RISK MANAGEMENT IN RICE FARMING USING HYBRID FMEA-AHP: A CASE STUDY FROM HAMPARAN PERAK, INDONESIA

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Highlight

This article presents to use of Hybrid FMEA-AHP for risk management in Rice Farming: An Indonesian Case Study from Hamparan Perak.

Abstract

Background and Objective: Climate change poses significant risks to the continuity of rice farming, necessitating precise risk management efforts. This study aims to analyze and prioritize risks in rice farming associated with climate change. **Materials and Methods**: Conducted on a micro-scale in Hamparan Perak District, Deli Serdang Regency, Indonesia, this research engaged two experts in risk analysis and assessment. The methodology combined Failure Mode and Effect Analysis (FMEA) with Risk Priority Number (RPN) calculations and integrated the Analytic Hierarchy Process (AHP) to enhance analysis accuracy. The research focused on production and cost risks, identifying 41 relevant failure modes. **Results**: The findings include a prioritized risk ranking based on RPN calculations multiplied by AHP relative weights. The four priority risks identified were: 1. Strong Winds: During the generative stage, strong winds knock down rice plants, severely impacting production. 2. Fertilizer Shortage: A shortage during the vegetative phase increases costs. 3. Floods during the Generative Period: Flooding damages the grain, reducing quality and lowering selling prices. 4. Floods during Vegetative Phase. This results in substantial damage to the rice plants. **Conclusion**: These results highlight the importance of targeted risk management strategies to mitigate the impacts of climate change on rice farming.

Keywords

Climate change; Risk management; Failure mode and effect analysis; Analytic hierarchy process; Rice farming

Introduction

The food sector is threatened by climate change so farmers must adapt to conditions that are difficult to predict [1]. Climate change is a serious challenge and has a major impact on agriculture [2,3]. Therefore, the impact of climate change cannot be underestimated for the sake of sustainable development [59,52]. In the food sector, efforts should focus on managing identified agricultural risks[2]. Because risk is a basis that is very much considered in development and investment in various fields, including agribusiness development[6]. Risks generally lead to loss of crops, income, and even disasters [6,7,4].

Rice is an agricultural commodity that is vulnerable to climate change [8]. Climate fluctuations affect rice production [9] and also farmer income [2]. The farmers themselves have also understood this influence [53]. Weather, for example, is a source of risk that reduces rice productivity [8,10]. A decrease in productivity directly or indirectly impacts the welfare of farmers and food availability in a region [11]. This is like a domino effect on the sustainability of rice farming, because the welfare of agriculture is an important factor for the long-term sustainability of agricultural businesses [12,5].

Therefore, it is important to implement risk management in response to climate change in rice farming [13]. The application of risk management is intended to order the focus of management efforts based on prioritized risks

[14,53]. A well-known tool for identifying and prioritizing risks is Failure Mode and Effect Analysis / FMEA [16,15]. The order of risks is sorted based on a risk score called Risk Priority Number (RPN).

However, as research has progressed, some literature has revealed significant weaknesses in the FMEA tool. For example, some risks can have the same RPN magnitude and the variable index multiplication in RPN is equally important, but in practice everything is different [17]. The RPN calculation in FMEA is considered simple and inadequate to reflect expert opinions [18] and other weakness-related expressions in their articles [16,19,55]. To overcome these weaknesses, it is necessary to develop methods for analyzing risks [3]. So, in this article, a risk analysis was performed through hybridization between RPN FMEA and the Analytic Hierarchy Process (AHP). Through the hybrid RPN FMEA with AHP, this research will find a new, more accurate ranking for the identified risks, so that risk management recommendations can be formulated according to the level of importance of each risk.

Materials and Method

This research was conducted in 2023, the duration of the research was six months, namely June to November year 2023.

Research Location

This study was conducted at the micro scale in Hamparan Perak Sub-district, Deli Serdang District, North Sumatra, Indonesia. This area was purposively selected because it is a center of rice production and vulnerable to climate change. [20] This region has an average altitude of only about 7 meters above sea level. Judging from its position, this area has a strategic role, especially as one of the suppliers of rice food to the surrounding cities (Medan City and Binjai City).

Data and Data Collection Methods

At the beginning of the study, 12 informants were recommended by local agricultural extension workers. They are a combination of agricultural extension workers who are active in rice commodities in Hamparan Perak District, farmers who have knowledge of rice plant science and experience in rice farming in the area. Through discussions with 12 informants and considering the criteria of the respondents needed, two experts were obtained who met the criteria. The two experts used in this study represent good knowledge and experience related to rice plant science and rice farming management.

The data used in this study is qualitative data obtained from two experts. Respondents were determined purposively, i.e. those interested in rice farming in the research area and willing to be involved in answering research questions. The respondents engaged in this study were considered experts and relevant to the research needs. They consisted of a rice agricultural extension worker and an agricultural graduate who served as the head of a rice farmer group and had about 10 years of experience in rice farming.

A questionnaire that had been prepared was given to the respondents, first an FMEA questionnaire and then an AHP questionnaire. The FMEA questionnaire is used to calculate RPN. The RPN is the result of multiplying the Severity (S), Occurance (O) and Detection (D) variables using a scale of 1 – 10 [21,22]. The scale-filling guide for each risk was shown in Table 1.

Table 1: Severity (S), Occurance (O) and Detection (D) variables guidelines in FMEA

Rank	Severity (S)		Occurance (O)		Detection (D)	
	Effect	**Description**	**Effect**	**Description**	**Effect**	**Description**
1	No	No impact	Almost never	Has not happened until now	Almost never	Easy and proven detection method
2	Very Slight	Farmers are not disturbed	Remote	Ever but very rarely	Very high	Detection method performed with computer aided tools
3	Slight	Farmers are a little distracted	Very slight	Events and failures are very rare	High	Solution is still initial modeling
4	Minor	Causes minor annoyance	Slight	Happened several times	Moderately high	There is a detection model but it is still being tested
5	Moderate	Some farmers suffered losses	Low	Occurs a few times and little impact	Medium	Model available but still in pre-production
6	Significant	Farmers beware	Medium	Some events have had an impact	Low	The detection method has been tested on similar cases
7	Major	Farmers experience losses	Moderately high	Several times occurred and the impact is moderate	Slight	Tested on a small scale
8	Extreme	Farmers are severely disadvantaged	High	Multiple occurrences and high impact	Very slight	Still in detection method testing
9	Serious	Potentially harmful	Very high	Frequent and moderate impact	Remote	Methods available but unproven
10	Hazardous	Harmful	Almost certain	Frequent and very high impact	Almost impossible	No solution for detection

