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GIS-AHP-Based Land Suitability Analysis for Abaca (*Musa textilis*) Production in Sorsogon, Philippines

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Abstract

Historically, Sorsogon has been among the top Abaca producers in the country, but production has recently declined, necessitating a multi-sectoral approach to optimize current production. In the context of land and crop suitability, this study assessed the capability of Sorsogon's agricultural areas to sustain and maximize Abaca production. A suitability map was developed using the BSWM nomenclature (S1 – highly suitable; S2 – moderately suitable; S3 – marginally suitable; and Not Suitable) and informed by a literature review, expert opinion, and multi-criteria analysis. AHP and GIS were used to produce a weighted suitability map that considered soils, topography, climate, vegetation, and economic and social factors. Economic, social, and soil aspects received weights of 27, 25, and 24 points, respectively, all significantly affecting area suitability. Given government support in the province and favorable environmental factors, about 69.06% of the 188,614 ha study area is classified as moderately to highly suitable (S1 = 42.85%; S2 = 26.21%). Areas classified as marginally unsuitable are characterized by sand and clay soils and steep slopes of 50% or more. Using Multi-Criteria Decision Making (MCDM) methods, the production's environmental, biological, and technological aspects were accounted for, and Sorsogon was found to be an ideal area for Abaca production, corroborating the government's intended land use for the area.

***Keywords**:* agriculture, Bicol region, future fibers, Manila hemp, multiple criteria decision making

1. Introduction

Abaca (*M. textilis*) is an important crop with many potentials. With the growing concern for addressing the United Nation's Sustainable Development Goals, particularly SDG 15, pollution, and deforestation, Abaca fibers could be a good replacement for fossil fuel-based materials (Berglund *et al*., 2019) and as a component of composites (Seculi *et al*., 2023). It could also be used as a renewable bio-resource for various industrial or extra-industrial applications due to the characteristics of its fibers (Armecin *et al*., 2014; Shahri *et al*., 2014).

The Philippines is the world's leading supplier of Abaca, dominating the global trade by providing approximately 87.5% of the world's Abaca fiber requirements (Business Mirror, 2020; Department of Agriculture (DA), Philippine Abaca Industry Road Map (2018-2022), 2021). According to a report from the Philippine Statistics Authority (PSA), the Bicol Region was the top producer in the country, accounting for about 43.7% (8.71 thousand metric tons) of the national output from July to September 2020 (PSA, 2020). This significant contribution is largely due to the high production levels in Catanduanes, the leading Abaca-producing province in the Philippines (Berglund *et al*., 2019). However, these achievements are at risk of being undermined by inefficient production activities, natural calamities, and diminishing resources allocated to the industry.

Despite the country and region being top producers, the industry is still unable to meet market demands (Berglund *et al*., 2019). With the current seedling production capacity, there is a deficit of 146.28 million planting materials (DA, Philippine Abaca Industry Road Map (2018-2022), 2021). This deficit necessitates aggressive interventions to strengthen the position of Philippine Abaca in global trade, as outlined in the Philippine Abaca Industry Roadmap.

The Abaca production sector requires support to meet global market demands. Beyond volume requirements, Philippine Abaca's quality is deteriorating and needs urgent attention. According to Glatfelter, the world's largest specialty paper manufacturer, the quality of fiber from the Philippines has declined compared to that from Ecuador and Costa Rica (as cited in Department of Agriculture Philippine Fiber Industry Development Authority [DA-PhilFIDA], 2021, p. xi). This decline can be attributed to several factors, including production management (Bande *et al*., 2013), processing, and grading standards (Richter *et al*., 2013). Moreover, the morphological and physiological performance of Abaca is influenced by multiple factors: the type of planting materials used, particularly those that exhibit fast root system recovery and increased leaf emergence rates, such as tissue-cultured seedlings (Obmerga, 2014; Aspuria & Garcia, 2018); plant nutrition; climatic and environmental factors, including strong winds and pests (Fernandez & Sabay, 2016); water availability during planting; and farm management and practices (Bande, 2004). Recognizing these challenges, the province of Sorsogon established the Sorsogon Abaca Industry Council (SAIDC) through Provincial Ordinance No.11-2017 to address these issues and promote the sustainability of the Abaca industry (PhilFIDA, Abaca Tuxy Buying Special Project Facebook page, 2018).

To address the declining relevance of the Abaca industry, a multi-faceted intervention, particularly in production, is essential for sustainability. One approach is to increase production through expansion and the adoption of better management practices. Identifying potential areas for expansion requires considering significant factors affecting production, particularly land suitability. Agricultural land suitability analysis for crop production is a critical tool for ensuring sustainable agriculture (Akpoti *et al*., 2019). In response, the Department of Agriculture launched the national color-coded guide map in 2017, providing Philippine farmers with a web-based guide for land and crop suitability for specific locations (DA, National Color-Coded Guide Map, n.d.). This guide covers major agricultural areas in the country. However, even the most widely used land and crop suitability maps may diminish in relevance over time, especially in the face of rapid global changes (Peter *et al*., 2020). Factors such as climate change and other human activities can also impact these maps' effectiveness (Abd-Elmabod *et al*., 2020; International Fund for Agricultural Development, 2021).

