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Strategic, Economic, and Potency Assessment of Sorghum (*Sorghum bicolor* L. Moench) Development in the Tidal Swamplands of Central Kalimantan, Indonesia

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Citation: Susilawati, S.; Surdianto, Y.; Erythrina, E.; Bhermana, A.; Liana, T.; Syafruddin, S.; Anshori, A.; Nugroho, W.A.; Hidayanto, M.; Widiastuti, D.P.; et al. Strategic, Economic, and Potency Assessment of Sorghum (*Sorghum bicolor* L. Moench) Development in the Tidal Swamplands of Central Kalimantan, Indonesia. *Agronomy* **2023**, *13*, 2559. https://doi.org/10.3390/agronomy13102559

Academic Editors: David W. Archer and Rosa Maria Fanelli

Received: 22 August 2023
Revised: 24 September 2023
Accepted: 30 September 2023
Published: 4 October 2023

Abstract: The potency and challenges of sorghum development in tidal swamplands in Indonesia have yet to be well studied. Thus, our study is the first to evaluate the land suitability, economic performance, and strategies for developing sorghum in the tidal swamplands in Central Kalimantan. We use the land suitability evaluation method, a gross margin and profit analysis, a break-even analysis, and a competitive analysis as the methods for assessing the potency and utilization of sorghum in this study. As a tool for decision-making, SWOT was also used, followed by a quantitative strategic planning matrix (QSPM) analysis. The results show that 578,511 ha of arable land is suitable for sorghum development. Economically, sorghum farming can generate IDR 12,894,000 per ha with a revenue-cost ratio of 1.72; the break-even price would be IDR 2447 per kg, around 42% lower than the current market price. Sorghum is also more competitive than cassava (Q = 0.76), sweet potato (Q = 0.58), and soybeans (Q = 0.61) and less competitive than maize (Q = 1.33). Based on the QSPM analysis, five alternative strategies were obtained for developing sorghum in tidal swamplands: (1) optimization of productivity; (2) improvement in the quality of human resources for farmers; (3) facilitation of partnership cooperation; (4) application of site-specific technology; and (5) optimization of waste utilization. These strategies show that the expansion of sorghum planting has potential in the tidal swamplands and economic value for the community.

Keywords: tides; spatial analysis; economic feasibility; competitive analysis; quantitative strategy planning matrix

1. Introduction

Indonesia needs to increase its agricultural production to feed its continuously growing population, which is expected to reach 305 million by 2035. However, the quest to enhance the production of food crops, particularly rice, a staple grain in Indonesia, has been hampered by several factors, including the negative effects of climate change and the conversion of agricultural areas to non-agricultural uses. The taste for high-quality foods rather than rice is also changing because of changes in economic success, better education, and the influence of Western culture on some people, particularly those of younger generations. Foods prepared with sorghum flour, such as bread and noodles, are becoming more popular. Sorghum consumption has increased as a result. However, sorghum is produced in relatively small amounts annually, i.e., 4.0 $t.ha^{-1}$, and the production target for 2024 is only 154,464 tons, with a planting area of only 40,000 ha in 17 provinces [1].

Sorghum (*Sorghum bicolor* L. Moench) is known for its good adaptability to sub-optimal lands due to its tolerance to drought [2], aluminum toxicity [3], and inundation [4,5]. Additionally, sorghum cultivation and seed production techniques are more manageable than those of corn. It does not require high inputs and can be ratified several times. It also has much higher biomass production than sugarcane and maize [6]. As a potential cereal plant, sorghum has economic value in all of its parts. As a food source, sorghum has a very high nutritional content in its seeds, which can be used as a substitute for wheat flour for various processed bread and cake products [7]. Its leaves and stems can be used as a source of feed to increase livestock weight and milk production. Furthermore, its sweet stems are a source of bioethanol, liquid sugar, crystal sugar, and other products, with different uses depending on the type of industry.

Sorghum cultivation in Indonesia is not as common as the cultivation of other staple crops such as rice, corn, and soybeans; however, it does have a presence in certain regions of the country. Sorghum is primarily grown for its grains, which can be used for various purposes such as human consumption, animal feed, and industrial applications. Its cultivation is mainly concentrated in regions with suitable climate and soil conditions. These regions include East Java, East Nusa Tenggara, and some parts of Sulawesi. Sorghum is a drought-tolerant crop and can grow in areas with less rainfall. It is well-suited to tropical and subtropical climates, making it suitable for some parts of Indonesia [8,9]. However, it does require a relatively warm growing season. Additionally, dry uplands, which can be used for growing sorghum, are also used for estates and other perennial crops, as well as for housing and other construction purposes. Therefore, the best option for sorghum expansion in the future is tidal swamplands.

Swamplands are low-lying lands that are regularly flooded. They consist of two types of lands, i.e., tidal swamps and monotonous swamps. Tidal swamplands are swamplands that are influenced by sea tides. They can be further classified based on their tidal influence into types A, B, C, and D [10]. Type A tidal swamplands are lands influenced by spring and neap tides, whereas type B tidal swamplands are lands influenced by neap tides only. If no flooding occurs, i.e., only a rise in the water table during tides, then those lands are classified as type C, while type D tidal swamplands are not influenced by sea tides at all and are, thus, basically drylands in swampy areas. Monotonous swamplands (inland or nontidal swamps) are lands formed in the inland valley where the water comes from upstream rivers or rain. It can be categorized into three categories based on the depth and duration of the flooding, i.e., deep, medium, and shallow monotonous swamplands.

In Indonesia, approximately 8.92 million ha of tidal swamplands are spread across the east and north coasts of Sumatra; the west, south, and east coasts of Kalimantan; the west and east coasts of Sulawesi; and the south coast of Papua. Around 2.99 million ha of tidal swamplands are present in Kalimantan, and about 0.663 million ha are in Central Kalimantan Province [10]. Tidal swamplands are traditionally cultivated for rice; however, sorghum has broad adaptability, which makes its cultivation in tidal swamplands, particularly types C and D, possible. However, the size and location of the tidal swamplands that are ideal for sorghum cultivation are currently unknown. Therefore, the potency and suitability of tidal swampland areas for sorghum growth need to be assessed, and the land capability evaluation method [11] and spatial analysis were chosen for this purpose.

Farmers' willingness to cultivate sorghum depends on its economic feasibility and profitability, as well as the market opportunity. To evaluate its economic feasibility, we used a gross margin and profit analysis, a break-even analysis, and a competitive and sensitivity analysis [12,13]. For large-scale development of sorghum in tidal swamplands, we need to develop strategies based on the strengths, weaknesses, opportunities, and threats (SWOT) of sorghum development in the tidal swamplands of Central Kalimantan. The final strategy was chosen based on the results of these available decision-making tools.

2. Materials and Methods

2.1. Location and Time of Research

This study was conducted in Central Kalimantan Province from August 2022 to April 2023. Since the tidal swamplands in Central Kalimantan are the largest swamplands in Indonesia, covering 3,208,269 hectares, or 21.49% of the province's total area, they were chosen as this study region. It has, however, not been used to its full potential, despite having great potential for the growth of food crops, particularly sorghum. This study focused on Kapuas Regency to identify the current biophysical characteristics of tidal swamplands in Central Kalimantan (Figure 1). Kapuas Regency contains the most tidal swamplands in Indonesia and is thought to be representative of the bio-physical characteristics of tidal swamplands in Central Kalimantan; therefore, it was specifically chosen as a purposeful sample.