The AHP questionnaire was used to calculate the new relative weights for each risk. The scale used in the AHP questionnaire was adapted from Saaty who is the expert who originated this method [23,24]. The scale and its definition can also be seen in the article Gómez et *al* [60]. To simplify the work, we converted the respondents' answers into digital data on the computer. [28]

Data Analysis Method

In this research, first analysis is used the FMEA method. FMEA is a tool to identify potential failures in various sectors [19,20]. Various articles have revealed the steps involved in using FMEA, briefly identifying risks and risk sources or failure modes, calculating risks based on RPN and prioritizing risks starting from the highest RPN [16,19]. RPN is a multiplication function of S, O, D (see Table 1).

$$RPN_i = S_i \times O_i \times D_i \qquad (1)$$

The RPN-FMEA method needs to be evaluated using a relative weighting method to be more accurate [16,20], so in this study, the RPN is evaluated with AHP. Some previous literature that overcomes the limitations of RPN uses AHP for risk analysis on an application technology [55,29], and also simulations in other sectors [26,27].

AHP was developed by Thoma L Saaty to select the best alternative by considering several criteria [23,63]. AHP principles are used to identify criteria in the selection through weighting to obtain a ranking [29,30]. AHP can even evaluate the consistency of input from decision makers [61,25]. In AHP calculations, the maximum inconsistency index is 0,1 [23,31]. AHP stages briefly start by defining the problem in the hierarchy, filling in the comparison matrix and calculating the relative weight [61,32]. In this study, to simplify the analysis, we used the super decision tool. It should be informed that the value entered into super decision is the geometric mean so that it represents the entire questionnaire with a maximum inconsistency threshold of 0,1 [23,31].

The relative weight which is the output of the AHP calculation using super decision in this study we symbolize with W. After the weight is obtained, the RPN value is then hybridized with W to obtain WRPN.

$$WRPN_i = W_i \times RPN_i \qquad (2)$$

Results

Failure Mode and Effect Analysis (FMEA)

- **Risk Identification**

Risk identification is conducted through discussions with experts. In these discussions, the experts outline the stages involved in rice farming, which include the land preparation stage (symbolized by A), seeding stage (symbolized by B), planting stage (symbolized by C), vegetative maintenance stage (symbolized by D), generative maintenance stage (symbolized by E), and harvesting stage (symbolized by F). At each stage, failure modes and effects closely related to climate change are identified. The results of the risk identification are presented in Table 2.

Table 2: Risk identified

Stages	Criteria	Code	Failure Mode (FM)	Effect	Code
(A)	Production Risk	RP	Rain	Land cultivation delayed due to tractor inoperability	A1
			Drought	Supply of irrigation water and other water reserves is low	A2
	Cost Risk	RC	Post-spraying rain	Costs increase for re-spraying pesticides	A3
			High rain intensity	Herbicide and weed control costs increase	A4
(B)	Production Risk	RP	Rain drenched the seedling area	Seeds are scattered and do not grow optimally	B1
			High rainfall	Mollusca emerges and damages seedlings	B2
			High rain intensity	Damaged embankment and flooding	B3
			Flood flow from outside the region	Sown seeds are submerged or washed away	B5
			Rain washes away fertilizer	Seedlings grow stunted and pale	B7
	Cost Risk	RC	Rain damages seeds	Increased costs for purchasing new seeds and reseeding	B4
			Flooding from outside the region	Additional costs for purchasing new seeds and reseeding	B6
(C)	Production Risk	RP	High rain intensity	Delayed planting resulting in older seedlings	C1
	Cost Risk	RC	Difficult to find labor for planting when the weather improves	Additional costs are incurred to access labor from outside the region	C2
			Rain damages the number of seedlings	Cost of buying seeds from other farmers	C3
(D)	Production Risk	RP	Rain frequency increases	Pest infestation is difficult due to rain	D2
			Fertilizer scarcity	Fertilization is delayed and available when rainfall intensity is high	D4
			Flood	Rice plants submerged and damaged	D7
			Flooding from outside the region	Rice plants submerged and damaged	D9
			Long dry season	Water supply is low so plants are disrupted	D11
	Cost Risk	RC	High rainfall	Triggers pest infestation, increasing pest control costs	D1
			Post-spraying rain	Increased costs for pesticide purchase and re-spraying	D3
			Fertilizer scarcity	Increased cost of accessing other fertilizers at the right time	D5
			Intermittent rain and drought	Pesticide costs increased due to increased pest infestation and spraying wages	D6
			Flood	Costs increase for replanting due to damaged paddy	D8
			Flooding from outside the region	Crop damage and increased production costs for replanting	D10
			Long dry season	Increased cost of supplying water to the field using a water pump	D12
(E)		RP	The wind is blowing hard	Damaged rice panicles	E1

Stages	Criteria	Code	Failure Mode (FM)	Effect	Code
	Production Risk		The wind is blowing hard	Rice clumps collapse and overlap each other	E2
			Floods inundate rice paddies	Biji padi rusak dan produksi menurun	E5
			Floods from outside the region inundate rice paddies	Tanaman rusak dan produksi turun	E7
			Weather transition and moist soil conditions	Pest infestation increases and damages grain (unfilled grains)	E10
	Cost Risk	RC	The wind is blowing hard	Additional cost to repair collapsed paddy	E3
			Wind knocks down rice	Uneven maturity resulting in low selling price	E4
			Floods inundate rice paddies	Rice is damaged resulting in low grain selling price	E6
			Floods from outside the region inundate rice paddies	Damaged grain resulting in low selling price	E8
			Intermittent rain and drought	Costs are rising as fertilizer consumption increases due to weather volatility and scarcity	E9
			Weather transition	Pest infestation including birds that damage rice seeds	E11
(F)	Production Risk	RP	Rain during harvest time	Harvest delays and bird pests	F3
	Cost Risk	RC	Sudden rain during harvesting	Wet/moist grain so that the selling price decreases	F1
			Rain soaks the access road	The cost of transporting grain from the harvest location increases	F2
			High rain intensity	Harvest delays, pest attacks resulting in lower revenue	F4

* The code is only used to summarize the description of each item.

