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Land Suitability Analysis for Tropical Fruit Commodities as a Conservation Effort in Highlands Area, Indonesia

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ABSTRACT

This study aims to spatially analyze the suitability and availability of land for annual tropical fruit horticultural commodities using the criterion-weighted method. The highlands of Banjarnegara and Wonosobo Regencies, Central Java Province, Indonesia, with a total area of 93,955.60 hectares was used as the study area. The multi-criteria decision-making analysis with an analytical hierarchy process (AHP) structure was used to determine the important criteria for complex land suitability. The criteria consisted of soil great groups, elevation, land slope, rainfall, temperature, humidity, type of land use, distance to market, and road access. Meanwhile, the weight of the importance of each criterion was based on the opinions of seven experts and the results were integrated as the basis for map overlays using ArcGIS ver 10.8. The calculation of pairwise comparisons showed that the soil great groups have the highest weight in determining land suitability, with the majority of land being hapludands. Furthermore, it also showed that 32.81% of the area is suitable and available for the development of fruit areas with the largest proportion of 17.48% in the moderately suitable (S2) category.

1. INTRODUCTION

The highland area is a center for producing horticultural commodities that faces challenges such as environmental degradation and land-use competition, especially for non-agricultural purposes. Since land degradation decreases productivity, soil and water conservation efforts are also required as part of the Sustainable Development Goals (SDGs) and not just an increase in production inputs such as the use of chemicals [1, 2]. In Southeast Asian countries with tropical climates and high populations including Indonesia, agricultural areas in the highlands are converted to forest land use [3, 4]. This occurred due to the disproportionate increase in food demand with the carrying capacity of the land [5].

Currently, there is an increase in the contribution of horticultural commodities to Gross Domestic Product (GDP) in Indonesia. In 2019, at constant and current prices, the GDP increased by 5.5% and 9.2% compared to the previous year. The interest of business actors in the horticultural sector has also increased due to its quick provision of economic benefits compared to other agricultural subsectors [6, 7]. Moreover, approximately 7.3% of the country's potential agricultural land area is in the highland area, which is dominant with vegetable horticulture commodities. Although the land area is relatively small, it has an important influence on climate and geomorphological conditions. The area is characterized by (1) being at an altitude greater than 700 meters above sea level, (2) being in the vicinity of volcanic activity, (3) slope that ranges from 9 to more than 45 degrees, (4) wavy topography, hilly, mountainous, and (5) dry land type, wet climate with high rainfall. Meanwhile, the high intensity of rainfall is a factor that triggers the high rate of erosion, decreases soil productivity, and causes high sedimentation in river water [8].

As a country also known as mega biodiversity, the highlands play an important role. Meanwhile, several studies that have been carried out on highland biodiversity in the country include Javan gibbon (Hylobates moloch) [9], Malayophython reticulatus, Garcinisa dioca L, and Shorea acuminate Dyer [10]. The results showed that the decline in biodiversity is caused by a lack of vegetation, cover crops, water retaining plants, and a decrease in water catchment areas in some vegetable cultivation areas [11, 12]. Therefore, conservation needs to be carried out to maintain a balance, avoid the threat of productivity losses, and preserve the function of the highlands as a protected area downstream [13, 14].

The highlands in Banjarnegara and Wonosobo regencies are one of the largest contributors of horticulture commodities that need improvement. This is because they are erosion-prone areas and buffer water that is needed in the downstream area. Similarly, areas with high erosion sensitivity are not only sufficient with simple conservation techniques such as making ridges and gully plugs. Previous studies have suggested that increasing education and awareness reduces monoculture horticultural cultivation by planting annual fruit crops to maintain the sustainability of highland farming [15, 16].

Besides agro-technology efforts, it is important to determine land suitability to overcome land limitations and forms of conservation efforts [17]. Generally, the suitability of land for fruit commodities is accomplished by analyzing the physical properties of the land unit under the conditions of plant growth. Since the land suitability analysis involved several important factors such as biophysical, social, and economic [18, 19], therefore, a multi-criteria approach is needed in decision-making as a system approach. The method has the potential to solve complex problems and combine with various approaches [20]. Therefore, this study integrates a Multi-criteria Decision Making (MCDM) with an Analytical Hierarchy Process (AHP) approach and overlays land physical condition based on Geographical Information System (GIS). In practical terms, the combination of this methodologies would be suitable because the system of fruit production is a relatively dynamic. Proper decision-making would enhance better management which would increase the efficiencies of input. Previous researches that have integrated MCDM with GIS include analytical hierarchy process (AHP) and fuzzy AHP [21-24], TOPSIS [25], and Analytical Network Process (ANP) [17, 26].