Land suitability assessments are usually conducted by matching the crop's ecological requirements with the limiting factors of the natural environment (Gross, 2014; Bato, 2018; Verheye *et al*., n. d.). This involves gathering data through remote sensing and on-site evaluations assessing spatial environmental datasets then comparing it with crop requirements through GIS. Also, a mechanistic approach for suitability scoring uses fuzzy sets (Ramirez-Villegas *et al*., 2013) and is also applied to crop growth models using the law of minimum (Paris, 1992).

By using this methodology, new sites may be identified for Abaca expansion that has higher return potential. This will boost the local industry due to its rippling effects which may start from mass production of seedling materials using the SorSU-Castilla tissue culture laboratory to the influx of investors that may help to uplift the local economy. Therefore, this study aimed to generate and apply agricultural land suitability indices using Multiple Criteria Decision-Making Methods for Abaca Production in the Province of Sorsogon.

The results will be used in the preparation of a Suitability Map which will inform possible investors and decision-makers on the allocation of resources for sustainability.

2. Methodology

2.1 Study Area

The study was conducted in Sorsogon, Philippines, located at the southernmost tip of Luzon, one of the three major island groups in the northern part of the country (Figure 1). The province extends westward from 123° to 124° east longitude and from 12° to 13° north latitude. Although the area frequently experiences typhoons, it generally enjoys a favorable tropical climate with significant rainfall that is evenly distributed throughout the year. Even April, the driest month, has a 30-year rainfall average of 171.2 mm. A major portion of the agricultural crop production areas is dedicated to coconut farming, with sparse intercropping. These areas present potential opportunities for Abaca production, as Abaca is highly suitable for intercropping with coconut and could be used for expanding production (Secretaria *et al.*, 2012).

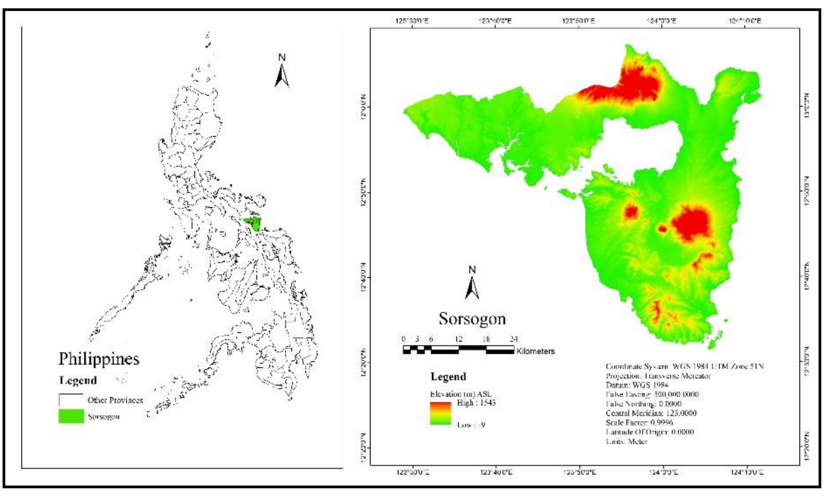

Figure 1. Location of the study (Sorsogon, Philippines)

2.2 Data Gathering

2.2.1 Selection of Variables Significant to Abaca Production

Attributes of the study area that affect Abaca suitability were identified (Table 1). Literature review and expert/stakeholder inputs were utilized in the study. Initial attributes were taken from the literature review. It included environmental parameters for soil (soil properties, topography, climate), biological (vegetation and land cover), and technological aspects (skills, economics, government support). Expert inputs on main and sub-variables were considered to allow the inclusion of other variables. The methodology employed allowed for soil evaluation (Dorronsoro, 2022) and the consideration of people's needs (Lech & Leppert, 2018). The social and economic aspects of land use were also important for sustainability (Llanto & Ballesteros, 2003; Nzubda *et al.*, 2013; Malmir *et al.*, 2016).

Table 1. Environmental, biological, and technological parameters including sub-criteria identified through literature and expert interviews affecting Abaca production suitability

Main and Sub criteria	Ideal condition/s	Reference
Soil Texture Depth Fertility	Clay loam to sandy clay loam	Philippine Fiber industry Techno guide (PhilFIDA, 2016) Expert input
Topography Elevation Slope	plains to slightly rolling to hilly or mountainous areas, Less than 1000m ASL	Abaca Sustainability Manual (PhilFIDA & GIZ, 2016)
Climate Type Temperature Rainfall	Type IV 20 to 25 degrees Celsius Evenly distributed (temporal and spatial) 1800 mm to 2500 mm annual rainfall	Philippine Fiber industry Techno guide (PhilFIDA, 2016) (Gutierrez *et al.*, 2022)
Vegetation Tree height Diversity Forest stand	40 to 50% shading away from corn and legumes, or under coconut trees with at least 10 m spacing	Abaca Sustainability Manual (PhilFIDA and GIZ, 2016) and (PNS /BAFS, 2019)
Economics Financial Aspect Access to market Availability of inputs	Presence of coops, traders, grading and balling establishments and processors	Abaca Sustainability Manual (PhilFIDA & GIZ, 2016) Expert input

Table 1. continued.