Table 2 shows that the identified risks and failure modes consist of two criterias of risks, namely production risk (RP) and cost risk (RC) and 41 failure modes. In the paper of Komarek et.*al* [6,] cost is a component of market risk. The production risk identified 19 failure modes (A1, A2, B1, B2, B3, B5, B7, C1, D2, D4, D7, D9, D11, E1, E2, E5, E7, E10, F3). Cost risk with 22 failure modes (A3, A4, B4, B6, C2, C3, D1, D3, D5, D6, D8, D10, D12, E3, E4, E6, E8, E9. E11, F1, F2, F4).

- **Calculating RPN and Ranking**

RPN is calculated using formula 1. In this case, experts are asked to provide opinions regarding the appropriate scale for S, O, D for each failure mode with the guidance of Table 1. Then calculate the geometric mean to get one scale that represents the answers of both experts[23] and round it up. After that, the risk ranking is sorted based on the highest RPN [17,33].

Table 3: Risk priority number and risk ranking

Stages	Criteria Code	FM Code	Severity (1-10)	Occurance (1-10)	Detection (1-10)	RPN	Rank
(A)	RP	A1	1	3	2	6	33
		A2	5	6	4	120	21
	RC	A3	7	5	4	140	19
		A4	4	2	2	16	32
(B)	RP	B1	7	4	3	84	25 **(1)**
		B2	6	2	2	24	30
		B3	7	2	8	112	23 **(1)**
		B5	7	2	8	112	23 **(2)**
		B7	7	3	1	21	31
	RC	B4	6	2	8	96	24 **(1)**
		B6	6	2	8	96	24 **(2)**

Stages	Criteria Code	FM Code	Severity (1-10)	Occurance (1-10)	Detection (1-10)	RPN	Rank
(C)	RP	C1	4	6	4	96	24 **(3)**
	RC	C2	6	6	4	144	17
		C3	7	3	4	63	25 **(2)**
(D)	RP	D2	8	5	6	240	11
		D4	8	7	4	224	12
		D7	7	6	9	378	7
		D9	8	5	9	360	8
		D11	8	4	4	128	20
	RC	D1	7	5	2	70	26
		D3	7	7	6	294	9
		D5	8	7	8	448	5 **(1)**
		D6	8	7	8	448	5 **(2)**
		D8	7	3	9	189	16
		D10	8	3	9	216	13
		D12	8	6	4	192	15
(E)	RP	E1	8	4	8	256	10
		E2	8	7	7	392	6
		E5	9	7	8	504	4
		E7	9	8	9	648	1 **(2)**
		E10	8	5	5	200	14
	RC	E3	8	8	7	448	5 **(3)**
		E4	8	8	8	512	3
		E6	9	8	8	576	2
		E8	9	8	9	648	1 **(1)**
		E9	7	2	4	56	27 **(1)**
		E11	8	3	5	120	22
(F)	RP	F3	5	5	2	50	28
	RC	F1	8	3	6	144	18
		F2	7	3	2	42	29
		F4	7	4	2	56	27 **(2)**

The risk ranking has been obtained through RPN calculation as shown in Table 3. Based on the calculation results, we found several failure modes that have the same RPN but with different S, O, D scales. This is evidence of the weakness of this method as mentioned by previous researchers[16,19,20]. Therefore, it is important to modify it to obtain a more accurate ranking.

Anayltic Hierachy Process

- **Defining the Problem**

Clarifying the purpose of the problem under study is the first step to start the analysis in both AHP and ANP [34]. At this stage, it has been clarified that the analyzed issue is the management of production and cost risks in rice farming in an effort to respond to climate change so that farming is profitable. The participation of experts in this study was also used to develop a hierarchical relationship of risks that have been identified. Then we input it into the superdecision application as shown in Figure 1.

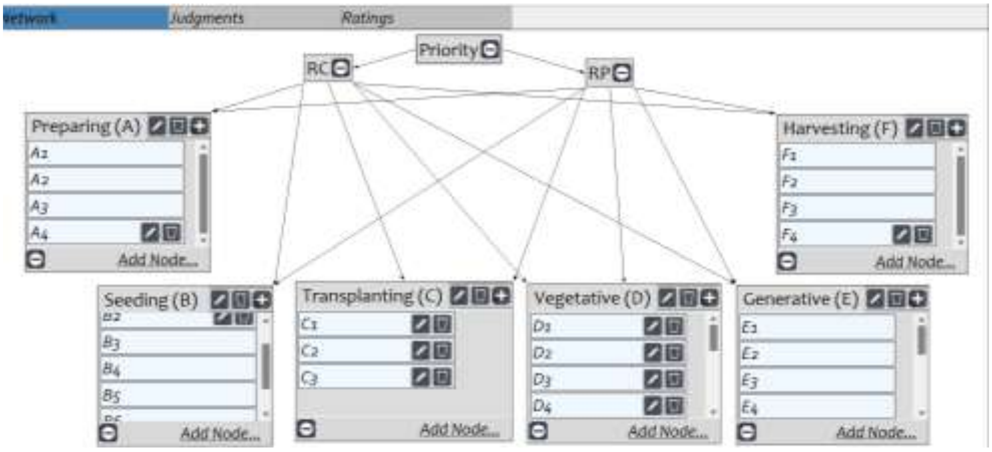

Figure 1. Defining problem with hierarchical model

The creation of a hierarchy aims to define the problem into a simpler and more organized structure. The priority serves as the main objective of the analysis, which is to obtain a decision in the form of prioritized risks. The subsequent level consists of the criteria influencing the decision (Cost Risk/RC and Production Risk/RP), while the lowest level represents the alternatives containing the risks being evaluated. [65]

- **Filling in the Comparison Matrix**

After finding the hierarchy, because we use the application to facilitate the work, the questionnaire that will be given to the expert is designed based on the questionnaire in the super decision application. This can be seen in the "judgments" tab as shown in Figure 1. That tab contains the pairwise comparison questionnaire.

- **Relative Weight Analysis (W)**

Both expert responses are geometrically averaged to obtain an integer number that is entered into the application. After the input process is complete, it is important to control the inconsistency index smaller than 0,1 [23,31].