This study aims to spatially analyze the suitability and availability of land for annual fruit horticultural commodities in the tropical highlands using the criterion-weighted method. The types of tropical fruit commodities analyzed are general and can be used as an overview for policymakers for spatial planning in highland areas, with a focus on conservation efforts. Furthermore, the characteristics of fruit commodities are adjusted to the potential of local superior fruit. The selection of mixed farming is expected to gradually solve the environmental degradation problem without reducing farm income.

2. MATERIAL AND METHOD

2.1 Study area

This study was conducted in Banjarnegara and Wonosobo Regencies, Central Java Province, Indonesia, at an altitude of more than 700 meters above sea level. The location covers 15 sub-districts with an area of 93,955.60 hectares hence the two districts contribute significantly to the adequacy of horticultural commodity needs nationally. A total of 7 sub-districts in Banjarnegara Regency and 8 sub-districts in Wonosobo are located in the highlands and have become centers of horticultural commodities. Geographically, Banjarnegara Regency is located between 7°12' - 7°31' South Latitude and 109°29' - 109°45'50" East Longitude, while Wonosobo Regency is located between 7°11' - 7°36' South Latitude and 109 °43' - 110°04' East Longitude.

2.2 Data sources

The primary data used in this study were obtained by interviewing 7 experts in weighting the criteria for land suitability for fruit commodities in the highlands. The experts can produce more suitable criteria because they have the expertise and know the specific characteristics of the study location [27]. Furthermore, the experts also come from the Directorate General of Horticulture, Center for Research and Development of Agricultural Land Resources (BBSDLP), Center for the Assessment of Agricultural Technology (BPTP) Central Java, Research Institute for Citrus and Subtropical Fruits (Balitjestro), Department of Agriculture, Fisheries and Food Security, Banjarnegara Regency, The Wonosobo Regency Food, Agriculture and Fisheries Service, and academics.

Land suitability parameters consisted of biophysical and social suitability. The biophysical criteria include soil type, altitude, land slope, rainfall, temperature, and humidity, while the social criteria include the type of land use, distance to the market, and road access. Furthermore, the secondary data in form of spatial data of soil types were from a 1:50,000 scale soil map from the Center for Research and Development of Agricultural Land Resources (BBSDLP). Spatial data on rainfall, temperature, and humidity were from the Meteorology, Climatology, and Geophysics Agency (BMKG). The topographic map was from the Geospatial Information Agency (BIG), while the land use and spatial data on spatial patterns at a scale of 1:50,000 were from the Ministry of Environment and Forestry (KLHK), and the Banjarnegara and Wonosobo District Spatial Plans (RTRW).

2.3 Data analysis

This study analyzed the suitability and availability of land for highland fruit commodities used mixed methods research (quantitative and qualitative). Each element of the criteria for biophysical and social parameters was measured with a score of 0-10 based on the level of importance. The land suitability was analyzed using a Multi-Criteria Decision Making (MCDM) with Analytical Hierarchy Process (AHP) method followed by map overlay with ArcGIS ver 10.8. This method describes the priority of dominating and being dominated by pairwise comparisons between criteria elements in form of a matrix. The scale used was 1-9, where 1 indicates that a criteria element is as important as the other elements, while a scale of 9 shows that an element is more important than others [28]. Furthermore, the examination of 7 experts was assessed for consistency and combined using a geometric mean, where the value of the Random index (RI) of all criteria is 1.45. The consistency ratio (CR) value is valid when it is not more than 0.10 (10%). The geometric mean based on the following equation:

$$\bar{X}_{G} = \sqrt[n]{\pi^{n} X_{i}} \tag{1}$$

where, $\bar{X}_G$ = geometric mean, n = number of expert, X_i = scoring from i-expert.

