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RANKING AGRICULTURAL SUPPLY CHAIN RISK IN GHANA: AN AHP APPROACH

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Abstract

This paper used the Analytical Hierarchy Process (AHP) method to rank agricultural supply chain risk in Ghana based on the categories in the agricultural sector which includes Crops, Livestock, Forestry and Logging and Fishing. The scores of both criteria and the alternatives were given based on Experts judgments using the Saaty's AHP pairwise comparison scale. Business Performance Management (AHP) priority software was then used to calculated the weights of the both the criteria and alternatives.The results revealed that,the agricultural sector in Ghana is highly affected by the market related risk followed by financial, logistical, weather, biological, operational, policy and political related risk respectively. Furthermore, among the categories studied, crops is highly influenced by the agricultural supply chain risk in Ghana. Aside crops, the order of importance based on the magnitude of risk effect are as follows Livestock, Forestry and Logging and Fishing respectively.

Keywords: Agriculture supply chain risk, MCDM, AHP, Ghana

INTRODUCTION

Numerous Multi Criteria Decision Making (MCDM) methods have been used to solve problems in the agricultural sector which includes agricultural location problem (Morteza et. al., 2011), regulating water consumption in irrigation practices (Yılmaz and Yurdusev, 2011), Leung et al. (1998)used AHP to address the fisheries management options in Hawaii. Even though MCDM is increasingly used in developed countries in Europe and America, it has not been widely used in

agricultural and environmental decision making in developing country like Ghana.In Ghana, the contributions of agricultural industries to the country's economy in terms of employment and Gross Domestic Product (GDP) cannot be neglected. Agriculture sector recorded a growth rate of 5.2 percent in 2013 as compared to 2.3 percent in 2012. The sector employs about 43.1% of the entire population (Ghana Statistics, 2014). The Ghanaian agricultural sector has been the prime contributor to the nations' Gross Domestic Product (GDP) for the past decade until recently (Ghana Statistics, 2014). For instance, the contributions of the agricultural sector to the Gross Domestic Product (GDP) deteriorated from 23.0 percent in 2012 to 22.0 percent in 2013 could be as a result of numerous risks the industries face as well as the unempirical decisions making in the sector.

Analytic hierarchy process (AHP) is an MCDM method used to solve complex decision making problems. Its analysis is based on a weighting process, in which several relevant attributes are represented through their relative importance. AHP has been extensively applied by academics and professionals, in fields involving financial decisions associated to non-financial attributes (Saaty,1996). Analytical Hierarchy Process method was used to rank agricultural supply chain risk in Ghana in relation to the four main categories of the agricultural sector which includes Crops, Livestock, Forestry and Logging and Fishing in this paper.

