

Prospect of Dry Land Corn Development in South Lembeh

Lientje Th. Karamoy¹, Mochtar L. Rayes², Sugeng Prijono³, Bobby Polii⁴

¹Ph.D Student, Graduate School of Environment and development Study, Brawijaya University, Malang 6545, Indonesia

¹Lecturer, Faculty of Agriculture, Sam Ratulangi University, Manado 95115, Indonesia

^{2,3}Faculty of Agriculture, Brawijaya University, Malang 6545, Indonesia

⁴Faculty of Agriculture, Sam Ratulangi University, Manado 95115, Indonesia

(¹lientjekaramoy@yahoo.com)

Abstract- Government programs to make the region agropolitan Bitung Municipality, must be balanced with the development of dry land crops. Potential land for dry land crops in South Lembeh is available. These regions include dry climate. Volcanic Landform occupying dry land. Soil on Landform was formed from volcanic materials, consisting of Humic Eutrudepts, Humic Dystrudepts, and Typic Hapludalfs. Only a small part of the total dry land is used for dry land crops, so it is an opportunity to improve productivity dry land agriculture in South Lembeh

Keywords- Dry land, corn, South Lembeh.

I. INTRODUCTION

Government to make the program as Agropolitan Bitung City in eastern Indonesia are oriented to the dry land, needs to be balanced with the development of dry land crops that have a selling value, given the very extent of the spread of dry land untapped. Among the dry land crops, corn is a strategic commodity to meet the needs still have to be imported as well as corn is commodity markets that have the Sulawesi with the development of corn on a large scale in Gorontalo. Farm diversification with different types of alternative crops according to land suitability and potential, will be able to reduce the risk of crop failure and the economy will ensure market opportunities.

Agro-ecosystems South Lembeh area including dry humid climates. Diversity properties in dry climates with real and long term sun exposure would be advantageous to the growth of generative including dry land for food crops. But its success will be largely determined by the timing and appropriate cropping patterns, in order not to experience water shortages during vegetative growth, and there is no excess water during the generative growth [1].

According to the research of land suitable for development of corn in South Lembeh approximately 1,035 ha (S2 = 600 ha and S3 = 435 ha). Can be used as study materials available data, including the mapping of the South Lembeh [2], semi-detailed mapping scales AEZ level 1; 50,000 [3].

This paper examines the corn crop development opportunities, to offset the Government's program to make the region Agropolitan Bitung City.

II. PORTRAIT OF LAND QUALITY SOUTH LEMBEH

Land component related to aspects of the growth and productivity of plants include climate, soil, and topography. The land component will largely determine the potential, input requirements, and management [4].

Climate

South Lembeh areas studied were reached 1133.5 ha, but the climate stations available is still very limited, so the possibility of differences in climate are difficult to predict and accurately monitored. Availability of rainfall data, temperature, humidity, solar radiation and long detailed planning is necessary especially for dry land crop development.

Temperature of the surrounding air in Bitung and Lembeh Island which includes obtained from the Meteorology, Climatology and Geophysics Agency Maritime Meteorological Station Bitung ranged from 30.5 degrees Celsius to 33.0 degrees Celsius maximum temperature and minimum temperature between 23.8 degrees Celsius to 24.8 degrees Celsius, the average monthly rainfall ranged from 67.3 and 207 mm with an annual average of 1,891 mm. and moisture conditions ranged from 78.2 percent to 81.8 percent, with 56.2 percent exposure to the sun between 73 percent and the average maximum wind speeds between 14.2 and 19 knots and the air pressure is between 86.2 to 92.2 mb.

State of climate elements in Bitung and Lembeh Island surrounding areas including, over a period of eleven years (1998 to 2010)) is presented in Table 1 below.