The weighted score of each criteria element and pairwise comparison assessment was used to overlay the map and obtain a GIS model of land suitability for fruit commodities. Land suitability class is categorized into very suitable (S1), moderately suitable (S2), marginally suitable (S3), and not suitable (N) based on the equation below [22]:

$$S = \sum_{i=1}^{n} w_i x_i \tag{2}$$

where, S = 1 and suitability, w_i = weight of land suitability criteria, x_i = sub-criteria score, and n = number of land suitability criteria

In the analysis, there is a need to identify constrained land uses because it is not used for cultivating agricultural commodities. These areas include water bodies, escarpments, rock outcrops, and residential areas. Meanwhile, existing land uses that are considered for the development of fruit areas are dryland agricultural areas and rice fields that have not been used optimally. The overlaying of land suitability for fruit commodities in the highlands with the availability of land makes land available and suitable for the development of fruit commodities. The data analysis process is shown in Figure 1.

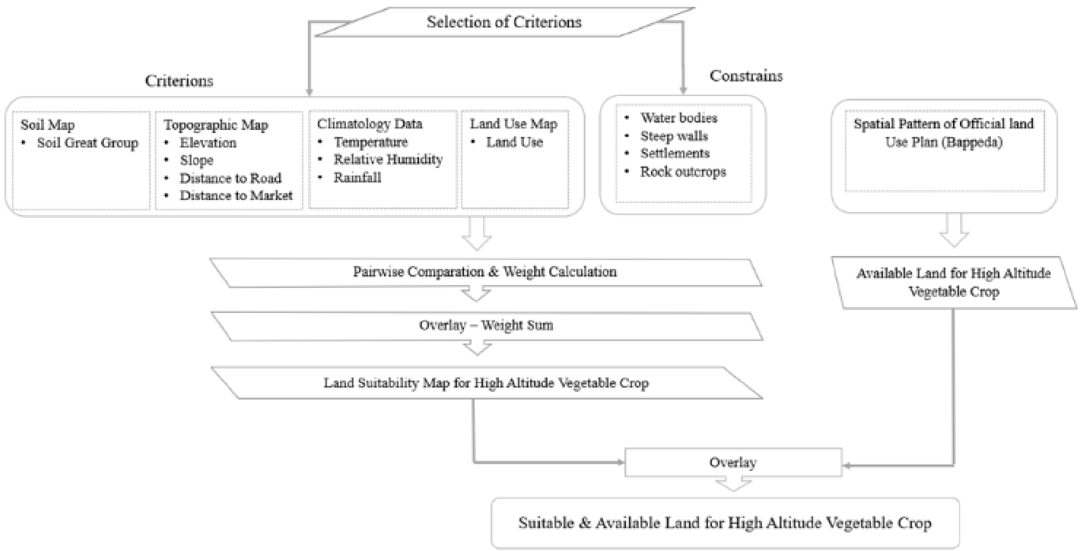


Figure 1. Data analysis process on the suitability and availability of fruit commodity land

