiting factor: erosion hazard (eh), oxygen availbility (oa), rooting condition (rc)
Source : field research 2012, modified from Bone Bolango agroecological zone 2006.

3.4. Land Optimization

In this recent study, the bases used in determining equations for Linear Programming in forms of mathematical models of land optimization for food crops and vegetables are finding out the land area for the land category without limiting factors (S1/highly suitable), land area for erosion hazard (S2/moderately suitable), land area for erosion hazard (S3/marginally suitable), and land area with rooting condition as the limiting factor (S3/marginally suitable).

For the sake of optimalization on areas of land for vegetables, data on land uses suitability and oxygen availability (moderately suitable/S2), erosion hazard (marginally suitable/S3), and rooting condition (marginally suitable/S3) for food coprs are presented in Table 4.

Table 4. The Width of Land Areas for Food Crops at Different Limiting Factors

Land suitability classes	Limiting Factors	Suitable land (ha)		
		Maize	Paddy Field	Peanuts
S2	Erosion hazard	226	0	168
S3	Erosion hazard	109	109	109
S3	Rooting condition	381	381	381

Note : S2= moderatelly suitable; S3= marginally suitable

Based on land class suitability for food crops (Table 3), the area of land without any limiting factors is 58 ha for maize, another 58 ha for paddy field, and 7 ha for peanuts. Thus, the total area which belongs to highly suitable class (S1), moderately suitable (S2), and marginally suitable (S3) was 2,015 ha. Optimization is done by maximizing the objective function can be illustrated as follows:

Maximizing $G1 = 58_{X1} + 58_{X2} + 7_{X3}$

Constraint function (C) can be illustrated as a mathematical function as follows:

1. $226_{X1} + 168_{X3} \leq 2.015$
2. $109_{X1} + 109_{X2} + 109_{X3} \leq 2.015$
3. $381_{X1} + 381_{X2} + 381_{X3} \leq 2.015$
4. $_{X1} \geq 0.\ _{X2} \geq 0.\ _{X3} \geq 0$

The results of optimization analyses using Linear Programming are presented in Table 5.

Table 5. Optimal Area of Land for Food crops.

Variable	Areas Used for Food crops (ha)			Optimal Land Area
	Maize (X1)	Paddy Field (X2)	Peanuts (X3)	
The Area of Land for food crops (G1)	306.75	306.75	37.02	650.52

Table 8 shows the optimal area of land—which can be used for planting food crops based on limiting factors or constraints of erosion hazard on marginally suitable/S2 class, of erosion hazard on marginally suitable/S3 class, and of rooting condition on marginally suitable/S2 class—was as wide as 650.52 ha, in which (1) 306.75 ha is for maize, (2) 306.75 ha for paddy field, and (3) 37.02 ha for peanuts. Distribution on optimal land area is presented in Table 6.

Table 6. Optimal Land Area Distribution in Langge sub-watershed, Gorontalo

Comodities	Land Suitability	No LU	Area (ha)		Limiting Factor
			Potential	Optimal	
Maize	S1	1	7	7	
		4	51	51	
	S3	3	281	281	rooting condition (rc)
		5	100	25.75	rooting condition (rc)
Paddy Field	S1	1	7	7	
		4	51	51	
	S3	3	281	281	rooting condition (rc)
		5	100	25,75	rooting condition (rc)
Peanuts	S1	1	7	7	
	S3	3	281	37.02	rooting condition (rc)

Note: S1 = highly suitable, S3 = marginally suitable

For the sake of optimalization on areas of land for vegetables, data on land uses suitability and oxygen availability (moderately suitable/S2), erosion hazard (marginally suitable/S3), and rooting condition (marginally suitable/S3) for vegetables are presented in Table 7.

Table 7. The Land Areas for Vegetables at Different Limiting Factors

Land Suitability classes	Limiting Factors	Suitable Land (ha)				
		Onion	Chili	Mungbean	Pickpea	Eggplant
S2	Oxygen availability	160	160	167	160	160
S3	Erosion hazard	226	226	226	226	226
S3	Rooting condition	381	381	381	388	388

Note: S2 = moderately suitable, S3 = marginally suitable

Based on land class suitability for vegetable (Table 4), the areas for vegetables under highly suitable class (S1) without the limiting factor identified as wide s 7 ha for onion, 7 ha for chili. The areas for vegetables under highly suitable class (S1), moderately suitable class (S2), and marginally suitable class (S3) was 2,015 ha.