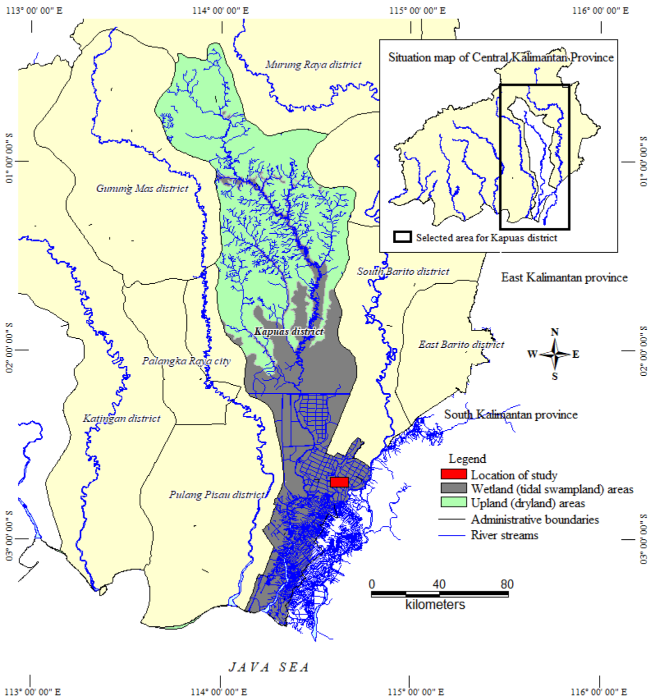

Figure 1. This map shows the location of this study in Kapuas Regency, Central Kalimantan.

2.2. Research Method

2.2.1. Suitability and Spatial Analysis

The assessments were conducted through a deskwork study with field verification and were focused on Central Kalimantan Province in Indonesia. At the landscape scale, the spatial division of the agricultural land regions was determined based on a land capability evaluation [14]. The main land characteristics essential for the land evaluation included the landforms, represented by slopes; erosion conditions; drainage; adequate depths; textures; flood conditions; and the presence of rocks on the ground surface [15]. The information on the land resources used as base digital maps in this study during reconnaissance included maps of the land system, soil types, and agroclimatic, topographic, administrative, and other relevant data.

A land evaluation was also performed to determine the suitability of the land for sorghum growth at this study site based on the biophysical conditions of the environment. The land system approach based on recurring patterns was used to determine other areas with similar biophysical aspects to the environment, in conformity with the conditions of this study site. A spatial analysis was used to integrate the information obtained through observation as well as to determine the suitability and availability of land and other resources on maps and geographic information systems (GISs), which were then converted into spatial formats for land use planning and for sorghum development in swamplands in other areas of Central Kalimantan [16–19].

2.2.2. Economic Performance

The economic analysis consisted of a feasibility analysis, a competitive advantage analysis, and a sensitivity analysis of farming. The agricultural feasibility analysis was used to determine the feasibility level of sorghum farming in tidal swamps. Furthermore, the competitive advantage analysis was used to determine the competitive advantage of sorghum plants against other food crops that developed in swamplands in Central Kalimantan. The sensitivity analysis was used to identify key sources of variability and uncertainty for the variation in expected results in order to make the best decisions considering future scenarios.

The feasibility of a type of farming can be measured with several parameters or eligibility criteria, namely the results of a cost analysis, the revenue, the benefits, the revenue-cost ratio, the benefit-cost ratio, and the break-even point (BEP) [20–22].

The competitive advantage of a particular type of crop (A) compared with other types of crops (B) can be determined by calculating the F value, with the productivity of crop A used as the benchmark [23–25]. The F value is calculated as follows:

$$FB = \frac{\text{Cost of farming crop A} + \text{Profit from farming crop B}}{\text{Price of crop A}} \tag{1}$$

where FB is used to determine the equivalent productivity of crop B and the price of crop A.

To facilitate the assessment of the competition between crop A and crop B, we can calculate the QB value using the following formula:

$$QB = \frac{FB}{\text{Productivity of crop A}} \tag{2}$$

where QB indicates how productive crop B is compared with crop A at the price of crop A. If QB > 1, crop B has a competitive advantage over crop A.

The sensitivity was also computed to explore the effect of assumptions regarding the changes in these determinant factors on the gross margin by using the principle of "what if" scenarios [26]. Fertilizer sales and yield prices can influence the gross margin (GM). To determine the profitability of sorghum production for the GM and profit, we compared four scenarios: (1) using subsidized fertilizer prices while yields and grain prices are fixed; (2) using non-subsidized fertilizer prices while grain yields and prices are fixed; (3) using subsidized fertilizer prices while yields are fixed and grain prices fall by 20%; and (4) using non-subsidized fertilizer prices while yields are fixed and grain prices fall by 20%.

2.2.3. Sorghum Development Strategy

This study used a survey method with interview techniques, field observation, and focus group discussions (FGDs). Interviews were conducted using the structure of questionnaires. The objectives are to collect data and information about the potentials, problems, strengths, weaknesses, opportunities, challenges, and threats of developing food crops in tidal swamps in Central Kalimantan. The data and information collected consist of: general data of respondents; data on agricultural activities; input and output food crop data. The sources interviewed consisted of farmers, with a total of 100 respondents. The results of the observations and in-depth interviews were then discussed through FGDs [27], which aimed to formulate data and information on the strengths, weaknesses, opportunities, and threats of developing sorghum in the tidal swamps in Central Kalimantan. Field observations were carried out to clarify the data and information obtained from the interviews via direct observation of the research object. The number of FGD participants was chosen deliberately based on specific considerations, with the 35 participants consisting of local governments, agricultural extension workers, research institution members, academics, agricultural practitioners, private company representatives, and farmer representatives.

A SWOT analysis was used to identify the internal factor evaluation (IFE), such as strengths and weaknesses, and the external factor evaluation (EFE), such as opportunities and threats presented by the external environment [28]. This analysis was used to formulate alternative strategies for developing sorghum cultivation in tidal swampland areas in Central Kalimantan. The analysis of the Internal Factor Analysis Summary (IFAS) and External Factor Analysis Summary (EFAS) is the next stage after the identification stage to obtain the total score resulting from the total weight multiplied by the rating of each strategic factor indicator. The weighting was carried out by classifying each variable according to its importance or rating based on the results of the FGD to obtain the weight of each internal (strengths and weaknesses) and external (opportunities and threats) strategic indicator, which is then presented in the form of an IFAS and EFAS matrix. Both IFAS and EFAS matrices were used to compile the SWOT table.

Regarding IFAS and EFAS matrices in the input stage, we extracted the Internal External Matrix (IEM). Then, we identified different strategy options and prioritized them by the quantitative strategic planning matrix (QSPM) using the IEM and the SWOT matrices [29,30]. We used a combination of the SWOT and QSPM methods in our research. Due to the limitations of organizational resources, sometimes policymakers need to prioritize implementing their strategies. When the number of identified strategies is considerable, prioritizing the strategy cannot be carried out by the SWOT method. Then, the process of the strategic development of sorghum in the tidal lands of Central Kalimantan was prioritized using the QSPM. The QSPM matrix will describe the best alternative strategies that can be used by looking at the Attractive Score (AS) and Total Attractive Score (TAS) [31]. From the calculation of the QSPM matrix, we determined five alternative strategies based on the highest TAS value.

3. Results

3.1. Suitability and Spatial Analysis

The information compiled from the map indicates that Central Kalimantan, with a total area of 15,451,287 hectares, can be classified into two types of land, i.e., wetlands and drylands. Geographically, due to their topographical conditions, the drylands are primarily located in the northern part of Central Kalimantan Province, also known as the uplands. On the other hand, the permanent wetlands are predominantly composed of tidal swamplands, characterized by entisols, inceptisols, and histosols as the main soil types, primarily found in the southern region, totaling 5,237,019 hectares, or 33.90% of the total area of Central Kalimantan.