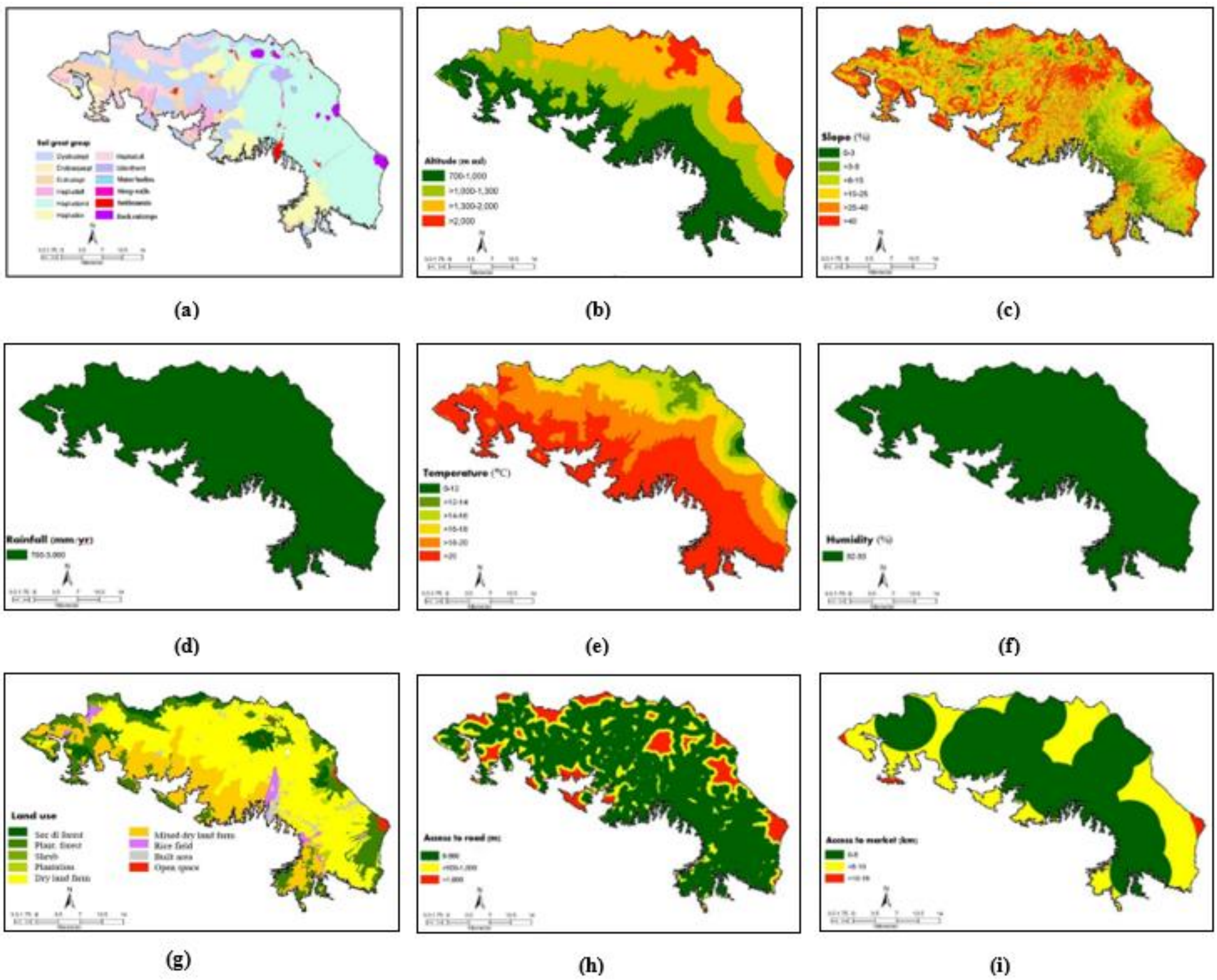


Figure 2. Spatial distribution: (a) soil type, (b) altitude, (c) slope, (d) rainfall, (e) temperature, (f) humidity, (g) land use, (h) access to road and (i) access to market

3. RESULTS AND DISCUSSION

3.1 The weight of the criteria and characteristics of the study area

The weight distribution of each criterion on biophysical and social parameters for land suitability for fruit commodities in the highlands is presented in Table 1, while the spatial distribution is shown in Figure 2. The soil type in an area affects farm productivity, which directly or indirectly influences environmental sustainability [29]. Indonesia has a diversity of soil orders, which is indicated by the discovery of 10 out of the 12 orders in the world. The soil orders that are not in the country are Aridisols which characterize very dry climate areas, and Gelisols in areas of extreme cold conditions [30]. The study location with a total area of 93,550.60 hectares has 6 soil orders, which are Andisols, Inceptisols, Alfisols, Oxisols, Ultisols, and Entisols. The categories of soil great groups include Hapludands, Hapludalfs, Dystrudepts, Endoaqupets, Eutrudepts, Hapludults, Hapludoxs, and Udorthents. Meanwhile, the hapludands are the dominant group, with an area of 44.57% of the total highland area or approximately 41,880.12 hectares.