Social Criteria Organized enterprise Farmer's skills Labor availability Access to information Government support	The presence of these production support services and inputs	Expert input

Note: GIZ = Deutsche Gesellschaft für Internationale Zusammenarbeit; PNS/BAFS = Philippine National Standards/Bureau of Agriculture and Fisheries Standards

Using the initial attributes, a two-stage survey was conducted with a pre-validated set of questionnaires. The first survey was done online with industry experts and practitioners. Additional attributes including sub–variables for each main variable were determined. Participants in the survey are as shown in Table 2 and Table 3.

Table 2. Initial (online) survey respondents

Participants from	Number of Participants
Philippine Fiber Industry (PhilFIDA)	1
Department of Agriculture (Provincial Office)	4
Department of Agriculture (Municipal)	1
Local Government Unit	1
Academe	4
Abaca Farmer	4

Table 3. Respondents on the final survey questionnaire (Matrix comparison of Abaca production variables) from the province of Sorsogon, Philippines

Office of the Municipal/City Agriculturist	Number of Participants
Barcelona	6
Bulusan	5
Casiguran	6
Castilla	5
Gubat	1
Irosin	5
Juban	3
Sorsogon city	1

The results of the initial survey were used to create a pairwise comparison of variables. Given that the Analytic Hierarchy Process (AHP) is suitable for both small groups (3 respondents) and large groups, its effectiveness relied on the availability of experts (Melillo & Pecchia, 2016). Given the absence of a rigid, standardized protocol for sample size and expert selection within Analytic Hierarchy Process (AHP) literature (Guillén-Mena *et al.*, 2023), a purposive sampling approach was employed to select key informants from the Abaca industry. Participants were selected based on domain expertise through their current professional roles, practical experience, and academic backgrounds (Saaty, 1994). Thirty-two (32) respondents from various Abaca-producing municipalities in Sorsogon, who were directly engaged in production, were interviewed. Approximately 50% of these respondents had more than 20 years of experience in agriculture, while the remainder had between 0 to 20 years of experience, evenly distributed. Additionally, 50% of the respondents were involved with or affiliated with PhilFIDA projects (Table 3).

2.2.2 Gathering of Data on Selected Production Variables

Spatial and temporal data such as soil, climate/micro-climate, topography, and other parameters were taken from various sources (Table 4) such as the Department of Science and Technology – Philippine Atmospheric, Geophysical and Astronomical Services Administration (DOST-PAGASA), National Mapping and Resource Administration Authority (NAMRIA), Department of Agriculture – Bureau of Soils and Water Management (DA-BSWM), DA – Bureau of Agricultural Research (DA-BAR), Central Luzon State University (CLSU) – GIS Center, and other online resources such as... Google Earth Engines including National Aeronautics and Space Administration - Earth Observing System and Data Information System (NASA EOSDIS) generated files were utilized to prepare accurate data for the study. PhilFIDA manuals were used as references for crop ecological parameters, aside from expert opinions and literature review.

Table 4. Data sets used in the study

Criteria	Source	Data format
Soils (texture, depth, fertility)		
texture	PhilGIS-BSWM	Rasterized
Topography		
Slope	Digital Elevation Model https://lipad.dream.upd.edu.ph/	Original data
Elevation	Digital Elevation Model https://lipad.dream.upd.edu.ph/	Original data
Climate		
type	PAGASA	Digitized
Rainfall	PAGASA	Climate description
Temperature	Weather Spark (n. d.)	Digitized into municipal map vector file

Table 4. continued.

Vegetation (tree ht., diversity, Forest stand, land Cover	PhilGIS-BSWM with Google Earth	Reclassification with reference to land cover
Economics		
Financial capability of farmers	Local Government Units	Digitized into municipal map vector file
Accessibility of equipment	Local Government Units	Digitized into municipal map vector file
Availability of farm inputs	Local Government Units	Digitized into municipal map vector file
Social Criteria		
Organized Enterprise	Directory of licensed Fiber stakeholders (2020-2021) - PhilFIDA	Digitized into municipal map shapefile
Farmer skills	Directory of licensed Fiber stakeholders (2020-2021)	Digitized into municipal map vector file
Availability of labor		
Access to information/Extension services	LGU website/office	Digitized into municipal map vector file
LGU/Govt support	Provincial government - LGU website/office	Digitized into municipal map vector file

2.3 Determination of Weight/Scores for Suitability Indicators

Given the complexity of determining weights/scores for each parameter, a multi-criteria decision-making tool was used. Weights were determined using AHP which is widely used in management decision-making processes (Saleshi *et al*., 2016). It is a “mathematical tool of problem-solving” (Juneja, 2021) that could be used for multiple criteria or alternative solutions to a problem.

Weights for each criterion were computed using the AHP method (Saaty, 1980; 2008) using the survey results. Tests of consistency for collected data were done to validate the compatibility and rationality between compared criteria (Herzberg *et al*., 2019).

2.3.1 Testing of Data Consistency

Collected data was tested for consistency using the methods of Saaty (2008). Consistency indices (CI) were determined as inputs for the computation of the Consistency Ratio (CR) (Equation 1) which indicates whether responses were reliable or not. These were done using MS Excel functionalities.

$$CR = \frac{CI}{RI} \tag{1}$$

Where CR is the Consistency Ratio; CI is the Consistency index computed based on the AHP process and the number of variables, and RI is a random index as shown in Table 5.