Table 4: Inconsistency recapitulation

No.	Cluster/Node Comparison	Inconsistency
1.	Cluster comparison with respect to (wrt) Priority	0,00000
2.	Cluster comparison wrt RP	0,04503
3.	Cluster comparison wrt RC	0,05668
4.	Node comparison of preparing (A) wrt RP	0,00000
5.	Node comparison of seeding (B) wrt RP	0,02177
6.	Node comparison of vegetative (D) wrt RP	0,00000
7.	Node comparison of generative (E) wrt RP	0,01265
8.	Node comparison of harvesting (F) wrt RP	0,02365
9.	Node comparison of preparing (A) wrt RC	0,00000
10.	Node comparison of seeding (B) wrt RC	0,00000
11.	Node comparison of transplanting (C) wrt RC	0,00000
12.	Node comparison of vegetative (D) wrt RC	0,00986
13.	Node comparison of generative (F) wrt RC	0,01315

Based on the inconsistency index recapitulation we obtained (Table 4), all indices are lower than 0,1. So this calculation is feasible to continue the relative weight analysis. The results of the relative weight calculation that we obtained using the superdecision application are shown in Table 5.

Table 5: Relative weight (W)

Name	Normalized By Cluster	Limiting
E1	0,02937	0,003960
E2	0,20288	0,027353
E3	0,05533	0,007460
E4	0,05533	0,007460
E5	0,07128	0,009610
E6	0,05533	0,007460
E7	0,07128	0,009610
E8	0,09731	0,013120
E9	0,21492	0,028977
E10	0,12424	0,016751
E11	0,02273	0,003064
F1	0,22318	0,015893
F2	0,38164	0,027177
F3	0,32993	0,023495
F4	0,06526	0,004647
A1	0,10517	0,007645
A2	0,31549	0,022934
A3	0,43451	0,031586
A4	0,14484	0,010529
Priority	0,00000	0,000000
Risk of Cost (RC)	1,00000	0,250000
Risk of Production (RP)	1,00000	0,250000
B1	0,04049	0,001659
B2	0,09200	0,003769
B3	0,22683	0,009293
B4	0,23447	0,009606
B5	0,14489	0,005936
B6	0,23447	0,009606
B7	0,02685	0,001100
C1	0,38004	0,020245
C2	0,41330	0,022017
C3	0,20666	0,011009
D1	0,07034	0,008935
D2	0,16378	0,020805
D3	0,07034	0,008935
D4	0,05459	0,006935
D5	0,17334	0,022019
D6	0,02696	0,003425
D7	0,16378	0,020805
D8	0,11374	0,014448
D9	0,05459	0,006935
D10	0,02696	0,003425
D11	0,05459	0,006935
D12	0,02696	0,003425

- **Calculating WRPN**

After obtaining the FMEA RPN value and relative weight (W) using AHP in superdecison, the WRPN is then calculated using formula 2. We present the results of these calculations in Table 6 below.

Table 6: WRPN and risk ranking

Stages	Criteria Code	FM Code	RPN	Rank RPN	W (AHP)	WRPN	Rank
(A)	RP	A1	6	33	0,10517	0,63102	39
		A2	120	21	0,31549	37,85880	9
	RC	A3	140	19	0,43451	60,83140	5
		A4	16	32	0,14484	2,31744	37
(B)	RP	B1	84	25 **(1)**	0,04049	3,40116	35
		B2	24	30	0,09200	2,20800	38
		B3	112	23 **(1)**	0,22683	25,40496	15
		B5	112	23 **(2)**	0,14489	16,22768	23
		B7	21	31	0,02685	0,56385	40
	RC	B4	96	24 **(1)**	0,23447	22,50912	18 **(1)**
		B6	96	24 **(2)**	0,23447	22,50912	18 **(2)**
(C)	RP	C1	96	24 **(3)**	0,38004	36,48384	10
	RC	C2	144	17	0,41330	59,51520	6
		C3	63	25 **(2)**	0,20666	13,01958	25
(D)	RP	D2	240	11	0,16378	39,30720	8
		D4	224	12	0,05459	12,22816	26
		D7	378	7	0,16378	61,90884	4
		D9	360	8	0,05459	19,65240	21
		D11	128	20	0,05459	6,98752	30
	RC	D1	70	26	0,07034	4,92380	33
		D3	294	9	0,07034	20,67996	20
		D5	448	5 **(1)**	0,17334	77,65632	2
		D6	448	5 **(2)**	0,02696	12,07808	27
		D8	189	16	0,11374	21,49686	19
		D10	216	13	0,02696	5,82336	31
		D12	192	15	0,02696	5,17632	32
(E)	RP	E1	256	10	0,02937	7,51872	29
		E2	392	6	0,20288	79,52896	1
		E5	504	4	0,07128	35,92512	11
		E7	648	1 **(2)**	0,07128	46,18944	7
		E10	200	14	0,12424	24,84800	16
	RC	E3	448	5 **(3)**	0,05533	24,78784	17
		E4	512	3	0,05533	28,32896	14
		E6	576	2	0,05533	31,87008	13
		E8	648	1 **(1)**	0,09731	63,05688	3
		E9	56	27 **(1)**	0,21492	12,03552	28
		E11	120	22	0,02273	2,72760	36
(F)	RP	F3	50	28	0,32993	16,49650	22
	RC	F1	144	18	0,22318	32,13792	12
		F2	42	29	0,38164	16,02888	24
		F4	56	27 **(2)**	0,06526	3,65456	34

Hybrid RPN with AHP has been able to provide a new, more accurate ranking in determining priority risks in this study. The calculations we performed in this study succeeded in prioritizing risks by 97.56%. After the hybrid process was carried out, we still obtained two failure modes that had the same WRPN value, namely local floods and floods coming from other areas.

The ranking results based on the four highest WRPNs are E2, D5, E8, D7. Failure mode E2 is a strong wind that blows when rice enters the generative phase, this knocks down rice and has an impact on rice production. The use of varieties with sturdy stems is one of the appropriate actions. Failure mode D5 is the increased cost of fertilizer due to scarcity of fertilizer in the vegetative phase. E8 is a risk due to flooding that occurs when rice has entered the generative period, resulting in damaged grain so that the selling price falls. While D7 is the risk of flooding that occurs in the vegetative phase and this damages rice plants. [62]

Discussion

The risk identification process carried out in this study supports previous studies such as the article by Sang et.al [22] which also identified risks at each stage carried out by rice farmers on their agricultural land. Based on previous research searches, the results of this risk identification strengthen the research findings in Table 7.