TABLE 1. IN THE STATE OF CLIMATE ELEMENTS BITUNG CITY AND SURROUNDING YEAR PERIOD 1998 - 2010

| NO. | CLIMATIC DATA | MONTH | | | | | | | | | | | | TOTAL | AVERAGE | | |
|-----|-----------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|---------|---------|--|--|
| | | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DES | | | | |
| 1 | Temperature | | | | | | | | | | | | | | | | |
| | Maximum (°C) | 32.3 | 32.4 | 32.0 | 32.4 | 31.8 | 31.0 | 30.6 | 30.5 | 31.2 | 32.0 | 32.7 | 33.0 | 381.9 | 31.8 | | |
| | Minimum (°C) | 23.9 | 23.8 | 24.7 | 23.8 | 24.2 | 24.6 | 24.4 | 24.8 | 24.6 | 24.1 | 24.0 | 24.2 | 291.1 | 24.3 | | |
| | Average (°C) | 27.8 | 27.5 | 27.2 | 27.4 | 27.9 | 27.6 | 27.3 | 27.3 | 27.8 | 27.9 | 28.0 | 28.0 | 331.7 | 27.6 | | |
| 2 | Precipitation | | | | | | | | | | | | | | | | |
| | Rainfall (mm) | 207.0 | 126.8 | 181.9 | 178.9 | 198.8 | 187.8 | 153.4 | 106.8 | 67.3 | 132.7 | 180.3 | 169.4 | 1,891.0 | 157.6 | | |
| | Rainy Days (days) | 23.4 | 19.4 | 21.1 | 20.5 | 21.2 | 20.5 | 18.2 | 14.0 | 11.0 | 14.5 | 19.8 | 21.8 | 225.2 | 18.8 | | |
| 3 | Sunshine (%) | 57.5 | 59.6 | 60.1 | 57.1 | 58.8 | 56.7 | 60.7 | 63.3 | 73.0 | 70.7 | 62.9 | 56.2 | 736.5 | 61.4 | | |
| 4 | Air Pressure (mb) | 86.2 | 86.7 | 86.6 | 86.4 | 86.6 | 87.0 | 87.2 | 87.7 | 87.7 | 87.1 | 86.0 | 92.2 | 1,047.6 | 87.3 | | |
| 5 | Relative humidity (%) | 79.1 | 78.3 | 80.0 | 81.7 | 81.7 | 81.8 | 80.5 | 79.4 | 78.5 | 79.8 | 78.2 | 79.3 | 958.1 | 79.8 | | |
| 6 | Wind | | | | | | | | | | | | | | | | |
| | Direction (degree) | 152.1 | 69.2 | 115.0 | 98.6 | 198.6 | 222.1 | 206.4 | 215.0 | 211.4 | 210.0 | 152.9 | 136.7 | 1,908.0 | 165.7 | | |
| | Speed | | | | | | | | | | | | | | | | |
| | Max (Knots) | 18.4 | 15.9 | 19.0 | 17.4 | 15.9 | 16.8 | 18.4 | 16.2 | 13.5 | 15.4 | 14.2 | 16.6 | 197.5 | 16.5 | | |
| | Average | 3.2 | 3.1 | 2.9 | 2.2 | 2.4 | 2.8 | 3.7 | 4.2 | 3.5 | 2.5 | 1.9 | 2.4 | 34.6 | 2.9 | | |

Source: [5]

Based on Agro-climate map and partly Bolaang Mongondow including Bitung and Lembeh Island by Oldeman and Damiaty [6], the type of climate in Lembeh island / district South Lembeh including climate type C1 and D1. What is meant by climate type C1 is the area with the number of wet months 5-6 months dry with less than two months. Type D1 climate with a dry month less than two months.

The big difference in agro-climatic zones and types of contrasting rainfall for the period indicated in this area has been a change of climate. In relation to water requirements for crops in rain-fed land, these events should be observed and anticipated, as it is very important to determine the timing and cropping patterns, as well as the right choice of plants. South Lembeh area including dry humid climates, the sun shines long enough and hot temperatures. If the water needs can be met during the vegetative growth, climatic conditions and the nature of this kind would be beneficial to generative growth in accordance with the requirements of the relevant commodities grows, so will be able to produce optimal [7].

Appropriate planting time setting is the key to success in dry land farming. From the data of rainfall, air temperature, and treated with the geographic location of the Newhall Simulation Model / NSM [8], showed dry land in the southern part of the soil moisture regime has hick, hick including the land, ie ≥ 90 days the soil is always moist. Soil temperature regimes throughout the region, including South Lembeh is isohyperthermic, which are characterized by differences in winter temperatures and summer $<5^\circ\text{C}$ [9].

Soil temperature regime that includes isohyperthermic correlated with air temperature typically 1°C higher than the air temperature. Soil temperature regime and the air temperature is too hot will affect less well to production capability, because the energy produced through the process of photosynthesis is used for respiration [10].