Table 5. Random Indices based on the number of criteria used in AHP. Values based on Mu and Pereyra-Rojas (2017)

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Accordingly, if $CR \leq 0.1$ the results of the criteria weight assignments can be used as recommended by Saaty (Herzberg *et al.*, 2019). Values that are greater than 0.1 have to be accepted sometimes for higher-order matrices (Pant *et al.*, 2022), but values 0.9 and above should be rejected as it indicate inconsistency of results (Coyle, 2004; Balash *et al.*, 2017).

2.4 Data Preparation and Processing

2.4.1 Data Preparation

Since values of the attributes differ in ranges and units, there is a need to re-classify the indicators. This will allow the comparison of input raster datasets by converting them into a common scale (Vafaei *et al.*, 2016; Lange, 2020) from minimum to maximum concerning a given criterion (Malczewski, 1996) for GIS Aided mapping (Mugiyo *et al.*, 2021). Parameters that are suitable for Abaca production are given the higher number and vice versa. A six-level classification was selected in which the value of zero (0) was assigned to the least favorable indicator and five (5) to the most favorable. This scale corresponds to the number of slope classifications by BSWM of the Philippines (Galido-Isorena, 2011) which are: 0%-3% (level to nearly level); 3%-8% (gently sloping to undulating); 8%-18%; Undulating to rolling; 18%-30% (rolling to moderately steep); 30% - 50% (steep) and over 50% (very steep). In cases wherein ideal parameters indicated two conditions such as in soil type, the maximum value was assigned to both and evenly distributed to zero towards the least favorable factor (Table 6). For indicators which the scale is not equal, it was customized to the same scale level as done by Yalew *et al*. (2016). This was done for all the attributes.

For the climate data, since ideal growing condition is at type IV climate, the maximum value of 5 is assigned to type IV, 3 for type III, and 0 for type II. And for rainfall, an even distribution throughout the year is ideal which is indicated for type IV climate according to the Philippine classification system. This is equivalent to the same rating as for the climatic type.

Table 6. Reclassified values for soil texture used in re-classification. The ideal soil texture is sandy clay loam to clay loam (PhilFIDA, 2016)

Soil Texture	Reclassified attribute values
Sand	0
Loamy sand	1
Sandy loam	2
Loam	3
Silt loam	3
Silt	4
Sandy clay loam	5
Clay loam	5
Silty clay loam	4
Sandy clay	3
Silty clay	1
Clay	0

Land cover values were standardized to have the same scale values as the other inputs (Table 7). For this, all that are considered to be non-convertible for Abaca plantation was assigned with a value of zero (0).

Table 7. Reclassified values for land cover (Ideal vegetation is 40 to 50% shading, or under coconut trees away from corn and legumes) (PhilFIDA & GIZ, 2016)

Land Cover/Shading	Reclassified attribute value
Crop land mixed with coconut plantation	4
Cultivated Area mixed with brushland/grassland	3
Open canopy mature trees covering <50%	5
Closed canopy mature trees covering >50%	3
Coconut plantations	5
Arable land, crops mainly cereals and sugar	2
Fishponds derived from Mangrove, mangrove vegetation, Built-up areas, coral reefs, and Siltation pattern in lake	0

2.4.2 Data Processing

GIS and remote sensing play a crucial role in environmental study (Bouwmeester *et al.*, 2010), monitoring, and remediation (Pascual *et al.*, 2023), and can be applied to a wide range of purposes (Abdullah *et al.*, 2011), such as land use/land cover classification and land suitability studies. Data gathered were processed and converted into formats suitable for analysis.

Notably, GIS-based maps serve as one of the most important sources for spatial analysis (Jain & Subbaiah, 2007). For this study, each parameter was rasterized (30 m × 30 m) to provide a representative value for each overlay. Map algebra using raster calculator was then employed to determine the suitability rating, with computed weights assigned to each parameter, resulting in the creation of a suitability map as shown in Equation 2.

$$lvl\ 1\ rating = \sum_{i=1}^{n}[lvl\ 2\ criteria\ att.value\ x\ lvl\ 2\ criteria\ weight]_i \quad (2)$$

Where lvl 1 rating is the level 1 suitability rating for the main criteria (0 – 5); lvl 2 criteria attribute value is the reclassified value of the attribute for the level 2 criteria (0 – 5), and $lvl\ 2\ criteria\ weight$ is the weight of the level 2 criteria as determined in AHP

Each sub-level classification was accounted for by multiplying the reclassified rating by the weight of the sub-level attribute. For the soil criterion (level 1), the rating is determined by multiplying the reclassified attribute value of the soil type (Table 6) (0-sand, 1 – loamy sand, 2 – sandy loam…, and 5 – clay loam) by the weight of the level 2 criteria then added to the result of the same computation for the other level 2 criteria under soil main criteria. The results will be multiplied by the weight of the level one criterion which was then added to the results of the other criteria following the same procedure to come up with a suitability rating, using Equation 3.

$$S\ rating = \sum_{i=1}^{n}[(level\ 1\ rating)_i\ x\ (weight\ of\ level\ 1\ criteria)_i] \quad (3)$$

where $S\ rating$ = Suitability rating or summary of the numerical equivalent of an area suitability reclassified into either not suitable, marginally suitable, moderately suitable, or highly suitable; $level\ 1\ rating$ = reclassified suitability value of sub-level attributes per cell (0-5), and $weight\ of\ level\ 1\ criteria$ = attribute weight (level 1) derived through AHP.