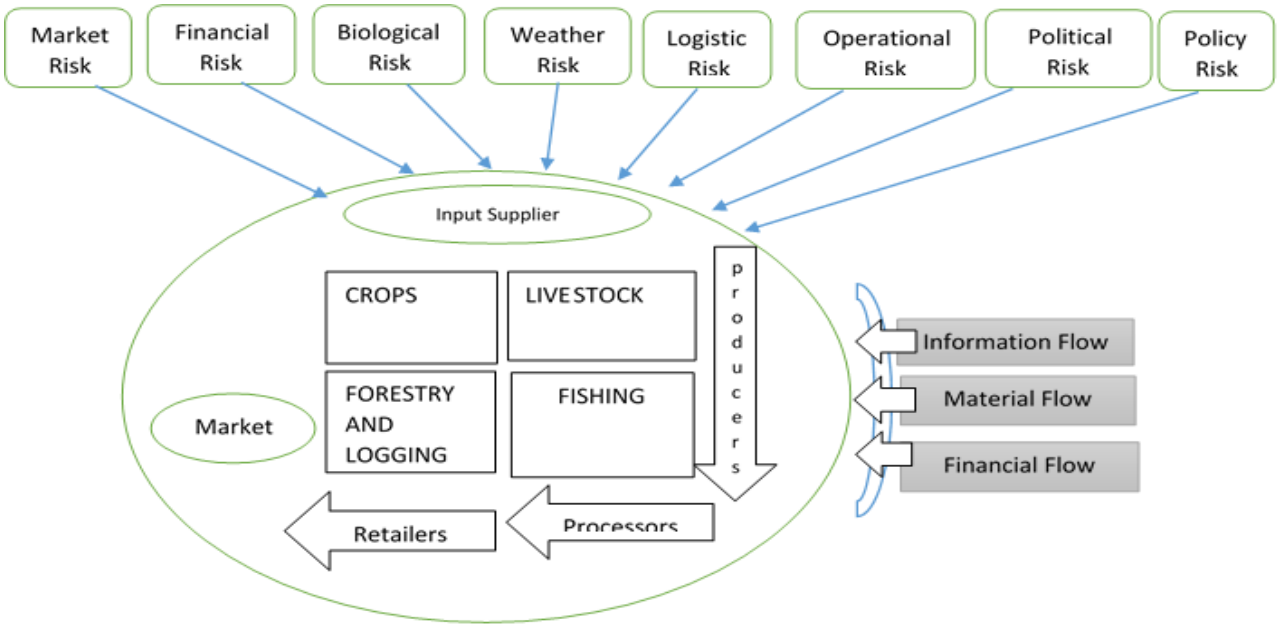
The probable supply chain related risks in Ghana agricultural supply chain has been identified which includes market risk, financial risk, biological risk, weather risk, logistical risk, operational risk, political risk and policy risk (Nyamah et. al., 2014). Identification of these risks are very important however ranking these risk in relation to the categories in the agricultural sector which includes the crops, livestock, forestry and logging and fishing could enhance government and policy makers to understand the various risk at the grassroots' level.

Supply chain risk is a disparity in the probable supply chain outcomes or any other undesired consequences (Juttner et. al., 2003). Numerous sources of risks exist in the agricultural supply chain in Ghana. These various risks include risk related to weather, demand, logistic and infrastructure supply, political, policy and institutional related, Financial, biological and Environmental (Nyamah et al., 2014). According to Hendrick and Singhal (2005), disruptions in supply chain operations could have negative consequences on firms' performance. However, these disruptions could be well managed if the highly influential risks factors that could erupt disruptions in the chains are ranked and mitigated based on their importance. In addition, to aid decision makers and other managers to make appropriate decision, this study ranks the risks in agricultural supply chain in Ghana based on the four main categories (crops, livestock, forestry and logging and fishing) in the agricultural sector since severity of the general agricultural supply chain risk may differ base on the categories affected.

Hence the main objective of this research is to rank the various risks occurring in agricultural supply chain and how these risks influence the various categories of the agricultural supply chain in Ghana using the Analytic Hierarchy Process (AHP).Figure 1 includes the numerous risk affecting the agricultural sector in Ghana that has been identified by the researchers above.

The contributions of this paper are numerous. First, this paper adds to the uses of the Analytic Hierarchy Process (AHP) in making scientific decision in agricultural sector. Secondly, the paper contributes an in-depth understanding of the degree at which the categories of the agricultural sector is affected by the various agricultural supply chain risk. Thirdly, this research enlightens government and policies makers in designing appropriate policies to curb these risks.

Figure 1 Agricultural sector in Ghana.



This study is mapped as follows, a general overview of literature on related works is presented in section 2. Section 3 explains AHP method and its application in agricultural supply chain in Ghana. Results and managerial implications were discussed in section 4 and finally section 5 includes conclusion followed by references.

REVIEW OF RELATED LITERATURE

Multi Criteria Decision Making (MCDM) method has been applied to most levels of decision making, from farm-level decision making to agricultural policy decision making as well as supply chain management decisions. MCDM methods such as Multi-Attribute Utility Theory, Data Envelopment Analysis(DEA) and PROMETHEE has been used in agricultural fields whilst

Technique for Order Preferences by Similarity to Ideal Solution(TOPSIS)has been used to solve supply chain management problems (Velasquez and Hester, 2013). Analytic Hierarchy Process (AHP) has been applied to enhance agricultural Preservation strategies in Delaware (Kent & William, 2010).