Classification and Soil Quality

Quality and characteristics of the soil and its potential for agriculture is determined by factors of lithology, climate, and topography or shape the region. In tropical climates most instrumental components in the process of rock weathering is the physical and chemical air temperature and precipitation

[11]. Weathered rocks will produce certain minerals, which are a source of nutrient reserves, which are toxic or adversely affect plant growth and productivity [4].

Limit land units including spatial land, reflected by landform conditions. Landform dry land in the South Lembeh is a volcanic group [12; [13]. Landform group is highly correlated with physical properties, morphology, and soil chemistry, and mineralogy, so it will affect the potential for agricultural development and management.

Land in the South Lembeh generally formed from intermediate volcanic material. According to the results of previous mapping, soil dominant on dry land in the South Lembeh after adjusting for Soil Taxonomy system [14], consists of 2 orders, 3 group and 3 subgroups ground. The third subgroup of the land in question, which is of the order Inceptisols are Humic Eutrudepts and Humic Dystrudepts; than Alfisols is Typic Hapludalfs.

1). Humic Eutrudepts

This soil has the texture of sandy clay loam and loamy, slightly acidic soil reaction to neutral pH range between 6.1 to 7.3. The content of C-organic medium, low nitrogen. P2O5 levels low, except in the lowest layer is very high, the low total K2O. Cation exchange rate low to high Ca, Mg, K, and Na is low. CEC is moderate to high, and BS extremely high ($\geq 60\%$).

2). Humic Dystrudepts

This soil has a clay texture dusty, reaction acid to slightly acid soil (pH 4.6 to 5.5). C-organic content of the upper layer of high, but low in the bottom layer. Nitrogen is low to moderate. P2O5 and K2O levels are very low to low. Cation exchange rate low to high Ca, Mg, K and Na is low. CEC is low and very low BS.

3). Typic Hapludalfs

The soil texture in the upper layer of sandy clay loam, while in the bottom layer of clay. Reaction slightly acid to neutral soil (pH 6.1 to 7.3), C-organic content in the top layer of low to high, in the bottom layer is very low. Nitrogen in the upper layer of low to moderate, very low in the lower layers. P2O5 and K2O levels between low and very low. Ca cation exchange rate is very low, low and very low Mg. K and Na are low. Low and high of CEC and BS.

Soil quality improvement

Constraints faced by the lands on dry land in the South Lembeh primarily soil chemical properties, physical properties and some morphology. To improve and enhance the quality and potential of the lands on dry land in the region for the development of food crops can be reached through the following efforts:

1). Provision of agricultural lime (Kaptan), especially on Humic soil Dystrudepts. Including the role of agricultural lime to overcome the acidic soil pH, low base saturation, and suppress the bad influence of Al and Fe, especially the availability of phosphate (P) in the soil for plants. With liming soil acidity will decrease, so the availability of P will increase.

2).Application of organic manures is needed primarily to address soil cation exchange capacity (CEC) is low, and improved physical properties, and the morphology of the soil. In this case repair the structure and consistency of the soil, and improve water and nutrient retention capacity. It is therefore very important role especially on coarse texture soils or sandy, namely Typic Udispammments, and Typic Quartzipsammments.

3).Complete fertilization N, P, K is absolutely necessary, and since then the pH of acidic soil nitrogen nutrient source that can be used is urea. While the source of nutrients and potassium phosphate, respectively fertilizer SP-36 and KCl. Doses of the three types of fertilizers, tailored to the needs of each type of commodity to be developed.

The Relief

Relief a part of the land component of a very determining management (management) for the development of agricultural commodities. To protect the environment, because of the hilly region steep slopes and unstable soil does not allow for agriculture, therefore used are directed to conservation areas or protected. Performance of shape area covering the slope, the height difference of the highest and lowest in each unit area contained in the form of South Lembeh are presented in Table 2.