In the highland area, most of the soil types are fertile for the development of agricultural areas because they contain volcanic ash and good hydrological conditions. Therefore, the expert gave the highest score of 10 for the soil great group Hapludans, followed by Dystrudepts (19.56%) and Hapludoxs (15.27%). Dystrudepts belong to the order Inceptisols and Eutrudepts, with a weighted score of 8 for the suitability of fruit commodities with soil characteristics from albic materials and high fertility. The same score was also given to the soil great groups Endoaquents which were alluvial gleic and had the smallest area, while the lowest score of 3 was given to the soil great groups, Udorthents. This soil belongs to the order Entisols, which developed from young alluvium with a layered arrangement and an irregular organic C content [30].

Table 1. Distribution of sub-criteria weights and their extent in the Central Java highlands

Criteria	Subcriteria	Expert's Score	Area (ha)	(%)
Soil taxonomy	Hapludands	10	41,880.12	44.57
(Soil great group)	Hapludalfs	9	2,815.50	3.00
	Dystrudepts	8	18,376.28	19.56
	Endoaquents	8	27.92	0.03
	Eutrudepts	8	7,056.87	7.51
	Hapludults	5	6,320.83	6.73
	Hapludoxs	4	14,345.37	15.27
	Udorthents	3	845.96	0.90
	Konstrain	0	2,287.01	2.42
Altitude (m. asl)	700-1000	10	37,917.16	40.36
	>1000-1300	6	26,061.36	27.74
	>1300-2000	4	24,957.89	26.56
	>2000	0	5,019.19	5.34
Slope (%)	<3	10	2,180.62	2.32
	>3-8	9	9,511.70	10.12
	>8-15	7	19,997.36	21.28
	>15-25	6	25,253.32	26.88
	>25-40	4	22,744.98	24.21
	>40	3	14,267.62	15.19
Rainfall (mm. yr^{-1})	700-3000	10	93,955.60	100.00
	>3000	5	0	0
Temperature (°C)	8-12	1	775.64	0.83
	>12-14	5	3,307.40	3.52
	>14-16	7	6,949.01	7.40
	>16-18	10	13,796.72	14.68
	>18-20	8	26,055.05	27.73
	>20-23	6	43,071.78	45.84
Humidity (%)	82-83	10	93,955.60	100.00
	>83-84	8	0	0
	>84-85	6	0	0
Land use	Secondary dry land forest	8	4,275.45	4.55
	Plantation forest	8	17,772.45	18.92
	Built area	0	2,024.57	2.15
	Dry land farm	10	46,078.48	49.04
	Mixed dry land farm	10	20,118.45	21.41
	Water body	0	0	0
	Plantation	4	584.36	0.62
	Rice field	2	2,024.06	2.15
	Shrub	8	538.84	0.57
	Open field	8	538.96	0.57
Access to the road (meters)	0-500	10	69,939.34	74.44
	>500-1000	8	15,231.73	16.21
	>1000	6	8,784.53	9.35
Access to market (kilometers)	0-5	10	62,339.41	66.35
	>5-10	8	30,743.29	32.72
	>10-15	7	872.90	0.93
	>15	5	0	0

Moreover, the altitude of the area affected other natural conditions such as temperature, humidity, light capture, and types of vegetation. Changes in light intensity in the highlands also caused a decrease in temperature and an increase in humidity. There is also a linear relationship between the altitude of the area and the level of fertility, where the extremely high areas have the quality of the land decreased sharply, causing difficulty in plants productivity [31]. The communities in the highlands also have local knowledge of using plant residues in form of weeds and crop residues in the soil. The residue is useful as organic fertilizer in conjunction with manure to increase soil fertility.

The results showed that 40.36% of the study area was at an altitude of 700-1000 masl with the majority of vegetable cultivation and was given a score of 10 for the development of fruit commodities. The height factor that affects the decrease in productivity of fruit plants caused a weight reduction. Approximately 26.68% of the study area is on a slope of more than 15 to 5%, which was included in the moderately steep category, while the next largest area was in steep and sloping conditions.

Generally, the development of agricultural areas is expected to be optimum in areas with flat to gentle slopes because the management of land with high slopes requires greater technical operational costs and mechanization. The efforts to plant landslide-resistant plants were also carried out, especially with Lamtoro or hedge plants, but in minimal quantities. Meanwhile, annual fruit crops can be recommended as landslide-resisting plants. Experts gave the highest score weight for the development of fruit in areas with a slope of less than 3%.