For a specific area's suitability rating, the summary of the results of the level 1 rating for all the criteria identified will be determined. The result will provide a numerical suitability rating for each parcel (30 m x 30 m). These values were then reclassified into four suitability classes.

Re-classification of suitability ratings into suitability classes was done using the standard re-scaling formula (Vassiliadis, 2017).

$$value_{new} = \frac{max_{new} - min_{new}}{max_{old} - min_{old}} x(value_{old} - max_{old}) + max_{new} \qquad (4)$$

where $value_{new}$ = reclassified rating from 0 to 5 into 0 to 3 scale; max_{new} = new maximum value in the suitability scale (3); min_{new} = the minimum rating which is zero(0); max_{old} = most desirable value in the input dataset's reclassified; rating scale (5); and min_{old} = least desirable value in the input dataset's reclassified rating scale (0).

2.5 Preparation of a Suitability Map

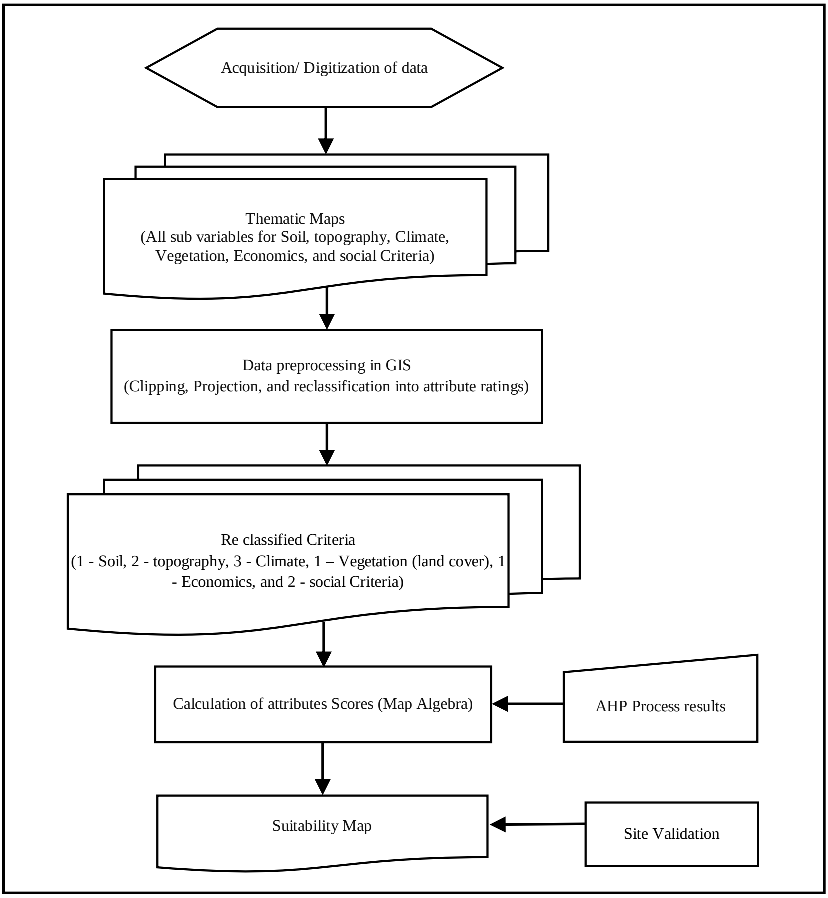

Figure 2. Flowchart for GIS-Aided Abaca suitability mapping

A suitability map was prepared to highlight the suitability for Abaca production based on computed ratings. Rasterized maps with corresponding suitability indices were converted into vector formats and processed within GIS with descriptors/color codes prior to exportation/conversion into color-code maps. A preliminary map was prepared and used for validation, which was conducted in multiple sites to determine the accuracy of the results. A final map was then prepared in a printable format following standard guidelines. The process is shown in Figure 2.

2.6 Abaca Suitability Mapping

The suitability of the research area was described using a choropleth map. Weighted variables were classified using natural breaks on ArcGIS (Liu *et al*., 2017). Classifications and color representation were done using BSWM color codes on land suitability (Table 8) mapping for various commodities (BSWM, nd).

Table 8. Color coding for land suitability mapping

Suitability classes	Color representation
Highly suitable (S1)	Green (accent 6)
Moderately suitable (S2)	Light green
Marginally suitable (S3)	Yellow
Not suitable/not relevant	White

2.7 Validation of Results

The generated suitability map was validated through ocular inspection and interviews with farmers. Identified areas that were considered highly suitable were visited to determine the validity of the analysis. Also, major producers in the towns of Irosin and Barcelona were interviewed, including validation of historical records and the recollection of old farmers and residents.

3. Results and Discussion

3.1 Abaca Production Variables

Abaca production variables that were identified include soil, environment, and socio-economic factors. Expert input resulted in the identification of sub-level criteria for each of the level 1 criteria selected.