TABLE 2. SLOPE REGIONAL SHAPE AND RANGE IN AREA SOUTH LEMBEH

| Relief | Slope (%) | Area (ha) | Percentage |
|------------------|-----------|-----------|------------|
| Flat-nearly flat | 0 - 3 | 31.68 | 2.64 |
| Undulating | 3 - 8 | 179.26 | 14.92 |
| Rolling | 8 - 15 | 723.83 | 60.28 |
| Hillocky | 15 - 30 | 18.13 | 1.51 |
| Hilly | 30 - 45 | 159.44 | 13.28 |
| Nountainous | > 45 | 3.61 | 0.30 |

Sources: [2] Mapping South Lembeh

Of aspect and slope regions form associated with the condition of the land, land development opportunity for dry land corn crop in this area is on a little flat to undulating topography, area reached 934.8 ha. Mechanization of farming systems, both for tillage, planting, or during and post-harvest, is an alternative option to overcome the obstacles and the amount of skilled labor is very limited

III. PERFORMANCE OF DRY LAND FARM

Based on the analysis of the topography of a composite Landsat bands 543, in the area of South Lembeh including volcanic group Landform dominant conditions including dry land [13]; [15].

The study of land suitability for corn in the South Lembeh [2] resulting in actual land that can be developed for the actual development of corn (Table 3 and Figure 1) and potentially (Tables 4 and Figure 2).

TABLE 3. ACTUAL LAND SUITABILITY FOR CORN IN SOUTH LEMBEH

| No. | Description | Area | |
|-------|---------------------|---------|-------|
| | | Ha | % |
| S3 | Marginally Suitable | 848.0 | 72.9 |
| N | Not Suitable | 285.3 | 27.1 |
| Total | | 1,133.3 | 100.0 |

Remark: Adapted and edited

TABLE 4. POTENTIAL LAND SUITABILITY FOR CORN IN SOUTH LEMBEH

| No. | Description | Area | |
|--------|---------------------|---------|-------|
| | | Ha | % |
| S2 | Moderately Suitable | 600.3 | 53,0 |
| S3 | Marginally Suitable | 434.9 | 38,3 |
| N | Not Suitable | 98.1 | 8,7 |
| Totals | | 1,133,3 | 100.0 |

Remark: Adapted and edited

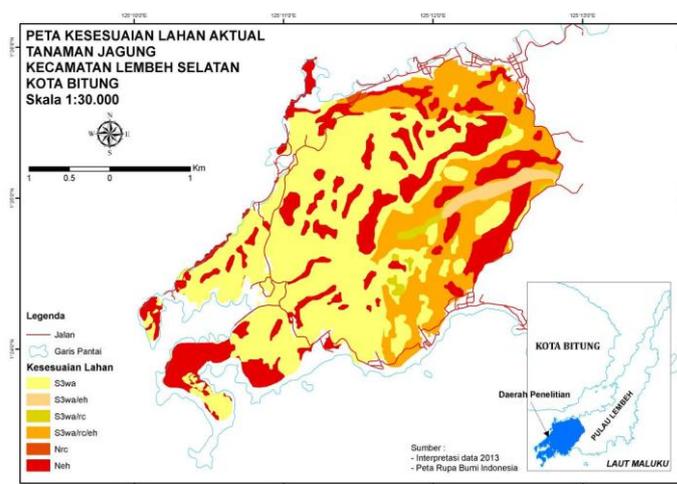


Figure 1. Map of Corn Land Suitability Class (actual).[16]

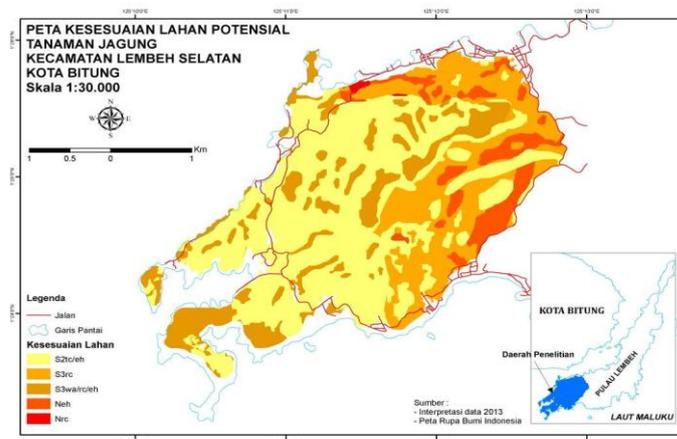


Figure 2. Map of Corn Land Suitability Class (Potential)

Corn production has been achieved at the farm level is relatively inadequate. It is possible the dose and / or the balance of the applied fertilizer is not in accordance with the quality and diversity of soil characteristics. As an illustration nutrient requirements to achieve certain production and production potential that can be achieved if cultivated in the smallholder farmer level, and commercial or commercial good yield is presented in Table 5.