Optimization is done by maximizing the objective function can be illustrated as follows:

Maximizing $G1 = 7_{X1} + 7_{X2} + 0_{X3} + 0_{X4} + 0_{X5}$

Constraint function (C) can be illustrated as a mathematical function as follows:

1. $160_{X1} + 160_{X2} + 167_{X3} + 160_{X4} + 160_{X5} \leq 2.015$
2. $226_{X1} + 226_{X2} + 226_{X3} + 226_{X4} + 226_{X5} \leq 2.015$
3. $381_{X1} + 381_{X2} + 381_{X3} + 388_{X4} + 388_{X5} \leq 2.015$
4. $_{X1} \geq 0.\ _{X2} \geq 0.\ _{X3} \geq 0.\ _{X4} \geq 0.\ _{X5} \geq 0$

The results of optimization analyses using Linear Programming are presented in Table 8.

Table 8. Optimal Area of Land for Vegetables.

Variable	Areas Used for Vegetables					Optimal Land Area (ha)
	Onion (X1)	Chili (X2)	Mung Bean (X3)	Pickpea (X4)	Eggplants (X5)	
The Area of Land for Vegetables (G1)	37.02	37.02	5.29	5.19	5.19	89.71

Table 8 shows the optimal area of land—which can be used for planting vegetables based on limiting factors or constraints of oxygen availability on moderately suitable/S2 class, of erosion hazard on marginally suitable/S3 class, and of rooting condition on marginally suitable/S3 class—was as wide as 89.71 ha, in which (1) 37.02 ha for onion, (2) 37.02 ha for chili, (3) 5.29 ha for mung bean, (4) 5.19 ha for pickpea, and (5) 5.19 ha for eggplants. Distribution on optimal land area is presented in Table 9.

Table 9 shows that optimal land area that can be used based on land evaluation results for vegetables was 89.71 ha, distributed on land units 1, 3, and 4. Other than the physical factors of the land, this condition is also supported by the results of chemical analysis on samples of soil taken from three different locations (Table 2)

Table 9. Optimal Land Area Distribution for Vegetables in Langge sub-watershed, Gorontalo.

Comodities	Land Suitabilitty	No LU	Area (ha) Potensial	Area (ha) Optimal	Limiting Factor
Onion	S1	1	7	7	
	S3	3	281	37.02	rooting condition (rc)
Chili	S1	1	7	7	
	S3	3	281	37.02	rooting condition (rc)
Mungbean	S3	3	281	5.29	rooting condition (rc)
Pickpea	S3	3	281	5.19	rooting condition (rc)
Eggplan	S3	3	281	5.19	rooting condition (rc)

Note: S1 = highly suitable, S3 = marginally suitable

Sun and Wu (2011) use Linear Programming to optimize land-use in Qinghe, China. The Linear Programming model is used in choosing alternatives of land-use and analysis of hierarchical processes (AHP) to gain the best decision. The results shows that the ratio of farming areas, gardens, and forest can be developed until 2020 which can gives maximum contribution to economy, ecology, and social feasibility of the land uses and the sustainable development of the land uses themselves.

3.5. Analysis on Farming Feasibility

To optimize land uses in Langge sub-watershed, analysis on farm and farming feasibility needs to be done in order to support crop diversification and rotation. The results of farming feasibility analyses (can be seen in Table 13 and 14) are important in the development of farming activities based on land suitability.

Analysis on farming feasibility is done through profit analysis shown by the value of R/C ratio (Table 10 and Table 11. The value of R/C ratio on paddy field, maize, and peanuts was 1.81, 1.16 and 1.29 respectively. For vegetables, the value of R/C ratio was 1.79; 1.28, 1.33; 1.42 and 1.21 for onion, red chili, mung bean, long bean, and eggplants.

Table 10. Analysis on Farming Feasibility in Langge sub-watershed.

Production Matters	Food crops (in thousand) Paddy field	Maize	Peanuts
I. Production Costs (IDR/ha)	**1,245**	**1,820**	**1,264**
Seed, Fertilizer, Insecticide, Fungiside			
II. Labor Costs (IDR/ha)	**2,708**	**2,800**	**2,470**
Tillage, Planting, Ferilization, Weeding, pest control and harves			
Total Cost (I + II) (IDR/ha)	**3,952**	**4,620**	**3,734**
Net production (kg/ha)	4.5	5	1
Product value (IDR/ha)	11,115	10,000	8,550
Unit price (IDR/kg)	2.47	2..0	8.55
Revenue (IDR/ha)	**7,163**	**5,380**	**4,817**
R/C ratio	1.81	1.16	1.29

Table 11. Analysis on Farming Feasibility in Langge sub-watershed

Production Matters	Vegetables (in thousand) Pickpea	Onion	Chili	Eggplants	Mungbean
I.Production Costs (IDR/ha)	**7,134**	**14,030**	**22,300**	**2,460**	**1,433**
Seed, Fertilizer, Insecticide, Fungiside					
II. Labor Costs (IDR/ha)	**1,860**	**3,500**	**7,750**	**3,750**	**3,450**
Tillage, Planting, Ferilization, Weeding, pest control and harves					
Total Cost (I + II) (IDR/ha)	**8,994**	**17,530**	**30,050**	**6,210**	**4,833**
Net production (kg/ha)	20.900#	5	7	10	0.8
Unit price (IDR/kg)	1.2	8.0	10.0	1.5	13.5
Product value (IDR/ha)	25,000	40,000	70,000	15,000	10,800
Revenue (IDR/ha)	**16,086**	**22,470**	**39,950**	**8,790**	**5,918**
R/C ratio	1.79	1.28	1.33	1.42	1.21