Type A represents areas that experience inundation during both high and low tides. These areas include coastal areas, coastal zones, and riverbanks. Type B represents areas that only experience inundation during high tides. These areas include back swamps extending more than 50 km inland from the river edges. Type C represents areas that do not experience direct tidal inundation but are influenced by tidal seepage, with groundwater levels below 50 cm. Type D is similar to type C but with less influence from tidal seepage, as the groundwater level is more profound, exceeding 50 cm. Type D areas are often likened to rain-fed agricultural lands (Figure 2) [32].

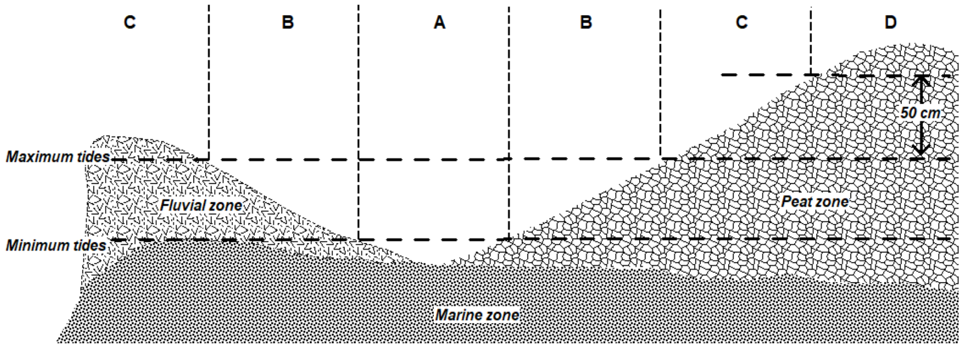

Figure 2. Classification of tidal swamplands based on flood types [32].

The agroclimatic conditions indicate that this region has a wet equatorial climate due to its proximity to the equator, with an average temperature range of 26.40 to 27.20 degrees Celsius. This suggests that the region experiences hot weather with an average daily duration of sunshine of 53.92%. By the end of 2021, based on records from the past ten years, the monthly rainfall in this area amounted to 207.57 mm per month. This high rainfall results from the high temperatures, leading to high evaporation intensities, subsequently causing saturated air conditions and active cloud formations that can bring rain (eight climate stations in Kapuas District).

The results of the land evaluation showed that the land suitability for sorghum cultivation in the study location is moderately suitable. The main limiting factors resulting from the land evaluation include soil acidity and nutrient availability. The relatively high soil acidity, with a pH of 4.17, can suppress the nutrient absorption capacity. In Kapuas Regency, where this study was conducted, the arable land suitable for sorghum cultivation was located in the southern part, where stream rivers and water networks exist (Figure 3).

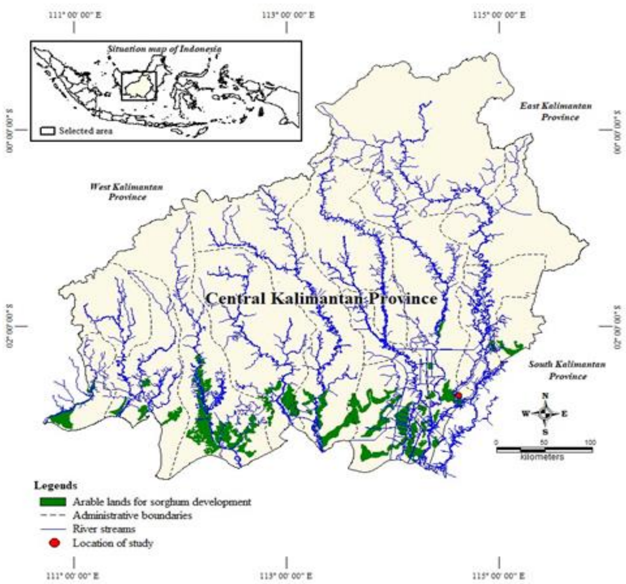

Figure 3. The arable tidal swamplands are areas for sorghum development in Central Kalimantan Province.

Following a further spatial analysis in the regional province, more arable land that is suitable for sorghum development was also found in the southern parts of the tidal swamplands of Central Kalimantan Province, with a total area of 578,511 hectares, or 3.74% of Central Kalimantan's total area. In these areas, agricultural fields, plantations, and human settlements are already prevalent.

3.2. Economic Performance

3.2.1. The Feasibility of Sorghum Farming

Our feasibility analysis of sorghum farming conducted in the tidal swamplands of Central Kalimantan is currently limited to its potential regarding its primary use, which is consumption as a grain. Other aspects of the plant, such as the stalk, leaves, and roots, that can be utilized for animal feed and compost have not been explored yet. This is because the main focus of the undertaken steps is the development of sorghum in tidal swamplands, which is primarily aimed at seed production as a source of planting material and ensuring plant resilience in challenging swamp conditions (Table 1).

Table 1. The feasibility analysis of sorghum farming in tidal swamplands in Central Kalimantan, 2022.

No	Description	Volume	Unit	Price (USD) *	Cost (USD)
1.	Production facilities				
	Sorghum seeds	5	kg	3.17	15.85
	Herbicides	1	liter	13.36	13.36
	Insecticides	2	kg	3.68	7.36
	Dolomites	8	sack	6.33	50.64
	Urea	50	kg	1.00	50.00
	Manure	1000	kg	46.67	40.67
	KCl	50	kg	1.00	50.00
	SP36	50	kg	1.00	50.00
	Rodenticides	1	kg	4.00	4.00
	Depreciation of equipment				10.33
	Total				*281.88*
2.	Labor				
	Land preparation	5	Working day	5.33	26.65
	Land processing	15	Working day	5.33	79.95
	Planting	5	Working day	5.33	26.65
	Fertilization	5	Working day	5.33	26.65
	Weed removal	5	Working day	5.33	26.65
	Harvesting	5	Working day	5.33	65.65
	Total				*213.20*
3.	Total Cost				495.08
4.	Production	3070	kg		
5.	Revenue	3070	kg	0.28	859.6
6.	Profit				*364.52*
7.	R/C				1.73
8.	B/C				0.73
9.	BEP of sorghum price			0.16	
10.	BEP of sorghum unit	1788	kg		

* Market price.

Based on the break-even value for the price of sorghum and the break-even value for sorghum products, sorghum farming in the tidal swamplands of Central Kalimantan provides an additional production value of USD 0.09 per kg and an additional price value of USD 0.16 per kg compared with actual production and prices. Based on these additional values, sorghum farming in the tidal swamplands of Central Kalimantan is considered sufficiently efficient, with a value of 41.75%.

3.2.2. Competitive Advantages of Sorghum Farming

The cultivation of sorghum as a commodity in the tidal swamplands of Central Kalimantan has not been widely practiced yet. However, it holds promising prospects if it can be developed based on the potential of the vast land resources available. The analysis of the competitive advantages of sorghum compared with other food crops grown in the same agroecosystem, such as maize, sweet potatoes, and soybeans, during the dry season of 2022 is presented in Table 2.

Table 2. Analysis of the competitive advantage of sorghum farming compared with other food crops farming in Kapuas Regency, 2022.

Commodity	Production (kg ha^{-1})	Price (USD kg^{-1})	Total Cost (USD ha^{-1})	Profit (USD ha^{-1})	F Value	Q Value
Sorghum [1]	3070	0.28	859.6	354.52		
Sweet potato [2]	900	1.00	722.67	177.33	2421.64	0.79
Maize [2]	5200	0.36	1229.33	642.67	4083.55	1.33
Soybean [2]	1200	0.07	821.50	218.50	2568.67	0.84

Source: Primary data, processed. [1] Research technology. [2] Farmer models.