TABLE 5. NUTRIENT NEEDS TO ACHIEVE A CERTAIN PRODUCTION, AND PRODUCTION OPPORTUNITIES THAT CAN BE ACHIEVED ACCORDING TO HIS MANAGEMENT LEVEL

| Commodities /to achieve production | Nutrient requirements (kg) /Ha | | | Production opportunities can be achieved Ton/Ha) | | |
|------------------------------------|--------------------------------|-------------------------------|------------------|--|-----------|------------|
| | N | P ₂ O ₅ | K ₂ O | Commodities | Farmer | Commercial |
| Corn/ 4 ton | 60 - 100 | 50 - 100 | 30 - 60 | Corn | 0.5 - 1.5 | 6.0 - 9.0 |
| Soybean/ 2 ton | 0 - 25 | 35 - 60 | 35 - 75 | Soybean | 0.8 - 1.3 | 1.5 - 2.5 |
| Ground nut/ 1 ton | 15 - 25 | 50 - 100 | 35 - 75 | Ground nut | 1.0 - 2.0 | 2.0 - 3.0 |
| Sweet potatoes/10 ton *) | 90 | 20 | 120 | Sweet Potatoes | 5 - 10 | 25 - 30 |
| Cassava/ 80 ton | 50 - 90 | 60 - 75 | 80 - 120 | Cassava | 30 - 40 | 5 - 15 |

Sources: [17]

Remarks: *) In addition to the N, P₂O₅ and K₂O are in uptake of sweet potato also need given CaO, MgO about 15 kg / ha

Cultivation of crops dry land corn, soybeans, peanuts, sweet potatoes and cassava in South Lembeh area, has been using fertilizer.

Doses of the three kinds of fertilizer / ha for each commodity, which is calculated based on the acreage and amount of fertilizers applied, are presented in Table 6. The availability of nutrients for plants including soil pH is determined by, cation exchange capacity and base saturation. The dominant upland soil acidic to slightly acid reacting the pH range between 4.5 – 5.5 in South Lembeh is Humic Eutrudepts, Humic Dystrudepts, Typic Hapludalfs.

TABLE 6. FERTILIZER DOSES ARE USED FOR SOME COMMODITIES

| Commodities | Fertilizer dose given Kg/ Ha | | |
|----------------|------------------------------|------------------------------------|----------|
| | Urea | TSP equivalent SP 36 ²⁾ | KCl |
| Corn | 200 | 100 | (127.78) |
| Soybean | 50 | 125 | (159.72) |
| Ground nut | 75 | 25 | (31.94) |
| Sweet Potatoes | 150 | 100 | (127.78) |
| Cassava | 150 | 100 | (127.78) |

Remark: 1) Processed 2) TSP = 46% P₂O₅ content; SP 36 = 36% P₂O₅ content,

Needs nutrients nitrogen (N), phosphate (P₂O₅), potash (K₂O), and CaO (Kaptan / Dolomite), and compost especially for sandy soil texture, which is in the region of South Lembeh are presented in Table 7.

TABLE 7. NEEDS OF NUTRIENT / HA ON ACID TO SLIGHTLY ACID SOIL (PH 4.5 – 5.5)

| Commodities | Nutrient needed | | | | | | | | |
|----------------|-----------------|---------------------|-------------------------------|---------------------|------------------|---------------------|-----|---------------------|------------|
| | N | Urea | P ₂ O ₅ | SP-36 | K ₂ O | KCl | CaO | Kaptan (Dolomit) | Compost *) |
| Corn | 165 | 358.7 ^{a)} | 55 | 152.8 ^{b)} | 135 | 225.0 ^{c)} | 75 | 258.6 ^{d)} | 5 - 7 |
| Soybean | 125 | 271.7 | 30 | 83.3 | 40 | 66.7 | 75 | 258.6 | 5 - 7 |
| Ground nut | 50 | 108.7 | 15 | 41.7 | 15 | 25.0 | 100 | 344.8 | 5 - 7 |
| Sweet Potatoes | 90 | 195.7 | 20 | 55.6 | 120 | 200.0 | 75 | 258.6 | 5 - 7 |
| Cassava | 120 | 260.9 | 30 | 83.3 | 150 | 250.0 | 75 | 258.6 | 5 - 7 |

Sources: [17] (processed)

Remark: a) Urea, b) SP-36, c) KCl, d) Kaptan / Dolomite

*) For sandy soil (Udipsamments, Quartzipsamments)

For soil pH is neutral or alkaline, and base saturation of more than 35%, in this case Humic Eutrudepts, fertilizer doses required would be lower, but until now there has been no definitive data. Therefore, to determine more precisely the dose of fertilizer that needs to be given to each type of plant, should be based on soil test results followed by field trials. But of course before should know the quality and characteristics of the soil or soil classification at the location of the development.