Table 7: Risk identified from previous research

References	Risk
Komarek et.*al* [6]	There are five risks in agriculture which include production risk, market risk, institutional risk, personal risk and financial risk. The majority of studies focus on production risk and only about 15% examine more than one type of risk.
Huang et.*al* [13]	Found that the authors disclosed production risks caused by flooding, drought.
Arifin et.*al* [35]	They examined the production and income risks of rice farmers. Factors that significantly affect production and income are land area, number of seeds, amount of fertilizer and pesticides.
Rath et.*al* [36]	18 risk factors were identified, including weeds, pests, birds, bacteria and viruses, lack of capital, misuse of fertilizers and pesticides, lack of agricultural knowledge. Environmental factors include floods, droughts, weak irrigation systems, lack of government support, and pandemic risk, Increased cost of raw materials (fertilizers, pesticides, improved seeds, and fuel); increased cost of transportation, labor, interest; lack of improved seeds, lack of labor, lack of agricultural equipment and machinery; low price of rice products, lack of market information, uncertainty in the amount of demand and quality of demand
Ulya et.*al* [37]	Risks in farming are caused by inadequate irrigation, poor seedlings, little seed supply, lack of machinery and equipment, scarcity of fertilizers, lack of capital, low grain selling prices, inappropriate policies, complicated bureaucracy, lack of insurance socialization, high labor costs, conversion of paddy fields, fluctuating rice prices, unstable climate, drought, flooding, pest resistance, soil damage due to pesticides and industrial / plantation waste.
Di Falco & Bulte [38]	Rising temperatures and rainfall risk depressing rice yields in many developing countries

The results of the analysis show that the four top priority risks are crop damage due to strong winds that disrupt production, increased costs due to fertilizer scarcity, and flooding that inundates rice during the generative period so that the selling price of paddy falls and during the vegetative period which adversely affects production. [52]

This research has obtained a new risk ranking which is the result of a hybrid FMEA with AHP. FMEA is recognized as a risk prevention-based management instrument in the future[19]. AHP can be used to improve the accuracy of FMEA [25,29].

Strong winds are indeed a threat to rice farmers in the research area. Facts about this news can be seen in Appendix 1. Strong winds are not only about the collapse of rice plants, they can cause huge economic losses for farmers [39]. Strong winds in the generative phase can also cause rice grains to fall and not be filled but can be treated through the selection of the right genotypes/varieties [40], or adjusting the rice spacing [41].

The second priority risk is increased costs due to scarce fertilizer. The same was found by Suryani et.*al* [15], but in cassava farming. Flooding is a serious threat to rice in many places [42]. Fertilizers and flooding are related to nutrients and water in rice fields. Nutrient and water management are important steps in dealing with climate change in rice farming [9]. Nutrients are about fertilizer availability while water is about irrigation, rivers, and storage ponds, and is closely related to the role of the government as a stakeholder. Based on supporting information in the field, the support of irrigation channels and sturdy embankments is essential for rice farming. Often, floods damage rice crops due to damage to embankments caused by high water discharge. Crop damage due to flooding is followed up by farmers by replanting [13]. While prevention can be through the use of varieties with a high level of tolerance to flooding [42].

Our research area is one of the rice producing areas and plays an important role in supporting food supply to Medan City and its surroundings. It is important to improve the capacity of the agricultural sector in the region to respond to weather shocks and design strategies to mitigate the adverse impacts of climate change [38]. Interventions should not only focus on agronomic aspects, but also be integrated with economic aspects [13] and of course a joint commitment is needed in facing all threats that hit food and energy [44,58].

The risk analysis in this study is expected to have an impact on structured risk management policies in developing better rice farming in the study area. The integration of each party is needed in managing risks as we have analyzed. The first action is that agronomic researchers, agricultural extension officers and rice farmers can discuss varieties that have resistance to strong winds and jointly organize a planting schedule that matches the weather forecast in the local area [45]. As for fertilizer scarcity and flooding issues, the government's participatory approach is a key factor. Climate change adaptation should not only discuss what the impact is, but each party works together to analyze when the case or change occurs in the future[46]. Priority setting to deal with uncertainty should be iterative and not limited to one-time setting [48-57].

This research has been conducted using the well-known FMEA method to analyze risks in various sectors. We have also tried to reduce the limitations of this method through hybrid FMEA with AHP so that the analysis results obtained are more accurate. [54,50] As a result, this research has successfully obtained a new ranking of priority risks as described.

Conclusions

Through the hybrid FMEA and AHP, this study concludes that the priority risks in this study are in order starting from the risk due to strong winds that knock down rice plants in the generative period, then the scarcity of fertilizers that occur in the vegetative phase of rice plants, then the problem of flooding whose management efforts are closely related to government support through a good irrigation system. This research has found risk priorities, but this risk prioritization should not only be done once and in Hamparan Perak regency only, but repeatedly to obtain a more updated strategy formulation and developed in other areas.

Acknowledgments

We would like to express our gratitude to the Ministry of Education and Culture for providing funding for this research through a fundamental research scheme with master contract number 177/E5/PG.02/00.PL/2023, contract number 022/LL1/AL.04.03/2023; 092a/LPPMUMNAW/B.06/2023. We would also like to thank LLDIKTI Wil. 1 and LPPM Universitas Muslim Nusantara Al-Washliyah as well as parties who have contributed to the implementation of this research.

Author Contributions

The first author is the party who develops ideas, collects data and digitizes research data and analyzes it, collects review literature, composes narratives and interpretations in the manuscript and is responsible for responding to reviewer comments. Meanwhile, the second and third authors contributed to developing ideas, helped collect data, especially during interviews and analyzed it using applications, collected relevant literature, reviewed the manuscript and assisted in responding to comments from reviewers.

Conflict of interest: The authors stated no conflict of interest.

Appendix 1

Link of the news about strong winds disrupting rice crops in Deli Serdang Regency

Source 1: https://tanamanpangan.pertanian.go.id/detil-konten/berita/360

Source 2: https://medanheadlines.com/2020/08/14/dilanda-angin-kencang-ribuan-hektar-padi-di-deli-serdang-rusak/

References

[1] Lu, B., & Louis, G. (2024). Portfolio Agriculture: A Model for Resilient Regional Agricultural Planning. *Research on World Agricultural Economy,* 5(4)*, December 2024*, 128–136. https://doi.org/10.36956/rwae.v5i4.1200

[2] Rite, A., & Abnave, V. (2024). Rainfall Variability, Risk, and Resilience: A Comparative Study of Insured vs. Non-Insured Farmers in Maharashtra, India. *Research on World Agricultural Economy*, 1-15. https://doi.org/10.36956/rwae.v5i4.1138

[3] Zandi, P., Rahmani, M., Khanian, M., & Mosavi, A. (2020). Agricultural risk management using fuzzy TOPSIS analytical hierarchy process (AHP) and failure mode and effects analysis (FMEA). *Agriculture*, *10*(11), 504. https://doi.org/10.3390/agriculture10110504

[4] Rahim., & Robbi. (2024). Scalable Architectures for Real-Time Data Processing in IoT-Enabled Wireless Sensor Networks. *Journal of Wireless Sensor Networks and IoT* 1(1) 28-31.

