Fuzzy Simple Additive Weighting Algorithm to Determine Land Suitability for Crop in Minahasa Tenggara

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ABSTRACT
The change of geographical situation such as weather and climate make farmers difficult to prepare the land for suitable crop. Consequently they depend on rainwater rice field. This paper explain the use of fuzzy simple additive weighting to rank the alternate crops suitable for planted in each sub district in Minahasa Tenggara. This information system can be used by local government and farmers to determine the type of crop to be planted. This information based on geophysics data existing in Dept. of Agriculture and Central Bureau of Statistics.

General Terms
Fuzzy Classification, Land-use Classification

Keywords
Fuzzy Simple Additive Weighting, Land suitability, crop.

1. INTRODUCTION
Planning management of land use is one of the factors to achieve the land use optimization. It is because of the limitation of the number of land and non renewable land resources, the occurrence of the damage due to the lack of land utilization, the reduction of water catchment area resulting from the alteration use of forest land into agricultural land area [1]. In support of food self-sufficiency government of Minahasa Tenggara district through Dept. of agriculture and farm will do land treatment of about 80 ha unmanaged land in Pusomaen. This area and the surrounding area is the areas those are suffered from land and food crisis caused by the sleep land.

From the pre analysis of Central Statistic Bureau (BPS) data the increasing production of rice in North Sulawesi is not balance with the increasing of need. On 2009, rice production in North Sulawesi is about 16.103 tons and the need is 11.463 tons [2]. On 2010 rice production reach 33.820 tons, but the need increase sharply to 96.766 tons over the production in North Sulawesi. As a main source of rice production, Minahasa Tenggara trying to increase food production by optimizing food land. It is not just rice but also corn and cassava.

The strategy of land use optimization as the agricultural cultivation need to be supported by the provision of all facilities and infrastructure required by improving its human resources and strengthening the capacity of institution. The first step in maintaining the stability of the food security and increase farmers' economy is utilizing the land for food plots, besides naturally preserve the ecosystem and reduce opening agricultural land by clearing forests land.

Clearing land for crops need proper evaluation and analysis according to the conditions of the environment. On 2011 Food and Agriculture Organization (FAO) renew the existing land evaluation indicators. Those indicators are land conformity, comparative advantage with the input that is required, the land use technology, evaluation of the physical condition of land, the socio-economic conditions, conformity on the sustainable land use without damaging nature, and the characteristic of land use [3]. Furthermore, this FAO land evaluation technique is called an FAO model.

This paper discusses an algorithm suitable to evaluate the land use that is Fuzzy Simple Additive Weighting (SAW) algorithm. This algorithm requires a number of alternatives and criteria that support the suitability of land for food crops. To simplify the criteria of FAO model, we reduce the criteria to be five criteria, those are rainfall intensity, the texture of land, irrigation, and the climate. We study the use of fuzzy SAW algorithm in determining the appropriate type of food plants to grown in sub districts of Minahasa Tenggara.

2. LITERATURE REVIEW

2.1 Fuzzy Simple Additive Weighting Algorithm
Fuzzy simple additive weighting algorithm is one of fuzzy multi attribute decision making algorithm that is used to choose the best alternative among alternatives by using certain criteria [4]. There are two steps to approach, that are calculating the aggregation of all decisions that approach to all destinations on each alternative, and then ranking the alternative against each of the decision based on the aggregation results [5]. The algorithm is [6]:

- Put a value on each alternate (A_i) on each criteria (C_j) that is determined. The given value is a set of crisp number $i = \{1,2,...,m\}$; $j = \{1,2,...,n\}$
- Give weight (W) to the crisp number that is determined.
- Do normalization to plot the membership degree of each fuzzy element by calculating the normalized performance value (r_{ij}) from alternate A_i to attribute C_j based on the equation that adjusted with the type of an attribute with maximum value (MAX X_{ij}) or minimum value (MIN X_{ij}).
- Rank all alternates by multiply the normalized matrix (R) with the weighted value (W).
- Determine the preference value for each alternate (Vi) by adding the product of normalized matrix (R) with the weighted value (W). The maximum V_i define that the alternate is better.

2.2 Alternate and Suitability Land
Alternate is determined for sub district in the Minahasa Tenggara through the type of food crops to be planted by calculating an average of the suitability of any food crop in a

fuzzy based on criteria of growing plants. The type of the specified food crops include paddy, dry field paddy (*gogo*), corn, and cassava. Each alternate is denoted as P_1, P_2, P_3 , and P_4.

Criteria is denoted by land class of multiple factor. The classification is using some factors to classify the observed object [3]. The factors that determined must be prominent characteristics. It is allow other people to use them without having to understand the whole characteristics used in the system of land use.