Based on economic analysis for corn in the region and surrounding Lembeh, is the cost of inputs (input) corn farming moderate Rp. 12,205,000, - with production (output) for class 1 is Rp. 30,270,000 then the economic analysis of corn business results are presented in Table 8.

TABLE 8. ECONOMIC ANALYSIS OF THE VALUE OF CORN (INPUTS ARE THE 15% SHRINKAGE)

| No. | Analysis | Kind Suitability Class | | | |
|-----|-----------------------|------------------------|----------|---------|----------|
| | | S1 | S2 | S3 | N1 |
| 1. | BCR | 2.16 | 1.73 | 1.29 | 0.54 |
| 2. | Gross Margin (Rp 000) | 18,065.0 | 12,011.0 | 5,957.0 | -4,637.5 |

Data resulting from soil mapping can be utilized for the development of agricultural commodities. Supported by the data distribution of land according to spatial classification, the results of a fertilization experiment agricultural commodities technology adapted will be converted to other places that have the nature of the climate, soil, and other similar biophysical environment [4]. For the purposes of technology transfer, usually land in the location specified classification experiments minimal soil family level, but ideally at the level of soil series. For comparison, the production of corn, soybeans, peanuts, sweet potatoes, and cassava at the national level for the period 2002 - 2006 is presented in Table 8 [18].

TABLE 9. PRODUCTION OF SOYBEAN, CORN, GROUND NUT, SWEETPOTATO, AND CASSAVA THE PERIOD 2002-2006

| Commodities | Developments Of Production (Ton/Ha) | | | | |
|----------------|-------------------------------------|------------|------------|------------|------------|
| | 2002 | 2003 | 2004 | 2005 | 2006 |
| Com | 9,654,105 | 10,886,442 | 11,225,243 | 12,523,894 | 11,610,646 |
| Soybean | 673,056 | 1,600 | 723,483 | 808,353 | 749,038 |
| Groundnut | 718,071 | 5,526 | 837,495 | 836,295 | 837,991 |
| Sweet Potatoes | 1,771,642 | 991,478 | 1,901,802 | 1,856,969 | 1,851,840 |
| Cassava | 16,913,1042 | 8,523,810 | 19,424,707 | 19,321,183 | 19,927,589 |

Source: [18]

From this table, it appears the national production of corn showed no increase, although in 2006 decreased compared to 2005 production. But compared with other years continued to show an increase. Something similar happened also in soybean plants, which tend to increase overall production. Fluctuate significantly increased production seen in sweet potato and cassava.

IV. CONCLUSION

To optimize land use in the study area District South Lembeh Bitung North Sulawesi requires data on soil characteristics. Formation parent materials formed from volcanic rocks of andesite parent material, breccias, tuffs and basalt. Research areas as part of the island lembeh with almost half circle shape is part of the old crater cliff. The conclusions of this research are:

1. Classification of land in the District of South Lembeh Bitung North Sulawesi soil classification system based on Soil Taxonomy gained 3 types of soil are: Typic Hapludalfs, Humic and Humic Dystrudepts Eutrudepts.
2. The physical properties of the soil showed that the textured sandy clay, sandy clay and argillaceous sand, moderate permeability and depth in the soil.
3. Formation parent materials in the District of South Lembeh Bitung City as the study area is formed of volcanic rocks of andesite parent material, breccias, tuffs and basalt. Research areas as part of the island lembeh with almost half circle shape is part of the old crater cliff.
4. Actual land suitability evaluation for corn (*Zea mays. L*) S3wa (LU 1), Neh (LU 2 and 7), Nrc (LU 3), S3wa/rc/eh (LU 4), S3wa/eh (LU 5), S3 wa/rc (LU 6).
5. Based on the assessment of potential land suitability of the corn crop suitability class 3 (corresponding marginal) into conformance class 2 (as appropriate) on the LU 1, 4, 5 and 6, land suitability classes are not suitable (N) be the congruence class S3 (marginally suitable) on LU 2, 3 and 7.
6. Economically on land suitability classes S1, S2, and S3 profitable corn farming.