Risk has been defined as any event with negative economic consequences (Paulson, 2005). Researchers have defined the various kinds of agricultural supply chains risk as follows; Market risks basically includes demand and supply disparities. Demand related risks includes disruptions in the distribution network (McKinnon, 2006), fluctuations in demand that impact domestic or international prices of inputs and output, changes in market demands, changes in food safety requirements among others (Jaffee, et al., 2010). Supply relative risk includes delayed and distorted information, sales promotions, order batching, price fluctuations and rationing, or shortage gaming as major causes (Lee et al., 1997).Biological risks are typically related to a specific geographic location in the short-term, but can move through the entire supply chain. It could also be associated with genetic malfunctions or diseases. Weather risk is related to conditions such as periodic deficit / excess rainfall or temperature, hail storms and strong winds (Jaffeeet al., 2010). Logistics related risk includes inventory management of perishable products (Nahmias, 2011), farm planning (Lowe and Preckel, 2004), food distribution management (Akkerman et al., 2010). Financial risk relates to the vulnerability of the financial strength of supply chain members (Tang, 2006b), fluctuations in interest and exchange rate policies among others. Political risk is the multi complex network when the chain extend over country boarders. Political risk would be the most significant constraint on investment in emerging markets(World Bank 2009).Administrative barriers such as customs, trade regulations, and decisions or actions of authorities Hendricks and Singhal (2005a, 2005b)could influence the operative performance of supply chains. According to Nyamah et al. (2014), all the aforementioned global supply chain risk exit in agricultural supply chain in Ghana irrespective of the categories of the agricultural product. These sources of agricultural supply chain risks could cause disruption in the operation of the firms in the chain which could lead to undesirable performance of the firm (Wagner & Bode, 2008).

METHODOLOGY

Different methodologies were employed in this study. First, Literature was reviewed to identify the key indicators of risks in the Agricultural Supply Chain. Data were obtained through exploratory interviews to experts in the agricultural sector. The data collected was then subjected to Analytic Hierarchy Process (AHP). According to Saaty (1980), AHP is among the most popular multi-criteria decision making (MCDM) methods that has been applied to practical

decision making problems in many fields. The paper establishes a goal of ranking the agricultural supply chain risk and also seeks the various risk impact on different categories of in Ghana. A total of eight (8) criteria (market, financial, biological, weather, logistical, operational, political and policy risk) and 4 alternatives (crops, livestock, forestry and logging, fishing) were considered for this study (Figure 2).

The decision matrix in table 1 below represents the decision criteria that is represented as (Ci where i =1,2,…,n) weights of criteria (Wk where k=1,2,…..n)) , alternative (Aj where j =1,2, …n) and the performance of alternatives (aij).

The major characteristic of the AHP method is the use of pair-wise comparisons, which are used to compare the alternatives with respect to the various criteria and to estimate criteria weights (Loken, 2007). There are several measurement scales that could be used to quantify managerial judgments, however, the 9-point scale in Table 2 below is the standard used for AHP.