The prominent characteristic is determined from the average rainfall per year, soil texture, the number of irrigation, climate, and topography [8]. The alternate and criteria of land use that has been determined can be seen in Table 1.

Table 1. Sub district and the characteristic of land use

Sub-dist	Rainfall (mm/year)	Soil texture	Irrigation (times/year)	Climate	Topography (m-amsl)
Ratahan	2955	Sandy clay soil, dusty clay soil, clay soil	41	5.43	600
Pusomaen	2984	Sandy clay	341	5.38	600
Belang	3241	Sandy clay	55	4.95	200
Ratatotok	2959	Clay, Sandy clay	22	5.42	500
Tombatu	2271	Clay, dusty clay, dust	81	7.07	600
Touluaan	3137	Clay, dusty clay, dust	432	5.12	500
North Tombatu	3005	Sandy soil, dusty soil, soil	156	5.34	500
East Tombatu	3360	Sandy soil, dusty soil, soil	337	4.77	500
South Tombatu	3097	Clay, dusty clay, dust	133	5.18	400
Silian Raya	2770	Sandy clay	149	5.79	400
East Ratahan	2812	Sandy clay soil, dusty clay soil, clay soil	76	5.71	600
Pasan	2964	Sandy clay	854	5.41	300

3. RESULT AND DISCUSSION

3.1 Fuzzy values to classify Criteria

Rainfall intensity is classified as very wet > 3,000 mm/year, wet 2,501-3,000 mm/year, moderate or humid 2,001-2,500 mm/year, dry 1,501-2,000 mm/year, very dry < 1,500 mm/year.

Soil texture is classified as coarse (sand, sand clays) with weighted value 0 - 0.2, a little rough (clay sand) with weighted value 0.21 – 0.4, moderate (clay, clay dust, dust) with weighted value 0.41 – 0.6, rather fine (sandy clay soil, dusty clay soil, clay soil) with weighted value 0.61 – 0.8, fine (sandy soil, dusty soil, soil) with weighted value 0.81 – 1.

Schmidt – Ferguson [8] classified climate based on the rainfall by calculating the average of dry season divide by the average of wet season multiply with 100%. The Irrigation is classified by calculating the amount of irrigation per year.

Topography is classified in five class based on height of above mean seal level (amsl). This classes are height range from 0 – 200 meter has weight 0 – 0.2; height range from 201 – 400 meter amsl has weight 0.21 – 0.4, height range from 401 – 600 meter amsl has weight 0.41 – 0.6, height range from 601 – 800 meter amsl has weight 0.61 – 0.8 dan height > 800 meter amsl has weight 0.81 – 1.

The result of the fuzzy calculation using increasing linear representation (eq 1) and for all criteria the calculation can be seen in Table 2.

$$\mu[x] = \begin{cases} 0; & x \le a \\ \frac{x-a}{b-a}; & a \le x \le b \\ 1; & x \ge b \end{cases} \quad (1)$$

Table 2. Fuzzy Result for all Criteria

Sub-dist	Rainfall (mm/year)	Soil texture	Irrigation (times/year)	Climate	Topography (m-amsl)
Ratahan	0.98	0.65	0.05	0.89	0.75
Pusomaen	0.99	0.32	0.38	0.88	0.75
Belang	1.00	0.30	0.06	0.81	0.25
Ratatotok	0.98	0.28	0.02	0.89	0.63
Tombatu	0.71	0.53	0.09	1	0.75
Touluaan	1.00	0.58	0.48	0.84	0.50
North Tombatu	1.00	0.90	0.17	0.88	0.38
East Tombatu	1.00	0.95	0.37	0.77	0.25
South Tombatu	1.00	0.92	0.15	0.85	0.63
Silian Raya	0.91	0.55	0.17	0.96	0.38
East Ratahan	0.92	0.45	0.08	0.94	0.38
Pasan	0.99	0.28	0.95	0.89	0.38

3.2 Calculation using Fuzzy Simple Additive Weighting

After the fuzzy value obtained from the overall criteria then determine the weighted vector value (w) for each criteria as be seen in the bottom of Table 3. Next step is calculating the normalized rating performance (r_{ij}) for each attribute and each criterion. Because the value assigned to each alternative for each criteria, then it is assumed that these criteria are criteria of profit. The results can be seen in Table 3 bellow.