[5] John, B., & Ghate, A. D. (2024). Digital Risk Management: A Study of How Firms Mitigate Digital Risks and Threats. *Indian Journal of Information Sources and Services*, *14*(4), 16–21. https://doi.org/10.51983/ijiss-2024.14.4.03

[6] Komarek, A. M., De Pinto, A., & Smith, V. H. (2020). A review of types of risks in agriculture: What we know and what we need to know. *Agricultural Systems*, *178*, 102738. https://doi.org/10.1016/j.agsy.2019.102738

[7] Wauters, E., Van Winsen, F., De Mey, Y., & Lauwers, L. (2014). Risk perception, attitudes towards risk and risk management: evidence and implications. *Agricultural Economics-Zemedelska Ekonomika*, *60*(9), 389-405. https://doi.org/10.17221/176/2013-AGRICECON

[8] Pokhrel, P., Dhakal, D., Gauchan, D., Panta, H., & Mainali, R. P. (2021). Impact of climate change on rice production: an empirical study in Kaski and Nawalparasi, Nepal. https://doi.org/10.3126/janr.v4i1.33229

[9] Van Oort, P. A., & Zwart, S. J. (2018). Impacts of climate change on rice production in Africa and causes of simulated yield changes. *Global change biology*, *24*(3), 1029-1045. https://doi.org/10.1111/gcb.13967

[10] Yang, X., & Entebang, H. (2024). Unveiling the Dynamics of Entrepreneurial Leadership and Radical Innovation Performance of China Internet SMEs: Resource-based View. *Journal of Internet Services and Information Security, 14*(4), 67-85. https://doi.org/10.58346/JISIS.2024.I4.004

[11] Nuraisah, G., Andriani, R., & Kusumo, B. (2019). Dampak Perubahan Iklim Terhadap Usahatani Padi Di Desa Wanguk Kecamatan Anjatan Kabupaten Indramayu [*Impact Of Climate Change On Paddy Farming In Wanguk Village Anjatan Subdistrict Indramayu District*]. *Mimbar Agribisnis: Jurnal Pemikiran Masyarakat Ilmiah Berwawasan Agribisnis, 5*(1), 60-71. http://dx.doi.org/10.25157/ma.v5i1.1639

[12] Andrejovská, A., & Glova, J. (2022). Sustainability of Farms in EU Countries in the Context of Income Indicators: Regression Analysis Based on a New Classification. *Agriculture, 12*(11), 1884. https://doi.org/10.3390/agriculture12111884

[13] Huang, J., Wang, J., & Wang, Y. (2015). Farmers' adaptation to extreme weather events through farm management and its impacts on the mean and risk of rice yield in China. *American Journal of Agricultural Economics, 97*(2), 602–617. https://doi.org/10.1093/ajae/aav005

[14] Baccarini, D., & Archer, R. (2001). The risk ranking of projects: A methodology. *International Journal of Project Management, 19*(3), 139–145. https://doi.org/10.1016/S0263-7863(99)00074-5

[15] 15.Prasanna, D. S. J. D., Punitha, K., Shrividya, G., Haval, A. M., & Vij, P. (2024). An Optimized and Cost - Effective Resource Management Model for Multi - Tier 5G Wireless Mobile Networks. *Journal of Wireless Mobile Networks, Ubiquitous Computing, and Dependable Applications, 15*(3), 136-149. https://doi.org/10.58346/JOWUA.2024.I3.010

[16] Pandey, A. K., Sharma, R. K., Pandey, A. K., & Sharma, R. K. (2017). FMEA-based interpretive structural modelling approach to model automotive supply chain risk. *International Journal of Logistics Systems and Management, Inderscience Enterprises Ltd, 27*(4), 395-419. https://doi.org/10.1504/IJLSM.2017.085221

[17] Balaraju, J., Govinda Raj, M., & Murthy, C. S. (2019). Fuzzy-FMEA risk evaluation approach for LHD machine-A case study. *Journal of Sustainable Mining, 18*(4), 257–268. https://doi.org/10.1016/j.jsm.2019.08.002

[18] Mandal, S., & Maiti, J. (2014). Risk analysis using FMEA: Fuzzy similarity value and possibility theory based approach. *Expert Systems with Applications, 41*(7), 3527–3537. https://doi.org/10.1016/j.eswa.2013.10.058

[19] Dhote, S. N., Vichoray, C. R., Karmore, P. Y., & Uparkar, S. S. (2024). Enhancing the Failure Mode and Effects Analysis Risk Prioritization Model Using Conservative Method Based on Enterprise Resource Planning Implementation. *Nanotechnology Perceptions, 20*(6). https://doi.org/10.62441/nano-ntp.vi.1026

[20] Xiao, N., Huang, H. Z., Li, Y., He, L., & Jin, T. (2011). Multiple failure modes analysis and weighted risk priority number evaluation in FMEA. *Engineering Failure Analysis, 18*(4), 1162–1170. https://doi.org/10.1016/j.engfailanal.2011.02.004

[21] Kavitha, M. (2024) Environmental Monitoring Using IoT-Based Wireless Sensor Networks: A Case Study. *Journal of Wireless Sensor Networks and IoT, 1*(1), 32-36.

[22] Sang, A. J., Tay, K. M., Lim, C. P., & Nahavandi, S. (2018). Application of a genetic-fuzzy FMEA to rainfed lowland rice production in sarawak: Environmental, health, and safety perspectives. *IEEE Access, 6*, 74628–74647. https://doi.org/10.1109/ACCESS.2018.2883115

[23] Saaty, R.W. (2016). Decision Making In Complex Environments The Analytic Network Process (ANP) for Dependence and Feedback. Creative Decisions Foundation: Pittsburgh, ISBN No. 1-888603-00-3.