3.1.1 Geospatial and Temporal Data Prepared and Processed in GIS

As shown in Figure 3, the selected parameters were presented in a geo-referenced map to indicate the details. These were processed in GIS software.

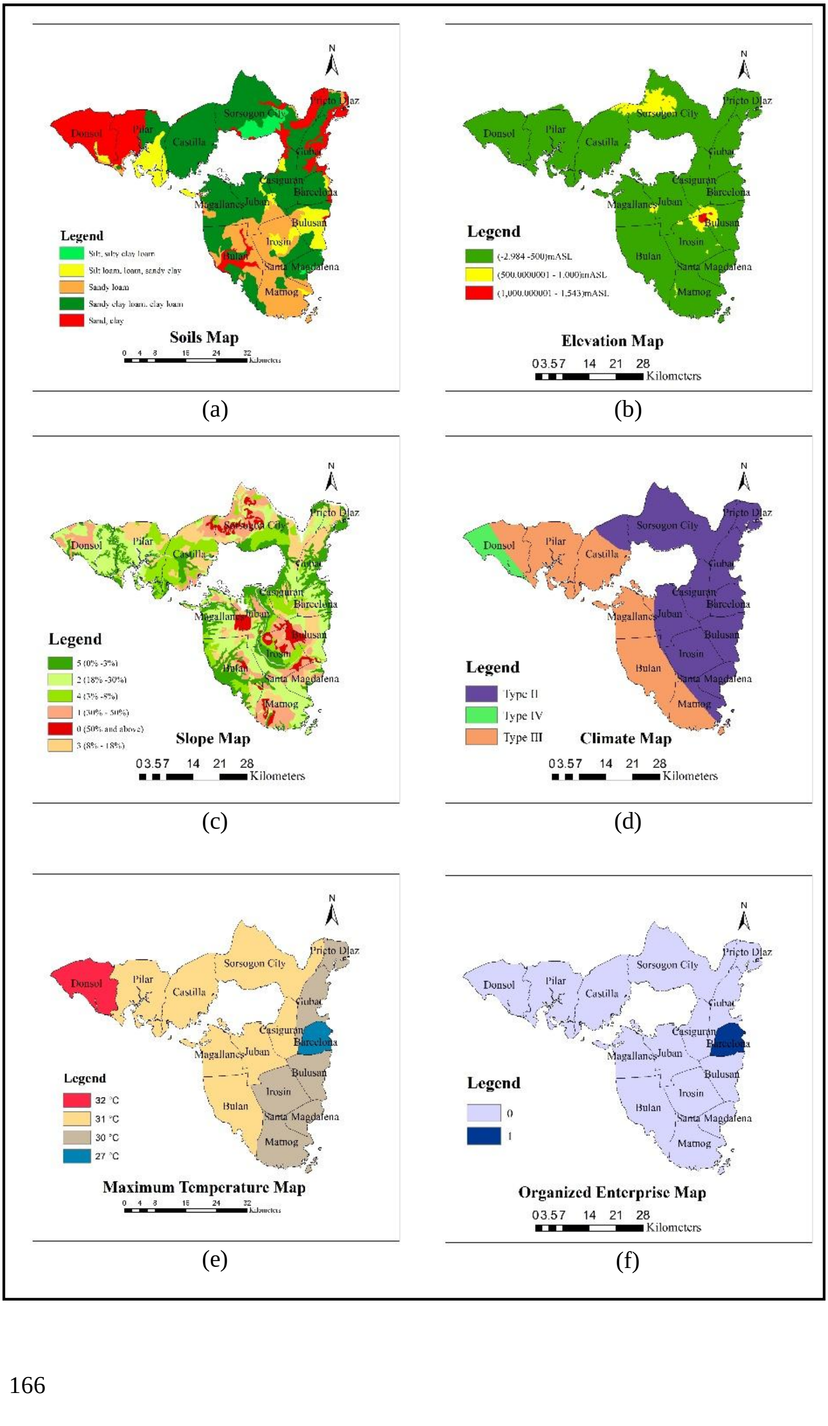

Figure 3. continued.