Note : Survey Data, # bundling unit

The commodity having highest revenue for food crops category was paddy field as much as IDR 7,163,000 /ha/season, while for vegetables the commodity having the highest revenue was onion as much as IDR 22,470,000/ha/season. However, considering the optimal land area and land suitability, then the commodity having highest potential to develop and economically feasible is maize, having optimal land area of 276.47 ha/season with revenue of IDR 5,380,000/ha, and mung bean, having optimal land area of 271.71 ha/season with revenue of IDR 5,918,000.-/ha/season.

4. CONCLUSION

The suitability of land for food crops and vegetables in Langge sub-watershed which is highly suitable (S1) was 58 ha (0.9%) without limiting factors. Then, 1,957 ha (33%) of the land belongs to S2 and S3 with oxygen availability, rooting condition, and erosion hazard as the limiting factors. The rest 4,307 ha (68%) of the land belongs to N class with erosion hazard as the limiting factor as well as the land position as secondary forest.

The areas which can be optimized for planting food crops and vegetables are 740.23 ha, consisting of (1) 650.52 ha for food crops (306.75 ha for maize, 306.75 ha for paddy field, 37.02 ha for peanuts), and (2) 89.71 ha for vegetables (37.02 ha for onion, 37.03 ha for chili, 5.29 ha for mung bean, 5.19 ha for pickpea, and 5.19 ha for eggplants).

Analysis on farming feasibility is done through profit analysis shown by the value of R/C ratio. The value of R/C ratio on paddy field, maize, and peanuts was 1.81, 1.16 and 1.29 respectively. For vegetables, the value of R/C ratio was 1.79; 1.28, 1.33; 1.42 and 1.21 for onion, red chili, mung bean, long bean, and eggplants. The commodity having highest revenue for food crops category was paddy field as much as 7,163,000 IDR/ha/season, while for vegetables the commodity having the highest revenue was onion as much as 22,470,000 IDR/ha/season. However, considering the optimal land area and land suitability, then the commodity having highest potential to develop and economically feasible is maize, having optimal land area of 306.75 ha with revenue of 5,380,000 IDR/ha/season, and paddy field, having optimal land area of 306.75 ha with revenue of 7.163.000 IDR/ha/season.

ACKNOWLEDGEMENTS

The author would like to thank the Indonesian Agency for Agricultural Research dan Development has provided an opportunity to pursue doctoral program at Brawijya University. The research was carried out for the help and co-operation with Mr. Ponidi, researchers from the Center for Land Resources, Research and Development Agency, BB Bolango Bone DAS and all those who have contributed so that the studies are completed. There is also the colleagues of Agricultural Sciences doctoral program who have provided encouragement and support to the author.

REFERENCES

Amien, L.I. 1994. Agroekologi dan alternative pengembangan pertanian di Sumatera. *J. Penelitian dan Pengembangan Pertanian* 13 (1): 1 – 8.

Amien, L.I., H. Sosiawan, dan E. Susanti. 1994. Agroekologi dan alternative pengembangan pertanian di Sulawesi, Nusa Tenggara dan Maluku. Prosiding Temu Konsultasi Sumberdaya Lahan untuk Pengembangan Kawasan Timur. Pusat Penelitian Tanah dan Agroklimat. Bogor. hal. 239 – 264.

Amien, L.I. 1997. Karakteristik dan Analisis Zona Agroekologi. Makalah disampaikan pada Apresiasi Metodologi Analisis Zona Agroekologi untuk Pengembangan Sumberdaya Lahan Pertanian. Kerjasama Universitas Udayana, Bali dan ARMP II, Badan Penelitian dan Pengembangan Pertanian.

BP DAS Bone Bolango. 2010. *Rencana Teknik Rehabilitasi Hutan dan Lahan Daerah Aliran Sungai (RTk-RHL DAS) Wilayah Kerja BP DAS Bone Bolango.*

BPS Gorontalo. 2011. Provinsi Gorontalo Dalam Angka.

Djaenudin, D. Marwan H,. H. Subagyo, Anny Mulyani and N. Suharta. 2000. Kriteria Lahan Untuk Komoditas Pertanian. Badan Litbang Pertanian, Kementan. Bogor.

Humphries H.C., Bourgeron, PS., and Reynolds K.M. 2010. Sensitivity analysis of land unit sustainability for conservation using knowledge-based system. *J. Environment Management.* 46 (2): 225 – 236. http://www.ncbi.nlm.nih.gov/ pubmed/20623353?dopt=Abstract .