[24] Gómez, W. A., Aranda-Camacho, Y., & Fuentes, J. C. B. (2020). Analytical model to assess the functionality of small farmers' organizations. *Economia Agraria y Recursos Naturales, 20*(1), 7–35. https://doi.org/10.7201/earn.2020.01.01

[25] Adam, B.M., & Tarigan, Z.J.H. (2022). Risk Analysis Using Multi-Attribute Failure Mode Analysis Approach in Mybeb Social Payment Application. *Journal of Applied Sciences, Management and Engineering Technology, 3*(1), 1-7. https://doi.org/10.31284/j.jasmet.2022.v3i1.2378

[26] Kehinde, S. I., Moses, C., Borishade, T., Busola, S. I., Adubor, N., Obembe, N., & Asemota, F. (2023). Evolution and innovation of hedge fund strategies: a systematic review of literature and framework for future research. *Acta Innovations*. https://doi.org/10.32933/ActaInnovations.50.3

[27] Wang, Z., Ran, Y., Chen, Y., Yu, H., & Zhang, G. (2020). Failure mode and effects analysis using extended matter-element model and AHP. *Computers and Industrial Engineering, 140.* https://doi.org/10.1016/j.cie.2019.106233

[28] Khorrami, B., Valizadeh Kamran, K., & Roostaei, S. (2018). Assessment of Groundwater-Level Susceptibility to Degradation Based on Analytical Network Process (ANP). *International Journal of Environment and Geoinformatics, 5*(3), 314-324. https://doi.org/10.30897/ijegeo.451067

[29] Semara, I. M. T., Sunarta, I. N., Antara, M., Arida, I. N. S. & Wirawan, P. E. (2024). Tourism Sites and Environmental Reservation. *International Journal of Environmental Sciences,* 10(1), 44-55. https://www.theaspd.com/resources/4.%20Tourism%20Sites%20and%20Environmental%20Reservation%20objects.pdf

[30] Gairola, S. P., Tyagi, Y., & Gupta, N. (2022). Mechanical properties evaluation of banana fibre reinforced polymer composites: A review. *Acta Innovations*. https://doi.org/10.32933/ActaInnovations.42.5

[31] Gu, W., Saaty, T. L., & Wei, L. (2018). Evaluating and Optimizing Technological Innovation Efficiency of Industrial Enterprises Based on Both Data and Judgments. *International Journal of Information Technology and Decision Making, 17*(1), 9–43. https://doi.org/10.1142/S0219622017500390

[32] Çiftçi, K., Şahin, A. N., Miran, B., Emeksiz, Ö. F., & Veziroğlu, P. (2017). Best Alternative Models to Increase Local Product Consumption. *Selcuk Journal of Agricultural and Food Sciences, 3*(3), 154–161. https://doi.org/10.15316/sjafs.2017.49

[33] Cooper, O., & Liu, G. (2017). Achieving The Desired Level Of Dependency In Anp Decision Models. *International Journal of the Analytic Hierarchy Process, 9*(1), 1-26. https://doi.org/10.13033/ijahp.v9i1.450

[34] Shih, H.-S., Cheng, C.-B., Chen, C.-C., & Lin, Y.-C. (2014). Environmental Impact On The Vendor Selection Problem In Electronics Firms: A Systematic Analytic Network Process With BOCR. *International Journal of the Analytic Hierarchy Process, 6*(2), 202-227. https://doi.org/10.13033/ijahp.v6i2.256

[35] Arifin, A., Biba, M., & Syafiuddin, S. (2021). Determinants of Production and Income Risks of Rainfed Lowland Farming: A Case Study in Maros Regency, Indonesia. *Caraka Tani: Journal of Sustainable Agriculture, 36*(2), 319-328. http://dx.doi.org/10.20961/carakatani.v36i2.47713

[36] Rath, B., Wonginta, T., & Amchang, C. (2022). Risk analysis of the rice supply chain in Cambodia. *Journal of International Logistics and Trade, 20*(2), 58–77. https://doi.org/10.1108/JILT-05-2022-0007
[37] Ullya, A. A. U., Profita, A., & Sitania, F. D. (2022). Risk Management Of Rice Supply Chain Based On Risk Correlation (Case Study: Penajam Paser Utara). *Journal of Industrial Engineering Management, 7*(2), 115–126. https://doi.org/10.33536/jiem.v7i2.1127
[38] Di Falco, S., & Bulte, E. (2013). The Impact of Kinship Networks on the Adoption of Risk-Mitigating Strategies in Ethiopia. *World Development, 43*, 100–110. https://doi.org/10.1016/j.worlddev.2012.10.011
[39] Mullangie, D. P., Thiyagarajan, K., Swaminathan, M., Ramalingam, J., Natarajan, S., & Govindan, S. (2024). Breeding Resilience: Exploring Lodging Resistance Mechanisms in Rice. *Rice Science, 31* https://doi.org/10.1016/j.rsci.2024.08.002
[40] Agusta, H., Santosa, E., Dulbari, Guntoro, D., & Zaman, S. (2022). Continuous Heavy Rainfall and Wind Velocity During Flowering Affect Rice Production. *Agrivita, 44*(2), 290–302. https://doi.org/10.17503/agrivita.v44i2.2539
[41] Santosa, E., Agusta, H., Guntoro, D., & Zaman, S. (2020). Strength assessment of rice hills from different planting distance by loading simulation. *Ilmu Pertanian (Agricultural Science), 5*(3), 131-139. https://doi.org/10.22146/ipas.31895
[42] Panda, D., & Barik, J. (2021). Flooding Tolerance in Rice: Focus on Mechanisms and Approaches. *Rice Science, 28*(1), 43–57. Elsevier B.V. https://doi.org/10.1016/j.rsci.2020.11.006
[43] Huet, E. K., Adam, M., Giller, K. E., & Descheemaeker, K. (2020). Diversity in perception and management of farming risks in southern Mali. *Agricultural Systems, 184*. https://doi.org/10.1016/j.agsy.2020.102905
[44] Masriadi, Fauziah, L., Gusmailina, Parandy, L. M., & Indaryati. (2024). Addressing the Global Food Security Crisis and Energy Shortages: Innovative Solutions and Policy Interventions for Sustainable Development. *International Journal of Science and Society, 6*(1), 748-759. https://doi.org/10.54783/ijsoc.v6i1.1060
[45] Koide, J., Yokoyama, S., Hirouchi, S., Hirose, C., Oka, N., Oda, M., & Yanagihara, S. (2021). Exploring climate-resilient and risk-efficient cropping strategies using a new pond irrigation system: An experimental study in northern Ghana. *Agricultural Systems, 191*. https://doi.org/10.1016/j.agsy.2021.103149
[46] Challinor, A. J., Müller, C., Asseng, S., Deva, C., Nicklin, K. J., Wallach, D., Vanuytrecht, E., Whitfield, S., Ramirez-Villegas, J., & Koehler, A. K. (2018). Improving the use of crop models for risk assessment and climate change adaptation. *Agricultural Systems, 159*, 296–306. https://doi.org/10.1016/j.agsy.2017.07.010
[47] Thornton, P. K., Whitbread, A., Baedeker, T., Cairns, J., Claessens, L., Baethgen, W., Bunn, C., Friedmann, M., Giller, K. E., Herrero, M., Howden, M., Kilcline, K., Nangia, V., Ramirez-Villegas, J., Kumar, S., West, P. C., & Keating, B. (2018). A framework for priority-setting in climate smart agriculture research. *Agricultural Systems, 167*, 161–175. https://doi.org/10.1016/j.agsy.2018.09.009
[48] Maltare, N. N., Sharma, D. & Patel, S. (2023). An Exploration and Prediction of Rainfall and Groundwater Level for the District of Banaskantha, Gujrat, India. *International Journal of Environmental Sciences*, *9*(1), 1-17. https://www.theaspd.com/resources/v9-1-1-Nilesh%20N.%20Maltare.pdf
[49] Bagga, T., Ansari, A. H., Akhter, S., Mittal, A. & Mittal, A. (2024). Understanding Indian Consumers' Propensity to Purchase Electric Vehicles: An Analysis of Determining Factors in Environmentally Sustainable Transportation. *International Journal of Environmental Sciences*, *10*(1), 1-13. https://www.theaspd.com/resources/1.%20Electric%20Vehicles%20and%20Enviorment.pdf
[50] Said, D., Youssef, D., El-Bayaa, N., Alzoubi, Y. I. & Zaim, H. (2023). The impact of diversity on job performance: evidence from private universities in Egypt. *Acta Innovations*, *49*, 17–30. https://doi.org/10.32933/ActaInnovations.49.2
[51] Muralidharan, J. (2024). Advancements in 5G Technology: Challenges and Opportunities in Communication Networks. *Progress in Electronics and Communication Engineering, 1*(1), 1-6.
[52] Mulder, M. (2017). A Five-Component Future Competence (5CFC) Model. *The Journal of Agricultural Education and Extension, 23*(2), 99–102. https://doi.org/10.1080/1389224X.2017.1296533
[53] Kyire, S. K. C., Kuwornu, J. K. M., Bannor, R. K., Apiors, E. K., & Martey, E. (2023). Perceived risk and risk management strategies under irrigated rice farming: Evidence from Tono and Vea irrigation schemes-Northern Ghana. *Journal of Agriculture and Food Research, 12*. https://doi.org/10.1016/j.jafr.2023.100593