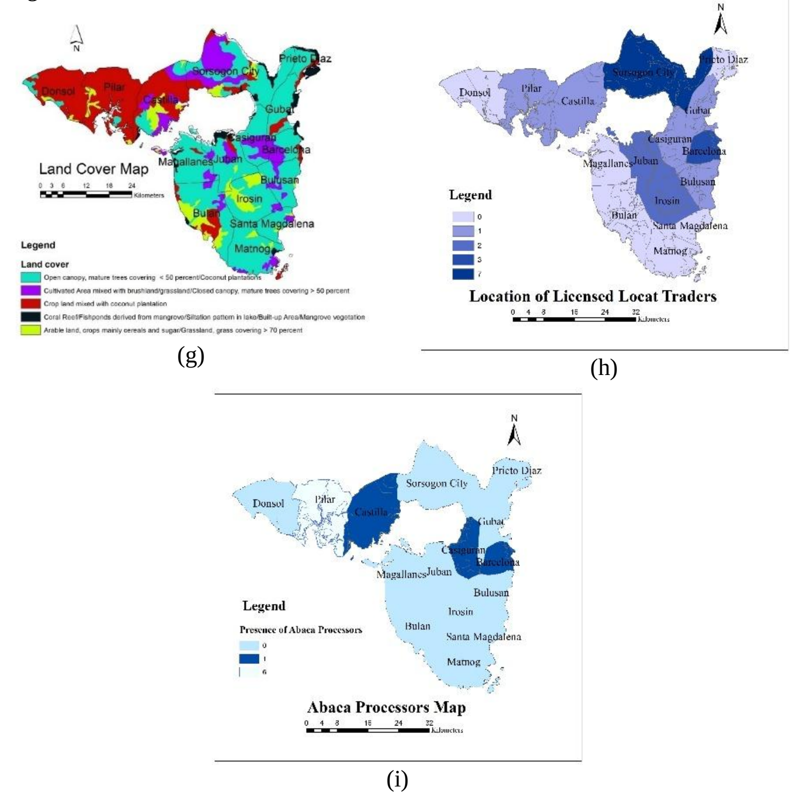

Figure 3. Geographic distribution of environmental, biological, technological, and social criteria for Abaca production suitability: soil texture (a), elevation (b), slope (c), climate (d), maximum temperature (e), organized enterprise map (f), land cover (g), licensed local traders (h), and Abaca processors (i)

3.1.2 Ranking of Variables Based on AHP Procedures

Table 9 shows the relative importance of the selected parameters affecting the production of Abaca. Economic aspects had the highest significance on suitability. Also, social criteria showed a significant weight in the evaluation process. Each sub-criterion for the social aspect had almost the same weight, except for the need for government support which had 36% of the weight allotted to the main criteria.

Table 9. Weights of Abaca production parameters derived using Analytic Hierarchy Process (AHP)

Level 1		Level 2	
Criteria	Weight	Criteria	Weight
Soil	0.241399	Soil texture	0.092
		Soil depth	0.392
		soil fertility	0.517
Topography	0.055206	Elevation	0.850
		Slope	0.149
Climate	0.082401	Climatic type	0.648
		Rainfall	0.112
		Temperature	0.240
Vegetation	0.10121	tree height	0.311
		Diversity	0.493
		forest stand	0.196
Economics	0.273791	Financial aspect	0.305
		Accessibility of markets	0.237
		Availability of inputs	0.457
Social Criteria	0.245994	Organized Enterprises	0.141
		Farmer's skills	0.123
		labor availability	0.178
		Access to information	0.198
		Government support	0.361

The combined impact of topography, climate, and vegetation (23.88%) is almost equal to the individual weights of the other main criteria. Soils with the highest weight on the environmental aspect (24.14%) have the sub-criterion soil fertility with the most significant effect identified with 51.67 % of the main criterion.

3.1.3 Consistency Analysis

After determining the relative weights of the different criteria, consistency ratios were determined to identify potential logical inconsistency in expert opinion which may require improvement of the process. Table 10 shows the results for the criteria identified.

The consistency analysis showed results that are acceptable. A limitation of this study is that pairwise comparison matrix yielded a Consistency Ratio (CR) of 0.12922 for the main variables which marginally exceeds Saaty's traditional threshold of 0.10. This variance could be attributed to the diverse perspectives inherent in a mixed panel of experts, whose varying backgrounds naturally introduce slight non-linearities in judgment (Ivanco *et al*., 2017). Because the aggregate values still reflect high logical results and the deviation is well within recommended the relaxed threshold of 0.20 for group decision making (Goepel, 2013), the data was retained to preserve the practical complexities of the Abaca value chain. Also, the results could still be accepted for higher order matrices (Pant *et al*., 2022), indicating that the pairwise judgments at this level is fair. Among the sub-variables, all fell within acceptable CR values (less than 0.1), reflecting reliable comparisons.

Table 10. Computed consistency indices for the main and sub-criteria considered for the analysis

Criteria	Index	
	Consistency Index	Consistency Ratio
Main criteria	0.180	0.129
Sub criteria		
Soils	0.056	0.097
Topography	-	0 (perfect consistency)
Climate	0.002	0.005
Vegetation	0.027	0.046
Economics	0.047	0.082
Social Criteria	0.105	0.093

3.1.4 Abaca Suitability Mapping

The area classified as highly suitable for Abaca production is 42.85 percent (Table 11) of classified areas. It is almost evenly distributed throughout the province except for parts of Irosin, Pilar, and Donsol. About 21,991.78 ha seemed not suitable which could be found in coastal locations, and within the vicinity of Bulusan volcano.

Table 11. Area distribution of land suitability in the province of Sorsogon

Suitability	Area (ha)	Percentage
Not suitable	21991.78	11.66
Marginally suitable	36350.47	19.27
Moderately suitable	49444.41	26.21
Highly suitable	80827.55	42.85

Note: the total land area of Sorsogon is 211, 901 ha, only about 188,614 ha were classified in this study

The municipality of Castilla has the highest potential for Abaca production in terms of land area. Most of its agricultural area is classified as moderately suitable (1,900 ha) to highly suitable (16,800 ha). This comprises about 90 percent of the total land area. Magallanes also has about 9,000 ha which is classified as highly suitable. Sorsogon City (22,000 ha) and Santa Magdalena (3700 ha) have a large portion of their land area classified for potential expansion. Bulan, Pilar, and Matnog, have a combined area of 13,000 ha classified as highly suitable. Other areas are classified as marginally to moderately suitable. Donsol is the only municipality with more than half of its total land area (15,620 ha) classified as marginally (6,000 ha) to not suitable (7,800 ha) for Abaca production, out of which only 675 ha is identified to be moderately suitable.