3.2.3. Sensitivity of Sorghum Farming

The results of our sensitivity analysis for determining the impact of changes in the input prices (fertilizers) and changes in the output prices on sorghum farming income in the tidal swamplands in Central Kalimantan Province in 2023 with four scenarios based on data on the financing structure and sorghum farming income in Table 1 can be seen in Table 3.

Table 3. Results of a sensitivity analysis of sorghum farming in tidal swamplands in Central Kalimantan Province in 2023.

Description	Existing	Changes in Financing and Revenue Structures			
		Scenario 1	Scenario 2	Scenario 3	Scenario 4
Input:					
Sorghum seeds	1.84	1.84	1.84	2.30	2.30
Herbicides	1.55	1.55	1.55	1.94	1.94
Insecticides	0.86	0.86	0.86	1.07	1.07
Liming (dolomite)	5.89	5.89	5.89	7.37	7.37
Urea	4.94	0.89	2.17	1.11	2.71
Manure	5.43	6.20	21.33	7.76	26.66
NPK	0.00	5.12	18.15	6.40	22.68
KCl	5.62	0.00	0.00	0.00	0.00
SP-36	5.62	0.00	0.00	0.00	0.00
Rodenticides	0.47	0.47	0.47	0.58	0.58
Other expenses	1.20	1.20	1.20	1.50	1.50
Labor	24.82	24.82	24.82	31.02	31.02
Total cost	58.25	48.85	48.85	61.06	97.85
Output:					
Revenue	100	100	100	100	100
Income	41.75	51.15	21.72	38.94	2.15
R/C	1.73	2.05	1.28	1.64	1.02
B/C	0.73	1.05	0.28	0.64	0.02

Notes: Scenario 1 used subsidized fertilizer prices while crop yields and sorghum prices were fixed; Scenario 2 used non-subsidized fertilizer prices while crop yields and sorghum prices were fixed; Scenario 3 used subsidized fertilizer prices while crop yields were fixed and sorghum prices fell by 20%; and Scenario 4 used non-subsidized fertilizer prices while crop yields were fixed and sorghum prices fell by 20%.

3.3. Sorghum Development Strategy

3.3.1. SWOT (Strengths–Weaknesses–Opportunities–Threats)

According to the information obtained from the survey and interview methods guided by direct questionnaires in the field, four main strengths, weaknesses, opportunities, and threats of sorghum development in the tidal swamplands of Central Kalimantan are finalized in Table 4.

Table 4. SWOT of the sorghum development in the tidal swamplands of Central Kalimantan.

Factors	Description
Internal Factors	
Strengths (S)	S1—Sorghum is more adaptive to the environment than maize S2—The stover is able to be used as animal feed S3—Swamplands that have not been utilized have relatively good potential S4—Motivation and availability of agricultural human resources
Weaknesses (W)	W1—Lack of knowledge and experience of farmers in sorghum cultivation W2—Biophysical land constraints and requiring well-drained soils W3—Difficulty in obtaining quality seeds W4—Limited number and capacity of agricultural tools and machinery
External Factors	
Opportunities (O)	O1—The substitution of part of the wheat imports with domestic sorghum O2—Sorghum products are being chosen for domestic and foreign markets O3—The development of adaptive varieties reduces production costs O4—Policies on fertilizer subsidizing and rural development to support small-scale cultivation
Threats (T)	T1—Extreme weather increase the risk of inundated or dry plants T2—Specific sorghum varieties for tidal swamplands are not yet available T3—Continuity of production for industrial needs T4—Uncertainty about the selling price

The influence of various internal and external factors was challenged during the expert meetings. Ultimately, the list of internal and external factors was finalized and evaluated during the FGDs. The final list of internal and external factors is presented in Tables 5 and 6. In these two tables, as mentioned, in addition to a list of internal and external influential factors, the score and importance of the factors are presented in the columns.

Table 5. IFAS matrix (strengths and weaknesses).

Internal Factors	Significance Factor (0–1)	Weight	Score (Rank Coefficient) (1–4)
S1—Sorghum is more adaptive to the environment than maize	0.172	10	1.720 (2)
S2—The stover is able to be used as animal feed	0.103	6	0.618 (4)
S3—Tidal swamplands that have not been utilized have relatively good potential	0.207	12	2.484 (1)
S4—Motivation and availability of agricultural human resources	0.138	8	1.104 (3)
Subtotal	0.621		5.926
W1—Lack of knowledge and experience of farmers in sorghum cultivation	0.086	–5	−0.430 (3)
W2—Biophysical land constraints and requiring well-drained soils	0.069	–4	−0.845 (4)
W3—Difficulty in obtaining quality seeds	0.121	–7	−0.847 (1)
W4—Limited number and capacity of agricultural tools and machinery	0.103	–6	−0.618 (2)
Subtotal	0.379		−2.171
Total score	1.000		3.755

Table 6. EFAS matrix (opportunities and threats).

External Factors	Significance Factor (0–1)	Weight	Score (Rank Coefficient) (1–4)
O1—The substitution of part of the wheat imports with domestic sorghum	0.196	10	1.960 (1)
O2—Sorghum products are being chosen for domestic and foreign markets	0.137	7	0.959 (3)
O3—The development of adaptive varieties reduces production costs	0.118	6	0.708 (4)
O4—Policies on rural development support small-scale cultivation	0.176	9	1.584 (2)
Subtotal	0.627		5.211
T1—Extreme weather increase the risk of inundated or dry plants	0.078	–4	–0.312 (3)
T2—Specific sorghum varieties for tidal swamplands are not yet available	0.098	–5	–0.490 (2)
T3—Continuity of production for industrial needs	0.059	–3	–0.177 (4)
T4—Uncertainty about the selling price	0.137	–7	–0.959 (1)
Subtotal	0.373		–1.941
Total score	1.000		3.273

An analysis of the internal factor analysis summary (IFAS) and the external factor analysis summary (EFAS) was the next stage after this identification stage to obtain the total score resulting from the total weight multiplied by the rating of each strategic factor indicator. The weighting was performed by classifying each variable according to its importance or rating based on the results of the FGD to obtain the weight of each internal (strengths and weaknesses) and external (opportunities and threats) strategic indicator, which was then presented in the form of an IFAS and EFAS matrix.

Regarding the IFAS and EFAS matrices in the input stage, we extracted the internal-external matrix (IEM). Both the IFAS and EFAS matrices were used to compile the SWOT (Table 7).

Table 7. Internal-external matrix to compile the SWOT table of sorghum development strategies in tidal swamplands in Central Kalimantan.

IFAS / EFAS	Strength Strategy	Weakness Strategy
Opportunity Strategy	Strategi SO 5.926 + 5.211 = 11.137	Strategi WO −2.171 + 5.211 = 3.040
Threat Strategy	Strategi ST 5.926 + (–1.938) = 3.988	Strategi WT −2.171 + (−1.938) = −4.109

Table 5 shows that the most suitable strategy for developing sorghum in tidal swamps in Central Kalimantan is the SO strategy, which is a strategy that uses internal strengths to take advantage of external opportunities.

Subsequently, a matrix space analysis was performed to hone the results. The purpose of the analysis space matrix is to determine the optimal location of the sorghum plants in the swamps in Central Kalimantan and the direction of their further development. In the analysis space matrix, rating values for positive factors, i.e., strengths and opportunities, are marked with +, while negative factors, i.e., weaknesses and threats, are marked with -. The analysis space matrix for the development of sorghum plants in swamps in Central Kalimantan is presented in Table 8.