Indonesia is a tropical country with rainy and dry seasons which makes it suitable for developing endemic fruit commodities that are not grown in non-tropical countries. The characteristics of the highlands in tropical countries include high air humidity and rainfall. Since the study area has a rainfall intensity of 700 to 3,000 mm/year, which is ideal for the cultivation of horticultural commodities, it was given a score of 10. Meanwhile, rainfall with an intensity of more than 3000 mm/year was given a lower score of 5 because the plants require more intensive handling such as pesticide spraying.

The relatively steep slope with high rainfall caused the soil layer to be easily carried away by the flow of water, which has an impact on fertility. The temperature is a climatic factor that has an important effect on plant growth. The optimum temperature for the cultivation of fruit commodities is 16 to 18°C, which makes the expert give a score of 10. A score of 8 was also given for areas with temperatures over 18 to 20°C. Although lower or higher temperatures can still be tolerated by plants, their productivity and fruit size are likely to be smaller.

Wet climatic conditions in the highlands lead to a uniqueness that is not in other highlands in Indonesia. During the dry season around July and August, the air temperature reaches almost 0 to -8°C, and condensed ice crystals are discovered or in the local language called "embun upas". A previous study has shown that several efforts are needed on the management of soil nutrients due to the low temperature that inhibits metabolism and nutrient absorption [31]. In this study, the location has a homogeneous air humidity ranging from 82 to 83%, which is optimum for the development of fruit areas, therefore, a score of 10 was given. The climate change parameters with a significant effect on the decrease in plant productivity are the unpredictable changes in rainfall patterns and high temperatures. In some fruit commodities, humidity and air temperature that changes sharply affect the quality of pollen in the flowering process. The explosion of pest populations due to climate change and the adaptability of fruit crops has also affected the development of fruit areas [32, 33].

The most dominant area is dry land, where the main commodity is vegetables. Therefore, the annual fruit development area is an alternative to landslide prevention on land with high slopes. In this study, a score of 10 was given by the expert on real and mixed dry lands suitable for the cultivation of fruit commodities. This was followed by a score of 8 given to secondary dryland and plantation forests, open land, and shrubs that were not yet optimally covered with annual fruit plants as a landslide barrier. Since land with a high slope has a high erosion rate, plants with deep root systems are expected to be a solution for landslides that often occur.

Access roads to tourist areas in the northern Dieng Plateau are relatively good and adequate. In this study, a score of 10 was given by the expert for village road and market access, which is closest and can be passed by transport vehicles. The perishable nature of horticultural products required fast handling, therefore, adequate access is expected to reduce transportation costs for marketing [34]. A total of 74.44% of agricultural land in the highlands has a distance of 0-500 meters from road access. The distance from the land to the market was also relatively close, with 66.35% located less than five kilometers to the nearest sub-district market. Farmers preferred to rent agricultural land with close access to roads, even though it is the highest transaction cost in their farming business.

3.2 Comparison of the importance of criteria elements

The Consistency Ratio (CR) value from the pairwise comparisons as shown in Table 2 is 0.089. This value showed the consistency of the expert's answers and the validity of the results because it has a value of 0.1. Furthermore, soil great groups have the highest weight since they are related to land productivity and as a determinant of erosion rate besides height and slope. This is supported by the previous study which stated that land in the Andisols order is more easily degraded and has an effect on methanogenesis [35, 36].

Meanwhile, the land height and slope are the criteria with the next highest weight. Local knowledge of farmers to overcome the relatively high slope contributes more to the manufacturing of terraces.

At the study location, at least 5 types of terraces were discovered, these include permanent and non-permanent bench terraces, drain, strip weed, and ridges Farmers carry out conservation efforts to remove the excess water that inundates the land during the rainy season.According to Sen et al. [37], the majority of farmers use ground cover mulch as the most popular form of adaptation to climate change. Meanwhile, limited farming capital and knowledge of small and medium-scale farmers were also obstacles to the implementation of climate change adaptation [38].

Rainfall is the fourth important factor and was included in the high category with an intensity of 230 rainy days per year. Highland areas with steep slopes, high rainfall, and dominant vegetables as vegetation require conservation efforts by planting annual fruit commodities to withstand the rainwater rate and minimize the soil movement that triggers landslides.