Ibrahim, M.C. 2008 *Analisis Erosi Pada DAS Bendungan Lomaya. Provinsi Gorontalo*. Institut Teknologi Bandung.

Kasryno, F., Effendi P. and Hermanto. 1997. Pengelolaan Irigasi dan Sumberdaya Air Berorientasi pada Efisiensi Pemberdayaan Petani dan Peningkatan Kemampuan Swasta. Badan Litbang Pertanian. Kementan. Jakarta.

Kwaschik, R., R.B.Singh, and R.S. Paroda. 1996. Technology Assessment and Transfer for Sustainable Agriculture and Rural Development in the Asia-Pacific Region. A Research Management Perspective. FAO.

Mahmoudi, B., Bahtiari, F., Hamidifar, M. and Daneh kar A. 2010. Effect of Landuse Change and Erosion on Physical and Chemical Properties of Water (Karkhe Watershed). *Int. J. Environment Research*, 4 (2): 217-228.

Milesi, C., Elvidge, C. D., Nemani, R. R. and Running, S. W. 2003. Assessing the impact of urban land development on net primary productivity in the southeastern United States. *Rem. Sens. Environ. Res*.,86: 401-410.

Oldeman, L.R., 1975 and Syarifuddin, D., 1971. *An Agroclimatic Map of Sulawesi.* SRIA (LP3). Bogor.

Potter KW. 1991. Hydrological impacts of changing land management practices in a moderate-sized agricultural catchment. *J.Water Resources Research* 27:845–855.

Rayes, M.L. 2006. Metode Inventarisasi Sumber Daya Lahan. Penerbit Andi. Yogyakarta.

Rosister, D.G. and A.R. Van Wembeke. 1997. Automated Land Evaluation System, ALES Version 46.5d. Cornell University, Departemen of Soil, Crops and Atmospheric Science. SCS. Ithaca, NY. USA.

Sitorus, S.R.P. 2004. Evaluasi Sumberdaya Lahan. Penerbit Transito. Bandung.

Sthiannopkao, S., Takizawa, S., Homewong, J. and Wirojanagud, W. 2007 . Soil erosion and its impacts on water treatment in the northeastern provinces of Thailand. *International J. Environment Research*, 33: 706-711.

Schmidt,F.H. and Ferguson,J.H.,1951. *Rainfall Types Based on Wet and Dry Period for Indonesian With Wester New Guinea*. Kementrian Perhubungan Djawatan Meteorologi and Geofisika. Versi 2. No. 42. Jakarta.

Soekartawi. A.Soehardjo, J.L.Dilon dan J.B. Hardaker. 1994. Ilmu Usahatani dan Penelitian untuk Pengembangan Pertanian Kecil. UI. Press.Jakarta.

Soil Survey Staff. 2006. Keys to Soil Taxonomy. A Basic System for Making and Interpreting Soil Surveys, Second edition, USDA-SCS Agric. Handb. 436.

Subagio, H., D. Dajenudin, G. Joyanto, dan A. Syahruddin. 1995. Arahan pengembangan komoditas berdasarakan kesesuaian lahan. Prosiding Pertemuan Teknis Penelitian Tanah dan Agroklimat. Paket Penelitian Tanah dan Agroklimat. Jakarta. hal. 27 – 54.

Sun, Ai-Qing and Wu, Ke-Ning. 2011. Optimization of land use structure applying grey linear programming and analytic hierarchy process. *J. IEEE* : 3146-3150. DOI 10.1109/AIMSEC.2011.6010512.

Thie, Paul R. and Gerard E. Keough. 2010. An Introduction to Linear Programming and Game Theory. Third Edition, Willey.

Van Niekerk, A. 2010. A comparasion of land unit delineation techniques for land evaluation in the Westren Cape, South Africa. *J. Land User Policy.* 27 (3) 937 – 945.
http://www.sciencedirect.com/science/article/pii/S026483770900210.

Vörösmarty CJ, Green P, Salisbury J, Lammers R**.** 2000. Global water resources: Vulnerability from climate change and population growth. J. *Science* 289:284–288.

Wang, G X. Wang, Y B, Qian, J and Wu, Q B. 2006. Land cover change and its impacts on soil C and N in two watersheds in the center of the Qinghai-Tibetan Plateau. *J. Mountain Research and Development* 26 (2): 153 – 162.

Wischmeier, W.H. and D.P. Smith 1978. *Predicting Rainfall Erosion Loses A Guide to Conservation Plannig* .USDA Agric. Handbok (53).

Xiana, G., Crane, M. and Suc, J. 2007. An analysis of urban development and its environmental impact on the Tampa Bay watershed. *J. Environment Management*. 5 (3)**:** 965-976.