Table 8. Space matrix analysis of sorghum development in tidal swamplands in Central Kalimantan.

Internal Factors	Rating	External Factors	Rating
S3—Swamplands that have not been utilized have relatively good potential	12	O1—The substitution of part of the wheat imports with domestic sorghum	10
S1—Sorghum is more adaptive to the environment than maize	10	O2—Sorghum products are being chosen for domestic and foreign markets	7
S2—The stover is able to be used as animal feed	6	O3—The development of adaptive varieties reduces production costs	7
S4—Motivation and availability of agricultural human resources	7	O4—Policies on rural development support small-scale cultivation	9
Total	35	Total	33
W1—Lack of knowledge and experience of farmers in sorghum cultivation	–5	T1—Extreme weather increase the risk of inundated or dry plants	–4
W2—Biophysical land constraints and requiring well-drained soils	–4	T2—Specific sorghum varieties for tidal swamplands are not yet available	–5
W3—Difficulty in obtaining quality seeds	–7	T3—Continuity of production for industrial needs	–3
W4—Limited number and capacity of agricultural tools and machinery	–6	T4—Uncertainty about the selling price	–7
Total	–22	Total	–19
Average S	9.000	Average O	8.000
Average W	–5.500	Average T	–4.750
Value on the X axis = S + (–W)	3.500	Value on the Y axis = O + (–T)	3.250

The average strength is 9.000, while the average weakness is −5.500, which means that for the development of sorghum in the swamps in Central Kalimantan, internally, the strengths are more dominant than the weaknesses. Externally, the opportunity factor is more prevalent than the threat factor, with an average opportunity of 8.000, while the average threat is −4.750. In the grand strategy matrix diagram, the x-axis value is obtained by adding up the average rating of internal factors (strengths and weaknesses). In contrast, the y-axis value is obtained by adding up the average rating of external factors (opportunities and threats) in the analysis space matrix. The grand strategy matrix diagram for developing sorghum plants in the swamps in Central Kalimantan is presented in Figure 4.

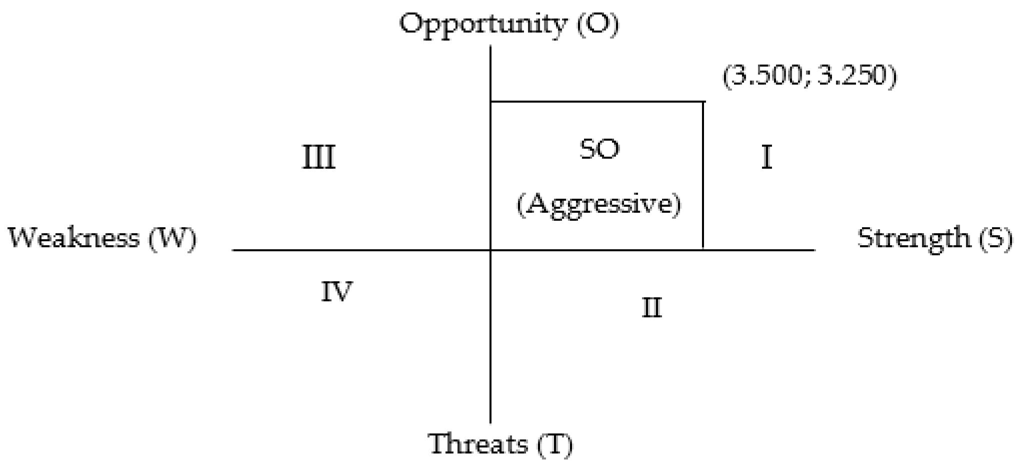

Figure 4. Grand strategy matrix diagram for sorghum development in tidal swamps in Central Kalimantan (the x-axis value = S + (-W) = 9.000 − (−5.500) = 3.500; the y-axis value = O + (-T) = 8.000 + (−4.750) = 3.250).

The diagram shows that the grand strategy matrix in position (x, y) in quadrant I is an aggressive strategy. This is because opportunities and strengths have a dominant influence compared with weaknesses and threats. These results followed from the calculations in the SWOT analysis, where the internal strategic factors' values showed that strengths > weaknesses (5.931 > 3.579) and the external strategic factors' values showed that opportunities > threats (5.216 > 1.491). Thus, developing sorghum plants in the tidal swamplands in Central Kalimantan is favorable. If the sorghum crop program is to be developed, it has the ability to take advantage of current opportunities.

The SWOT matrix clearly illustrates how external opportunities and threats can be combined with internal strengths and weaknesses resulting from the input stage (IFAS and EFAS matrix) to formulate a strategy for the development of sorghum cultivation in the tidal swamps of Central Kalimantan. Matching the critical internal and external factors is the key to effectively generating feasible strategic alternatives. This matrix produces four possible alternative strategy cells: the S–O strategy, the W–O strategy, the S–T strategy, and the W–T strategy. The strategy resulting from a combination of internal factors (strengths and weaknesses) and external factors (opportunities and threats) using the SWOT matrix consists of ten alternative strategies, as shown in Table 9.

Table 9. SWOT matrix of sorghum cultivation strategies in the tidal swamps of Central Kalimantan.

Internal Factors / **External Factors**	**Strength (S)** S1—Sorghum is more adaptive to the environment than maize plants S2—The stover is able to be used as animal feed S3—Swamplands that have not been utilized have relatively good potential S4—Motivation and availability of agricultural human resources	**Weakness (W)** W1—Lack of knowledge and experience of farmers in sorghum cultivation W2—Biophysical land constraints and requiring well-drained soils W3—Difficulty in obtaining quality seeds W4—Limited number and capacity of agricultural tools and machinery
Opportunity (O) O1—The substitution of part of the wheat imports with domestic sorghum O2—Sorghum products are being chosen on domestic and foreign markets O3—The development of adaptive varieties reduces production costs O4—Policies on fertilizer subsidizing and rural development to support small-scale cultivation	**S–O strategy** Increase production by optimally utilizing available swampland resources, technological innovation, human resources, and market potential (S1, S2, S3, S4, O1, O2, O3, and O4) Optimize the utilization of sorghum plant waste as animal feed (S1, S2, S3, S4, O1, O2, O3, and O4) Increase and maintain production continuity by utilizing the potential of land, technology, and human resources for farmers (S1, S4, O3, and O4) Increase productivity and processed products by optimizing land resources, technological developments, and government policies to reduce wheat imports (S1, S2, S3, S4, and O4)	**W–O strategy** Increase farmers' knowledge and skills regarding cultivation, land management, and sorghum seed production technology (W1, W2, W3, W4, O1, O2, O3, O4, and O5) Facilitate farmer/farmer group collaboration with sorghum seed breeders (W4, O1, O2, O4, and O5)
Threats (T) T1—Extreme weather increase the risk of inundated or dry plants T2—Specific sorghum varieties for tidal swamplands are not yet available T4—Uncertainty about the selling price T3—Continuity of production for industrial needs	**S–T strategy** Increase production by optimally utilizing available swampland resources, technological innovation, human resources, and market potential (S1, S2, S3, S4, O1, O2, O3, and O4) Optimize the utilization of sorghum plant waste as animal feed (S1, S2, S3, S4, O1, O2, O3, and O4) Increase and maintain production continuity by utilizing the potential of the land, technology, and human resources for farmers (S1, S4, O3, and O4) Increase productivity and processed products by optimizing land resources, technological developments, and government policies to reduce wheat imports (S1, S2, S3, S4, and O4)	**W–T strategy** Improve the quality of human resources by providing training in land management, climate and weather, production, and marketing management (W1, W2, W3, W4, T2, T3, and T4) Machine tool facilitation

The final strategy was chosen based on the SWOT analysis, namely an aggressive approach (SO strategy), as follows:

(1) Increase production by optimally utilizing available swamp tidal land resources, technological innovation, human resources, and market potential;
(2) Optimize the utilization of sorghum plant waste as animal feed;
(3) Increase and maintain production continuity by utilizing the potential of the land, technology, and human resources for farmers;
(4) Increase productivity and processed products by optimizing land resources, technological developments, and government policies to reduce wheat imports.