The municipality of Juban, 7,943 ha out of 12,149 ha was classified to be moderately-to-highly suitable for production. Its suitability was boosted by the presence of a new tissue culture laboratory with a 4-hectare nursery farm at Brgy Cogon (Recebido, 2022). This facility can boost provincial land suitability for Abaca production. Barcelona, the only town with existing stakeholders' cooperative, has almost all its land area classified as highly suitable (4,912 ha) and about 440 ha with moderate suitability. Approximately 40 hectares located in the coastal parts were determined not suitable (Figure 4).

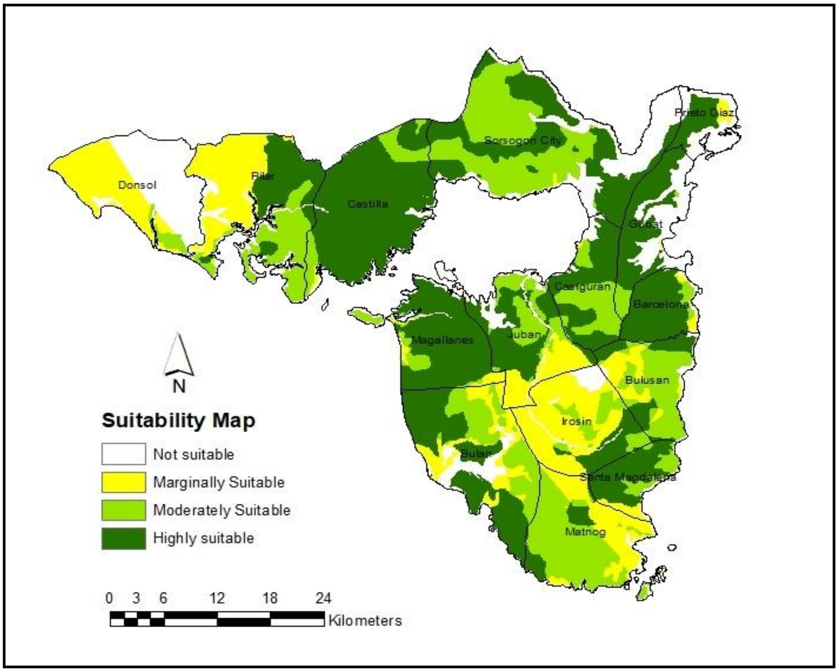

Figure 4. Abaca suitability map for the province of Sorsogon based on multiple criteria analysis

At present, rehabilitation of Abaca plantations is being undertaken by PhilFIDA, with a station at the municipality of Casiguran. Most areas of the province are beneficiaries of these projects, particularly Juban, Irosin, and Barcelona. Training and seminars are also being conducted for focal people from each LGU. Although some of the municipalities have no active commercial plantations, processors and traders are present and active such as in Pilar and Castilla. Most of their raw materials are taken from nearby municipalities such as Daraga, Albay, and Barcelona of Sorsogon.

3.1.5 Validation of Results

Site visitation including interviews with local farmers conducted in Castilla, Irosin, and Sorsogon city confirmed the results of the research. In Castilla, at present, Abaca is not commercially produced, characterized by sparse production sites that could be found in the upland barangays in the Southeastern side. But interview with the locals revealed that historically, it was produced in these areas. In Irosin, a local government official confirmed the historical existence of Abaca Plantations in the identified areas. These findings validated the suitability of the identified areas.

However, it is acknowledged as a study limitation that validation process relied on qualitative assessments—specifically field observations and historical expert testimonies. No quantitative accuracy assessments, such as a confusion matrix, receiver operating characteristic (ROC/AUC) analysis, were conducted. Consequently, while these qualitative findings robustly confirm the historical and environmental suitability of the land, they do not provide statistical metrics of classification accuracy.

4. Conclusion and Recommendation

This study developed an Abaca suitability map for the province of Sorsogon through a systematic literature review, expert consultation, and multi-criteria analysis. The integration of the Analytic Hierarchy Process (AHP) and Geographic Information System (GIS) enabled the generation of a weighted suitability surface. Economic, social, and soil factors emerged as the most influential criteria, with weights of 0.27, 0.25, and 0.24, respectively. Results indicate that approximately 69.06% of the province is moderately to highly suitable for Abaca cultivation, classified as S1 (42.85% = 80,827.55 ha) and S2 (26.21% = 49,444.41 ha). The remaining 30.93% (58,342.25 ha) of land categorized as marginally to not suitable is primarily constrained by unfavorable soil properties and topographic limitations.

Overall, the findings confirm that Sorsogon remains a highly favorable area for Abaca production, consistent with historical cultivation patterns. The suitability map aligns with most existing land-use intentions of the government, providing a valuable reference for planning and resource allocation. The results underscore the need to strengthen components that received lower scores, particularly the organization and capacity of farmers' enterprises—to enhance production viability. It is recommended that policymakers prioritize investments in areas identified as suitable and address economic constraints that may limit the expansion and sustainability of the Abaca industry in the Sorsogon.

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