REFERENCES

- [1] Djaenudin, D., Marwan H., A. Hidayat dan H. Subagyo, 2003. Petunjuk Teknis Evaluasi Lahan untuk Komoditas Pertanian. Balitanah, Puslitbangtanak, Badan Litbang Pertanian. ISBN: 979-9474-27-2
- [2] Karamoy Lientje Theffie, 2012. Penelitian Sumberdaya Lahan daerah Lembeh Selatan
- [3] Balai Pengkajian Teknologi Pertanian (BPTP)-Sulawesi Utara, 2006. Analisis Zona Agroekologi Di Sulawesi Utara Skala 1: 50.000 Di Kabupaten Minahasa Utara, Provinsi Sulawesi Utara. Badan Penelitian Dan Pengembangan Pertanian Departemen Pertanian
- [4] Djaenudin, D., 2008. Prospek Penelitian Potensi Sumberdaya Lahan di Wilayah Indonesia. Orasi Pengukuhan Profesor Riset Bidang Pedologi dan Penginderaan Jarak Jauh. Badan Litbang Pertanian Deptan - LIPI. ISBN: 978-602-8039-07-9
- [5] Badan Meteorologi Klimatologi dan Geofisika, 1998-2010. Data unsur iklim. Stasiun Meteorologi Maritim Bitung
- [6] Oldeman, L.R, and Darmiyati S., 1977. The Agroclimatic Map of Sulawesi, scale 1: 2,500,000. Contr. Centre. Res. Inst. Agric. Bulletin No.60, Bogor.
- [7] FAO. 1996. Agroecological Zoning Guidelines. FAO Soil Bulletin 73. Rome Italy.
- [8] Wambeke, A. R, Van., P. Hastings, and P. Tolomeo. 1985. New Simulation Model (NSM) for Moisture Regimes. Dep. Agr. Bradford Hall. Cornell University, NY.
- [9] Soil Survey Staff, 2003. Key to Soil Taxonomy. USDA. Natural Resources Conservation Services (NRCS). Ninth Edition, 2003. Washington, D. C
- [10] Kannegieter, A., and H. Huizing, 1983. Aspect of Agriculture. Lecture Notes N.-2 Rural Survey Course ITC Enschede The Netherlands
- [11] Wilding, L. P., N. E. Smeck, and G. F. Hall, 1983. Pedogenesis and Soil Taxonomy. Concepts and Interactions. Developments in Soil Science 11 A
- [12] Desauettes, JR, 1977. Catalogue of Landforms for Indonesia. Examples of a Physiography Approach to Land Evaluation for Agricultural Development. SRI-FAO. AGL/TF/INS/44. Working Paper No. 13
- [13] Marsoedi, Ds., Widagdo, J. Dai, N. Suharta, Darul SWP, S. Hardjowigeno, J. Hof dan E.R. Jordens.1997. Pedoman Klasifikasi Landform. Versi 3.0. LREP II, Part C. CSAR, Bogor
- [14] Soil Survey Staff. 2010. Key to Soil Taxonomy. USDA Natural Resources Conservation Services.pp. 338.
- [15] Hendrisman M., Hikmatulloh dan D. Djaenudin, 2005. Analisis Topografi dari Citra Landsat-7 ETM; Studi Kasus Daerah Sidangoli-Sofifi, Halmahera. Pros. Puslitbangtanak ISBN. 979-9474-49-35. Hal. 223-239
- [16] Balai Pengkajian Teknologi Pertanian (BPTP)-Sulawesi Utara, 2006. Analisis Zona Agroekologi Di Sulawesi Utara Skala 1: 50.000 Di Kabupaten Minahasa Utara, Provinsi Sulawesi Utara. Badan Penelitian Dan Pengembangan Pertanian Departemen Pertanian
- [17] Sys C., E. Van Ranst, J. Debaveye, and F Beernaert, 1993. Land Evaluation Part III. Agric. Public. No 7. Brussels – Belgium
- [18] Badan Pusat Statistik, 2007. Statistik Indonesia. Statistical Yearbook of Indonesia. Jakarta - Indonesia. 315.598. ISSN: 0126-29132. No. Publ: 06300.0708. Katalog BPS: 1401.