3.3.2. Quantitative Strategic Planning Matrix (QSPM)

Due to the limitations of organizational resources, policymakers often need to prioritize implementing their strategies. When the number of identified strategies is considerable, prioritizing the strategy cannot be achieved with just the SWOT method. Therefore, the strategic development of sorghum in the tidal swamplands of Central Kalimantan was prioritized using a QSPM analysis. The QSPM describes the best alternative strategies that can be used by looking at the attractive score (AS) and the total attractive score (TAS). From the calculation of the QSPM, we determined five alternative strategies based on the highest TAS value. From the calculation of the QSPM (Table 10), the best strategy based on the highest TAS value is to increase production by utilizing existing land resources, technological developments, human resources, and production facility resources to optimally utilize the market potential.

Table 10. QSPM of sorghum development strategy in tidal swamplands in Central Kalimantan.

Key Factors	Weight	Alternative Strategy							
		1		2		3		4	
		AS	TAS	AS	TAS	AS	TAS	AS	TAS
Strengths									
1. Swamplands that have not been utilized have relatively good potential	0.207	4	0.828	3	0.621	4	0.828	4	0.828
2. Being more adaptive to the environment than maize plants	0.172	4	0.688	3	0.516	4	0.688	4	0.688
3. The stover is able to be used as animal feed	0.103	2	0.206	4	0.412	3	0.309	2	0.206
4. Motivation and availability of agricultural human resources	0.138	3	0.414	3	0.414	3	0.414	3	0.414
Weaknesses									
1. Lack of knowledge and experience of farmers in sorghum cultivation	0.086								
2. Biophysical land constraints and requiring well-drained soils	0.069								
3. Difficulty in obtaining quality seeds	0.121								
4. Limited number and capacity of agricultural tools and machinery	0.103								
Opportunity									
1. The substitution of part of the wheat imports with domestic sorghum	0.196	3	0.588	2	0.392	2	0.392	3	0.588
2. Policies on rural development support small-scale cultivation	0.176	2	0.352	2	0.352	2	0.352	3	0.528
3. Sorghum products are being chosen for domestic and foreign markets	0.137	4	0.548	2	0.274	2	0.274	2	0.274
4. The development of adaptive varieties reduces production costs	0.118	3	0.354	4	0.472	3	0.354	3	0.354
Threats									
1. Specific sorghum varieties for tidal swamplands are not yet available (bird resistance)	0.098								
2. Extreme weather conditions increase the risk of inundated or dry plants	0.078								
3. Uncertainty about the selling price	0.137								
4. Continuity of production for industrial needs	0.059								
Total Attraction Value (TAS)			3.98		3.45		3.61		3.88
Rank			1		4		3		2

Notes: AS 1 = not important or weakly impacts the strategy; AS 2 = moderately important or has a moderate impact on the strategy; AS 3 = important or has a significant impact on the strategy; and AS 4 = very important or has a strong impact on the strategy.

4. Discussion

4.1. Tidal Swamplands' Potential for Sorghum Development

Government policies have fostered the development of tidal swampland areas to develop agriculture, notably for food crops [10,33,34]. In Central Kalimantan, the growth of crop commodities, particularly sorghum, is aided by the enormous potential land area and the application of site-specific technologies. According to a prior study, sorghum can be grown in wetlands, although it has been noted that its production levels in Asia are still relatively low, at about 1 ton per hectare (t ha^{-1}). However, these production levels can be enhanced by employing sensible land management [35–37].

Similar results were seen in studies in the Central Kalimantan tidal wetland regions. Sorghum seeds can be produced on land adjacent to bare primary water channels at a rate of 3.07 t ha^{-1}. Due to the removal of many constraints present in the swamp areas, including soil acidity, low soil fertility, pyrite presence, soil toxicity, and flood threats during the rainy season, the productivity level is higher than that in earlier research [38,39]. The application of amelioration agents such as lime and organic fertilizers and the management of other inputs, including water management, are examples of land improvement technologies and agricultural methods. This demonstrates that tidal swamplands can be developed for agriculture through wise land and water management. Consequently, these locations could be recommended for food crop commodities [39,40].

The productivity of sorghum farming in tidal swamplands is comparable, if not promising, and can be on par with the productivity in other regions. Sorghum productivity in drylands ranges from 3.0 to 4.0 t ha^{-1}. Tidal waters do not inundate the area, according to observations of the hydrological system at the research site, which is heavily influenced by tidal movements. This area is a type C area in terms of water overflow, meaning that the groundwater levels are below 50 cm and the area does not directly receive tidal overflow but is nonetheless impacted by tidal impacts. Geographically, as depicted in Figure 2, water is still accessible even though the region is considered dry.

The peat layer formerly atop the mineral soil has generally been removed from the type C lands in the research area through reclamation. Due to this, acid sulfate could potentially arise, increasing soil acidity, as indicated by a pH of less than 5. According to basic soil information maps and land system techniques, the research region mainly comprises organic soil with associations such as haplo-hemists, haplosaprists, and endoaquepts. Through changes in the water table, tides indirectly impact the land. Tidal flows fluctuate in tertiary channels rather than flooding the land's surface. Acid-sulfate soils with significant acid damage are predominant in the type C zone's soil. These restrictions may be considered in land management efforts for seasonal crop agriculture [41,42].

Furthermore, effective water management can maximize land use. Water control is used in tertiary canals to keep the cultivated land's water level high enough. Given that the research was conducted on unproductive land, the initial stage of land management entails enhancing the soil's physical characteristics, including its texture, structure, moisture content, drainage, and porosity. Technically, soil cultivation with agricultural equipment attempts to loosen the soil so that roots can enter the top soil layer and the plant roots can absorb nutrients.

This study's intriguing discovery is that small groups inhabit the productive lands along the river channels. This suggests that one of the variables promoting sorghum development can be considered to be the availability of human resources. Due to their geographic dispersion, these farmed lands are mainly distributed in concentrated locations. Specific location-based agriculture policies should be developed to increase agricultural competitiveness [43].

4.2. Economic Aspects of Sorghum in Tidal Swamplands

4.2.1. Feasibility Analysis of Sorghum Farming in Tidal Swamplands

The research findings explain that sorghum cultivation in tidal swamplands is economically feasible, with an R/C (return on cost) ratio of 1.73 and a B/C (benefit-cost) ratio of 0.73. Based on the R/C ratio, sorghum cultivation in Central Kalimantan's tidal swamplands is considered efficient as the R/C value is more significant than one, indicating that the returns from total farming costs exceed the investment. Similarly, based on the B/C ratio, for every IDR 1 spent by farmers on sorghum cultivation, the return on investment is IDR 0.73, indicating a 73% return.

The cash income from sorghum farming increases when labor costs involve family labor. The profitability of sorghum farming also improves when the sorghum crop residues are utilized as animal feed during the dry season. Sorghum farming combined with the production of sorghum residues using a planting distance of 60 × 10 cm provides the highest profit of USD 1233.80 per hectare (R/C: 2.86), while the lowest profit is obtained with a planting distance of 70 × 20 cm, amounting to USD 305.53 per hectare (R/C: 1.51). Sorghum residues can be ensiled through fermentation to enhance nutrition, economic value, and storage stability, thus providing animal feed during the dry season and increasing farmers' income [44].