Table 3. Normalized Criteria (r_{ij})

Sub district	Rainfall (mm/year)	Soil texture	Irrigation (count /year)	Climate	Topography (m-amsl)
Ratahan	0.982	0.68	0.05	0.89	1
Pusomaen	0.99	0.34	0.40	0.88	1
Belang	1	0.32	0.06	0.81	0.33
Ratatotok	0.98	0.29	0.03	0.89	0.83

Tombatu	0.71	0.56	0.09	1	1
Touluaan	1	0.61	0.50	0.87	0.83
North Tombatu	1	0.95	0.18	0.91	0.83
East Tombatu	1	1	0.39	0.80	0.83
South Tombatu	1	1	0.15	0.88	0.67
Silian Raya	0.92	1	0.17	1	0.67
East Ratahan	0.94	0.9 0	0.09	1	1
Pasan	1	0.56	1	1	0.67
Weighted vector (w)	0.68	0.50	0.28	0.88	0.56

The last step of fuzzy SAW calculation is ranking preference value (V_i) come from sum of weighted vector multiplication (w) and normalized matrix (r_{ij}). The result of the calculation can be seen in Table 4.

Table 4. Ranking (V_i)

Sub-dist	Rank
Ratahan	2.38
Pusomaen	2.30
Belang	1.76
Ratatotok	2.08
Tombatu	2.23
Touluaan	2.36
North Tombatu	2.48
East Tombatu	2.47
South Tombatu	2.38
Silian Raya	2.43
East Ratahan	2.56
Pasan	2.50

3.3 Analysis of the Result

From the ranking on Table 4, we cannot yet determine whether a particular sub district can be planted food crops such as rice paddy irrigation, dry field paddy (*gogo*), corn and cassava. In this analysis we calculate the amount of the requirement of growing plants with the approach of each criterion specified previously in the fuzzy. The result is presented in Table 5.

Table 5. Requirement of growing plats by using Criteria approach

Alternate	Rainfall	Soil texture	Irrigation	Climate	Topography	Amount
Irrigation paddy (P1)	0.800	0.7	0.111	0.44	0.500	2.555
dry field paddy (*gogo*) (P2)	0.600	0.6	0.055	0.44	0.500	2.200
Corn (P3)	0.600	0.6	0.011	0.44	0.375	2.031
Cassava (P4)	0.520	0.5	0.011	0.25	0.250	1.540

From these results it can be determined that the food commodities can be planted in a particular sub district. Suppose in Ratahan value rank 2.38 is matching with *gogo* because the nearest ranking value with the amount of requirement of growing plants with the criteria approach is 2.2004. The reality on the field that sub district Ratahan has data of rainfall, irrigation, soil texture, climate and topography suitable for rice plant *gogo*. It can be seen also to other food such as alternative irrigation of rice planted in suitable districts of North Tombatu, East Tombatu, East Ratahan, Pasan, Silian Raya. *Gogo* rice is suitable planted in Ratahan, Pusomaen, Tombatu, Touluaan, and South Touluaan. Corn is suitable planted in Ratatotok. Cassava is suitable planted in Belang.

To clarify the result we plot it on the map from google map API, that can be seen in figure 1. The rank is classified into three classes, that is very suitable, suitable, and unsuitable. The classes of the rank are marked with the different color. On that map there are also information about how much land area suitable for a specific plant. This information can be used by local government to control the productivity of crop on their area.

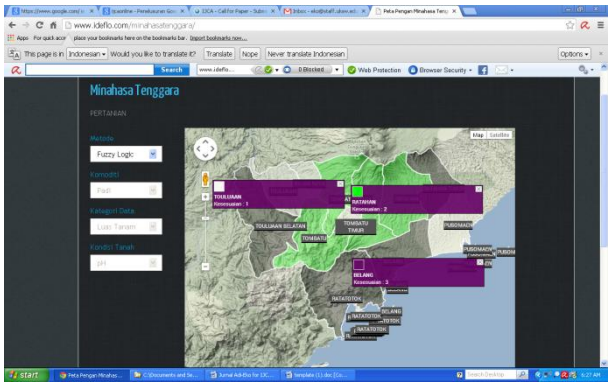

Fig 1: Rank Plot of Land Suitability in Minahasa Tenggara

4. CONCLUDING REMARK

4.1 Conclusion

From the results of the analysis it can be concluded that the fuzzy simple additive weighting algorithms (SAW) can be used to determine the type of food crops grown on a given area by using a number of criteria such as soil texture, rainfall, irrigation, climate and topography. Validation with the data in the field also show a match with data calculated by using fuzzy.

4.2 Future Research

Upcoming research is expected to use more criteria in accordance with the standardization of land suitability or standardization of FAO to strengthen data and results. Furthermore this research can be used as input to the Department of agriculture in Minahasa Tenggara District. It can also be used in other regions to increase food productivity.

The use of google map is somewhat imposed to show the spread of suitable area for certain crop. It is better if we use landsat image from Satellite as explain by Salman at.al [9] and Zhan et.al [10].

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