[54] Suryani, A., Masyhuri, M., Waluyati, L. R., & Utami, A. W. (2023). Risk Analysis on the Cassava Value Chain in Central Lampung Regency. *AGRARIS: Journal of Agribusiness and Rural Development Research, 9*(2), 150–173. https://doi.org/10.18196/agraris.v9i2.333

[55] Admodisastro, V. A., Ransangan, J., Ilias, N., & Tan, S. H. (2022). Oyster farming potential in Sabah, Malaysia. *International Journal of Aquatic Research and Environmental Studies*, *2*(1), 17-22. https://doi.org/10.70102/IJARES/V2I1/3

[56] Kuswardhani, N., & Yulian, N. F. (2019). Supply chain risk potential of smallholder Robusta coffee farmers in Argopuro mountain area. *IOP Conference Series: Earth and Environmental Science, 250*(1). https://doi.org/10.1088/1755-1315/250/1/012061

[57] Carpitella, S., Certa, A., Izquierdo, J., & La Fata, C. M. (2018). A combined multi-criteria approach to support FMECA analyses: A real-world case. *Reliability Engineering and System Safety, 169*, 394–402. https://doi.org/10.1016/j.ress.2017.09.017

[58] Hu, X., & Sinniah, S. (2024). The Role of Green Risk Management Approaches in Promoting Green and Sustainable Supply Chain Management. *Natural and Engineering Sciences*, *9*(2), 33-54. https://doi.org/10.28978/nesciences.1569144

[59] Surendar, A. "Emerging Trends in Renewable Energy Technologies: An In-Depth Analysis." *Innovative Reviews in Engineering and Science* 1.1 (2024): 6-10.

[60] Gebregiorgis, G., Zeweld, W., Hdgot, A., Gebregziabher, D., Azadi, H., Van Huylenbroeck, G., Tesfay, G., & Speelman, S. (2024). Lessons Learned from Adopting Sustainable Agricultural Practices to Address Food Insecurity and Climate Change Risks: Opportunities, Constraints, and Limitations. *Research on World Agricultural Economy, 5(*3), 60–75. https://doi.org/10.36956/rwae.v5i3.1131

[61] Halily, R., & Shen, M. (2024). Directing Techniques for High Frequency Antennas for Use in Next Generation Telecommunication Countries. *National Journal of Antennas and Propagation*, *6*(1), 49-57. https://doi.org/10.31838/NJAP/06.01.07

[62] Minutolo, M. (2023). Application of the Analytic Hierarchy Process for Solving Social Wicked Problems: Keynotes and Plenary Sessions from the 2022 International Symposium of the AHP. *International Journal of the Analytic Hierarchy Process, 15*(1). 1-8. https://doi.org/10.13033/ijahp.v15i1.1156

[63] Toro, J. A. R., Sampietro-Saquicela, J. L., Suryasa, I. W., Solórzano, L. E. H., Cervantes, X. L. G., & Quiñónez, B. F. C. (2024). Optimal Scheduling of Renewable Energy Resources in Energy Management Systems Using Hybrid Genetic Algorithm and Particle Swarm Optimization. *Acta Innovations*, *52*, 19-27. https://doi.org/10.62441/ActaInnovations.52.3

[64] Roux, I. J., & Makrigeorgis, D. C. (2016). Applying The Analytic Hierarchy Process To Oil Sands Environmental Compliance Risk Management. *International Journal of the Analytic Hierarchy Process, 8*(1), 92-111. https://doi.org/10.13033/ijahp.v8i1.304

[65] Anand, A. & Sharma, M. (2023). Unveiling the Impact of Environmental Factors on Consumer Purchase Intention for Sustainable Products. *International Journal of Environmental Sciences.* 9(2), 88-101. https://www.theaspd.com/resources/6.%20Aastha%20Anand.pdf