Although the R/C ratio indicates the efficiency of sorghum farming in tidal swamplands, the B/C ratio being less than one indicates that the economic benefits are still relatively low or not optimal. Therefore, more effective measures are needed to improve sorghum productivity to optimal levels.

Sorghum farming with a B/C ratio greater than one is generally observed in dryland sorghum farming [45]. In another analysis of sorghum farming feasibility in the Pleret sub-district, Bantul Regency, in 2019, the B/C ratio was 1.43 and the R/C ratio was even higher, reaching 4.55 in the Kebun Pedes sub-district, Sukabumi Regency [46].

The break-even point (BEP) for sorghum prices is reported to be USD 0.16 kg^{-1}, which is lower than the actual price (USD 0.28 kg^{-1}), indicating that sorghum farming in tidal swamplands has an added value of USD 0.11 kg^{-1}. The BEP for sorghum production is 1778 kg ha^{-1}, which is lower than the actual production (3070 kg ha^{-1}), indicating an additional production value of 1282 kg ha^{-1}. Based on the added value of price and production, the tolerance value for changes in sorghum price and production in the tidal swamplands in Central Kalimantan is considered efficient, with a value of 41.75%. The higher the percentage of the tolerance value, the more efficient the farming practice [47].

4.2.2. Competitive Advantages of Sorghum in Tidal Swamplands

The competitive analysis results indicate that sorghum, with technological innovation (the use of new varieties), can achieve similar profits to other crops (sweet potato and soybean) cultivated by farmers using traditional methods at minimum production levels of 2421.64 kg ha^{-1} and 2568.67 kg ha^{-1}, respectively. This means that with sorghum production reaching 76% of the actual production, it can compete with the actual production of sweet potatoes (84%), and soybeans. However, sorghum farming with some new, improved varieties cannot compete with the production of maize, even if the minimum production achieved is 4083.55 kg ha^{-1}, 133% of the actual production.

Sorghum cultivation during the 2022 dry season was more competitive than other food commodities or competitors (sweet potato and soybean), except for maize (with a Q value of 1.33). The adaptation of sorghum in Central Kalimantan's tidal swamplands has a competitive advantage over several other food crops (cassava, peanuts, and soybean), the region's second-most essential commodity after rice. This indicates that sorghum farming in tidal swamplands has economic potential for development and can increase income and provide a food source for families. Sorghum has not been widely cultivated in Central Kalimantan's tidal swamplands; however, it has a promising prospect for development. The available land area is extensive, and other studies have shown that sorghum can thrive in less fertile and low pH conditions, typical of swamplands [48]

Farmers in tidal swamplands not only face internal challenges, such as land conditions and limited farming capital, but also external challenges, including the lack of supporting factors such as infrastructure, rural economic institutions (financing and marketing), extension intensity, and necessary government policies to encourage agricultural development and improve farmers' access. Farmers are also hesitant to develop sorghum farming in tidal swamplands due to the absence of a market, which needs to be addressed to establish competitive sorghum farming that produces high-quality and sustainable products, among other things, through allocative and technical efficiency in sorghum farming [49,50]. One approach could be encouraging farmers to collectively manage their businesses through cooperatives to achieve more advanced and competitive agriculture. Placing farmer cooperatives as economic drivers in the region is the key to achieving advanced, independent, and modern agriculture in Indonesia [51]. Incorporating farmers into cooperatives can be achieved by increasing the scale of farming operations, enhancing competitiveness, and implementing upstream-to-downstream industrialization while optimizing existing resources and community institutions.

4.2.3. Sensitivity of Sorghum Farming in Tidal Swamplands

The results of the sensitivity analysis on sorghum farming in tidal swamplands in Central Kalimantan to the utilization of subsidized fertilizers led to a reduction in the input prices and an increase in income from 41.75% to 51.15%, or an increase of 9.40%, even though the crop yields and sorghum prices were fixed (Scenario 1). This can also be seen from the increased R/C value. In scenario 2, the use of non-subsidized fertilizers on sorghum farming in tidal swamplands while crop yields and sorghum prices remained fixed caused increased input prices, resulting in decreased income from 41.75% to 21.72%, or a decrease of 20.03%. When the R/C value is greater than 1, farming is still feasible and provides benefits to farmers, though small. In scenario 3, the use of subsidized fertilizer in sorghum farming causes a reduction in input prices. However, sorghum prices decreased by 20% despite the fixed yields. As a result, income decreased from 41.75% to 38.94%, or a decrease of 2.81%. However, the R/C value is still more than 1, meaning that it still benefits farmers, although the price of sorghum is reduced by 20%. In scenario 4, using non-subsidized fertilizers while crop yields remained fixed and sorghum prices decreased by 20% caused increased input prices. As a result, income decreased from 41.75% to 97.85%, or a reduction of 39.60%. The R/C value on sorghum farming broke even (no profit or loss) due to an increase in the input value accompanied by a decrease in the output value by 20%, even though the value of the other (production) outputs remained fixed.

Based on the sensitivity analysis of sorghum farming in the tidal swamplands in Central Kalimantan with increased fertilizer prices and a decrease in sorghum prices of 20% from the actual price, the following can be concluded: (1) Sorghum farming in tidal swamplands provides better profits for farmers and can be developed sustainably by using subsidized fertilizers; however, the amount of production should not decrease, and sorghum prices should not decrease by more than 20% compared with the current (existing) conditions. (2) Farmers can continue sorghum farming in tidal swamplands by utilizing non-subsidized fertilizers. However, production has to remain the same, and sorghum prices cannot decrease by more than 20% compared with the current (existing) conditions. The results of this study are in line with those of a previous study, which stated that based on the results of a sensitivity analysis in which the farming input costs were increased (increase in fertilizer prices by 20%) and the Arabica coffee selling price was decreased in Simalungun Regency, sorghum farming is still feasible to pursue [52].

4.3. Development Strategies for Sorghum in Tidal Swamplands

The strengths, weaknesses, opportunities, and threats (SWOT) analysis was performed to determine the strengths of sorghum development in the tidal swamplands of Central Kalimantan and to provide guidelines for minimizing the weaknesses and risks and for improving sorghum development. Examples of studies on sorghum development using a SWOT analysis include those undertaken in [28,53,54]. We used a combination of the SWOT and QSPM methods in our study. As a result, the strategic priorities have been formulated based on the highest TAS value and the last sequence with the lowest TAS value.

The first strategy is to increase production by optimally utilizing available swampland resources, technological innovation, human resources, and market potential, with a final TAS score of 3.98. The availability of land resources is an essential factor for developing agricultural commodities because land is the main production factor. Therefore, the program to expand the planting area by developing sorghum plants in tidal wetlands is a strategic one considering the significant potential of the tidal swamplands in Central Kalimantan. The potential for swamplands that have yet to be utilized in Central Kalimantan is more than half a million hectares, while the planting index is still below one; therefore, the existing plant area does not need to be replaced. Sorghum can be used in crop rotations on suboptimal lands, such as lands with soil conditions that are less fertile, have high acidity, have high salinity, or are flooded. The cultivation technique is almost the same as maize; therefore, it is already familiar to farmers. The cultivation and processing of sorghum can be carried out on a small scale and will become an option for small farmers to contribute to food security at the household level.

The development of adaptive types significantly tolerant to high acidity and iron toxicity will reduce production costs, such as ameliorants and fertilizer applications. Breeding efforts in this direction must continue to be improved, along with innovations in various cultivation technologies, to increase sorghum production in tidal swamplands.