Climate change affects the inconsistency of the vegetation response caused by each climate parameter. Although there are very sensitive vegetations against extreme rainfall and humidity, some were still sensitive to temperature and the length of the dry season [39]. The rainfall and humidity in the study area which is a plateau of more than 700 masl are homogeneous. Environmental factors related to soil fertility, rainfall, temperature, humidity, and physical form of land are difficult for humans to change in a short time, however, soil quality can be gradually improved by changing plant habitats and building terraces [40].

Land use, distance to market, and access to the road are the three lowest elements because the study area is mostly dryland agriculture and mixed dry land as a cultivation area. The northern part is a tourism and cultural conservation area, therefore, access to roads and markets is adequate. At several points, problems with the quality of road infrastructure were encountered due to extreme rainfall. Improvements and construction of farm road infrastructure, apart from receiving financial assistance from the government, are often carried out in cooperation with the community.

3.3 Land suitability and availability for the development of highland fruit commodities

The results of the land suitability map overlay for highland fruit commodities with the availability of land from the spatial planning map of the Banjarnegara and Wonosobo Regencies are shown in Figure 3 and clarified by Table 3. The majority of land in the study area is in the S2 category (moderately suitable) for fruit area development by 42.26%, which showed that the land has severe limiting factors for sustainable land use. The limiting factor encountered is the hazard of erosion due to the high slope level and the undulating to the hilly topography. The development of annual fruit commodities in locations are is of the efforts to minimize erosion, however, these limiting factors can reduce productivity because it requires additional farming inputs.

Furthermore, marginally suitable (S3) and highly suitable (S1) classes were 25.57% and 18.17% of the total area, respectively. Most of the highlands are also at temperatures above 18℃, while the most suitable temperature for the growth of annual fruit plants in tropical climates is 16-18℃. A previous study has shown that perennial species are more resistant to climate change [41]. The characteristics of climate change indicated by extreme rainfall often damage plants that are more susceptible to high humidity and long droughts. Meanwhile, the inappropriate of the land is due to its location in a conservation area with an altitude of more than 2,000 meters above sea level and a slope of more than 40%. Water bodies and rock outcrops were also included in the constraints that are not in the development potential analysis.

Based on Table 3, a total of 63.76% of the land is not available for fruit area development. The unavailable land includes forest, plantation, and built-up areas that cannot be converted. The results showed that the land conditions are in various categories with the majority 17.48% of land in the S2 (moderately suitable) category were suitable and available for fruit area development. The forests in the north of the study area which are included in the Dieng Plateau have not been fully converted into conservation forests. In regulations, forests located at an altitude of more than 1000 masl are used for water storage and erosion prevention [42]. However, only part of the upper reaches of the Serayu River, the Telaga Warna area, and the Hindu Temple area is designated as nature and cultural reserves.

According to Mucharam et al. [43], the implementation of sustainable regional development requires the collaboration of local and central government authorities. Site-specific planning can be developed to a wider level with adaptation, especially to the characteristics of areas that have similarities. Meanwhile, several studies on economic aspects of conservation efforts in sustainable land management suggested the provision of incentives to farming households [35, 44]. This is used as a stimulus to replace the decrease in income at the beginning of adaptation to changes in farming behavior.

Table 2. The results of pairwise comparisons of land suitability criteria for fruit commodities in the highlands

Criteria A	Criteria B									
	SGG	ALT	SLP	RF	TEM	RH	LU	MD	RD	Skor
SGG	1	2	2	5	5	6	7	8	9	0.279
ALT	1/2	1	4	5	5	6	7	7	8	0.268
SLP	1/2	1/4	1	4	4	5	5	7	8	0.170
RF	1/5	1/5	1/4	1	3	4	5	6	7	0.102
TEM	1/5	1/5	1/4	1/3	1	3	4	5	6	0.070
RH	1/6	1/6	1/5	1/4	1/3	1	3	4	5	0.046
LU	1/7	1/7	1/5	1/5	1/4	1/3	1	2	3	0.028
MD	1/8	1/7	1/7	1/6	1/5	1/4	1/2	1	2	0.021
RD	1/9	1/8	1/8	1/7	1/6	1/5	1/3	1/2	1	0.016

SGG: soil great groups; ALT: altitude; SLP: slope; RF: rain fall; TEM: temperature; RH: relative humidity; LU: land use; MD: markets' distance; RD: roads' distance

Consistency vector (p): 10.029

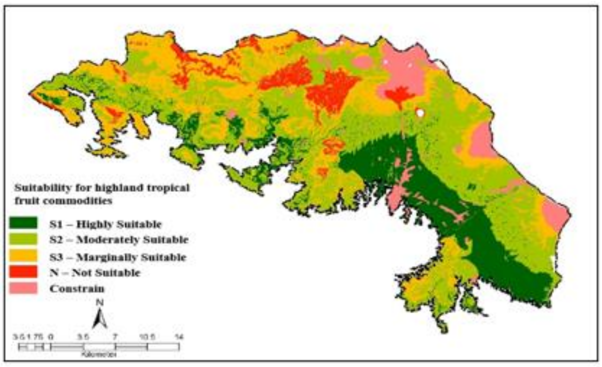
Consistency index (CI): (p-n) / (n-1) = (10,029 - 9) / 8 = 0.129

Random index (RI): 1.45

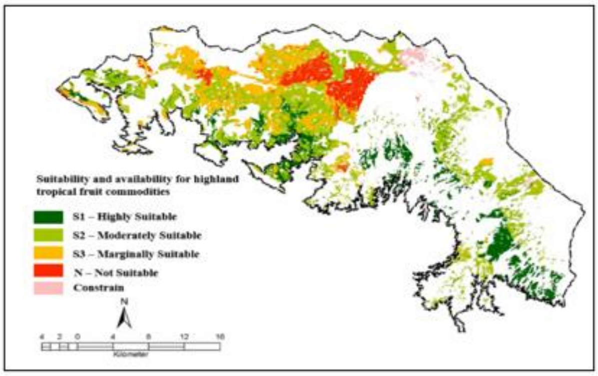
Consistency ratio (CR): CI / RI = 0.089≤ 0.10

Table 3. Land suitability and availability for the development of tropical fruit commodities

Suitability Class	Area of Fruit Crops		Suitability and Availability Area	
	ha	%	ha	%
S1-Highly Suitable	17,071.08	18.17	6,202.89	6.60
S2 (Moderately)	39,701.59	42.26	16,20.87	17.48
S3 (Marginally)	24,021.03	25.57	8,205.2	8.73
N (Not Suitable)	5,493.78	5.85	3,187	3.39
Constrain	7,668.12	8.15	30.96	0.03
Not Available			59,908.68	63.76
Total	**93,955.60**	**100**	**93,955.6**	**100**



a



b

Figure 3. Map of analysis results: (a) land suitability for highland fruit commodities; (b) land suitability and availability for highland tropical fruit commodities

4. CONCLUSION

The tropical highland characterized by high slopes and hilly topography is prone to erosion hazards. Therefore, spatial planning and land management in highland areas need to focus on conservation efforts. Vegetable horticultural cropping pattern as the main commodity in the area tends to be a monoculture, causing a decline in biodiversity, there is a need to integrate annual fruit plants. In addition to the agrotechnology efforts, it is required to determine land suitability as an important prerequisite for land use.

In this study, land suitability parameters used include biophysical and social parameters. The results of pairwise comparisons based on multi-criteria decision-making showed that the soil great group is the most important criterion as a determinant of land suitability. Furthermore, the spatially integrated analysis showed that most of the land in the highlands is in the moderately suitable category (S2) for the development of fruit areas. The total area of land available and in various categories from highly suitable (S1) to marginally suitable (S3), while the land category that is not suitable (N) has the smallest proportion.

This result is expected to be a strategic material for the formulation of land use policies that focus on conservation efforts to achieve sustainability. The determination of land suitability is the first step in minimizing the hereditary habits of farmers when cultivating agricultural commodities without considering environmental aspects. Furthermore, the use of biophysical and social parameters needs to be complemented by economic parameters which often lead to the exploitation of natural resources without considering the carrying capacity of the environment. Collaboration between the central and local governments, researchers, academics, financial institutions, the private sector, and local communities is also needed to change the orientation of farmers. Gradual efforts are needed comprehensively to develop local potential as a regional advantage for the highlands to become a source of production and also environmental education.

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