The strength of sorghum products lies in their nutritional content, which can be compared with that of rice, wheat, and maize in terms of carbohydrates, protein, fat, and vitamins. In addition, it does not contain gluten (gluten-free), contains antioxidants, and has a low glycemic index, making it the best solution for consumers allergic to gluten, especially children. It can be used for various industrial products such as sorghum sugar, soy sauce, noodles, and pastries. However, the market is new and growing. Sorghum-based entrepreneurial opportunities in the future will be vast, starting with planting cultivars from which the products match market demand. The central government must make it a national movement, socialize its nutritional content and health benefits, and provide digital marketing training to open new markets for sorghum products as an alternative food.

The next strategy is to increase productivity and processed products by optimizing land resources, technological developments, and government policies to reduce wheat imports, with a final TAS score of 3.88. Sorghum productivity has the potential to be increased because sorghum has wide adaptability [55,56], and sorghum cultivation technology innovations in Indonesia are also continuing to develop. The average world sorghum productivity is 2.7 t ha^{-1}, and the highest is in the Americas, 3.7 t ha^{-1} [57]. In Indonesia, with 5 t ha^{-1} of organic fertilizer, 100 kg ha^{-1} of urea fertilizer, 50 kg ha^{-1} of SP36, and 20 kg ha^{-1} of KCl, sorghum productivity can reach 4.12 t ha^{-1} [58]. Processed products made from sorghum as the primary raw material provide opportunities for food diversification and increase added value for farmers. This success allows the government to issue policies to suppress wheat imports.

The third strategy is to increase and maintain production continuity by utilizing farmers' potential for land, technology, and human resources, with a final TAS score of 3.61. Several strategies can be used: (1) conducting intensification and extensification of agricultural land to meet the needs of raw materials; (2) conducting thorough soil and climate assessments to determine optimal planting times and suitable sorghum varieties for each region; (3) collaborating with agricultural research institutions to develop and distribute high-yielding and disease-resistant sorghum varieties; (4) introducing precision agriculture techniques, such as GPS-guided planting and data-driven irrigation management, to optimize resource usage; (5) promoting technological innovation and institutional innovation to accelerate the delivery and adoption of secondary products of sorghum (i.e., bioethanol); (6) developing a secondary product industry cluster that is supported by the infrastructure cluster; (7) organizing workshops, field demonstrations, and training sessions on modern sorghum cultivation techniques; (8) empowering farmers with knowledge about sustainable practices, pest management, and post-harvest handling; (9) establishing partnerships with financial institutions to provide affordable credit for purchasing quality seeds, fertilizers, and technology; (10) creating partnerships with local markets, food processors, and value-added product manufacturers to ensure a consistent demand for sorghum; (11) promoting soil conservation techniques, such as cover cropping and minimal tillage, to maintain soil fertility and structure; and (12) Encouraging the use of organic matter and compost to enrich the soil [59].

The last strategy is to optimize the utilization of sorghum plant waste as animal feed. Sorghum has the potential to be used as ruminant animal feed because it produces forage and grain with a final TAS score of 3.45. Sorghum stems and leaves can be silage-based ruminant feed [60]. For example, heifers fed 65% sorghum silage were able to produce rumen fermentation, VFA, rumen pH, digestibility, and feed efficiency values that were higher than 55, 75, and 85% [61]. Furthermore, goats fed sorghum silage can increase production by up to 30% [62]. Thus, the opportunity to use sorghum as animal feed is very much open because the nutritional content in the stems and leaves of sorghum is almost equivalent to that of elephant grass, which was previously famous as a ruminant feed ingredient [63]. Sorghum seeds can be used as a poultry feed ingredient by paying attention to their tannin content and can even substitute the use of maize in feed rations for chickens, ducks, goats, cattle, and pigs without causing side effects [63]. The addition of sorghum seeds to feed also effectively increases feed consumption and feed digestibility in cattle [64,65].

5. Conclusions

About 578,511 ha of tidal swamplands in central Kalimantan are suitable for sorghum cultivation and have a productivity comparable with that of other regions, provided that necessary measures such as effective water management, soil amelioration, and fertilization are taken. Sorghum farming in tidal swamplands is feasible, efficient, and more competitive than other non-rice crops such as cassava, sweet potato, and soybean, but less competitive than maize.

Four priority alternative strategies were obtained for developing sorghum in tidal swamplands: (1) increasing production by optimally utilizing available swampland resources, technological innovation, human resources, and market potential; (2) optimizing the utilization of sorghum plant waste as animal feed; (3) increasing and maintaining production continuity by utilizing the potential of the land, technology, and human resources for farmers; and (4) increasing productivity and processed products by optimizing land resources, technological developments, and government policies to reduce wheat imports. The findings of this study can assist policymakers in promoting sustainable sorghum production and can guide researchers to focus on specific improvements in swamp-tolerant sorghum cultivars.

Author Contributions: Conceptualization, S.S. (Susilawati Susilawati), Y.S., E.E., A.B., T.L, A.A., M.H., D.P.W., R.Q., S.L. and Y.R.D.; Methodology, S.S. (Susilawati Susilawati), Y.S., E.E., A.B., T.L., S.S. (Syafruddin Syafruddin), A.A., W.A.N., M.H., D.P.W., N.S., B.B., B.S., M.S., K.S., R.Q., Y.R.D., S.L. and E.N.T.; Software, W.A.N., D.P.W., M.S. and S.L.; Validation, S.S. (Susilawati Susilawati), Y.S., E.E., A.B., S.S. (Syafruddin Syafruddin), M.H., N.S., B.B., M.S., S.L. and E.N.T.; Formal Analysis, Y.S., E.E., A.B., T.L., S.S. (Syafruddin Syafruddin), A.A., W.A.N., D.P.W., N.S., B.B., B.S., M.S., K.S., R.Q., Y.R.D. and E.N.T.; Investigation, Y.S., E.E., S.S. (Syafruddin Syafruddin), N.S., M.S. and Y.R.D.; Resources, S.S. (Susilawati Susilawati) and Y.R.D.; Data Curation, S.S. (Susilawati Susilawati), Y.S., A.B., T.L., S.S. (Syafruddin Syafruddin), A.A., W.A.N., M.H., N.S., B.B., B.S., R.Q., Y.R.D. and E.N.T.; Writing—original draft, S.S. (Susilawati Susilawati), A.B., T.L., A.A., D.P.W., R.Q. and S.L.; Writing—review and editing, S.S. (Susilawati Susilawati), Y.S., E.E., S.S. (Syafruddin Syafruddin), W.A.N., M.H., N.S., B.B., B.S., M.S., K.S., Y.R.D. and E.N.T.; Visualization, A.B., M.H. and K.S.; Supervision, S.S (Susilawati Susilawati), E.E., S.S. (Syafruddin Syafruddin), M.H., N.S., B.B., B.S., M.S., K.S., R.Q., S.L. and E.N.T.; Project administration, T.L., D.P.W., B.B., R.Q. and E.N.T.; Funding Acquisition, S.S. (Susilawati Susilawati), Y.S., E.E., A.B., T.L., S.S. (Syafruddin Syafruddin), A.A., W.A.N., M.H., D.P.W., N.S., B.B., B.S., M.S., K.S., R.Q., Y.R.D., S.L. and E.N.T. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Research and Innovation Agency of Indonesia through the Research Organization for Agriculture and Food through a research project titled Adaptation Test and Biomass Yield of Several Varieties of Sorghum on Unproductive Land Along the Primary Canal of the Food Estate Area, grant number B-3973/III.11/HK.01.01/10/2022.

Data Availability Statement: The data presented in this study are available from the corresponding author upon request.

Conflicts of Interest: The authors declare no conflict of interest.

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