Figure 2 Decision model of the agricultural sector

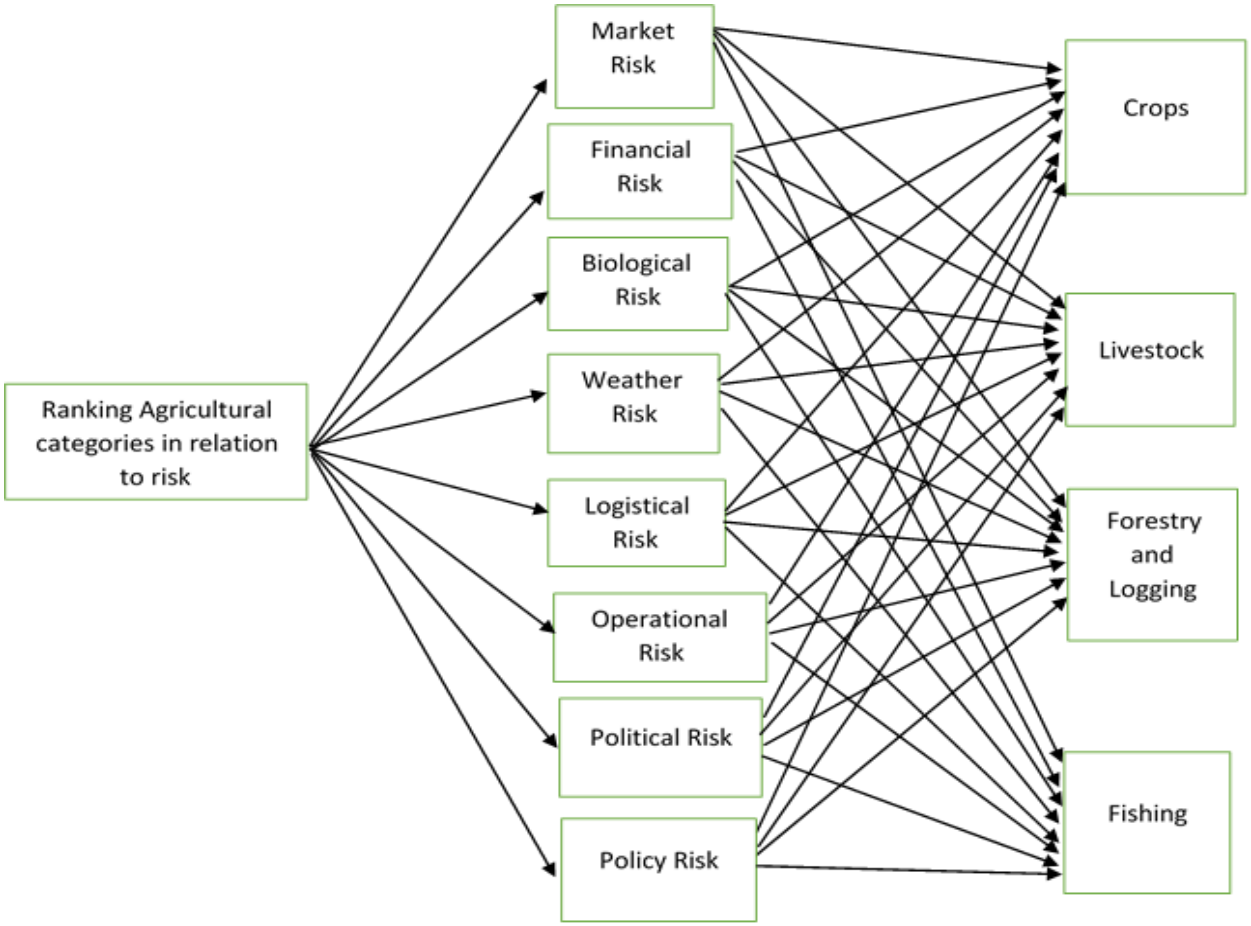


Table 1 Decision matrix

		CRITERIA							
		C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
	Weights	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8
Alternatives	A1	a_{11}	a_{12}	a_{13}	a_{14}	a_{15}	a_{16}	a_{17}	a_{18}
	A2	a_{21}	a_{22}	a_{23}	a_{24}	a_{25}	a_{26}	a_{27}	a_{28}
	A3	a_{31}	a_{32}	a_{33}	a_{34}	a_{35}	a_{36}	a_{37}	a_{38}
	A4	a_{41}	a_{42}	a_{43}	a_{44}	a_{45}	a_{46}	a_{47}	a_{48}
		CRITERIA							
		C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
	Weights	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8
Alternatives	A1	a_{11}	a_{12}	a_{13}	a_{14}	a_{15}	a_{16}	a_{17}	a_{18}
	A2	a_{21}	a_{22}	a_{23}	a_{24}	a_{25}	a_{26}	a_{27}	a_{28}
	A3	a_{31}	a_{32}	a_{33}	a_{34}	a_{35}	a_{36}	a_{37}	a_{38}
	A4	a_{41}	a_{42}	a_{43}	a_{44}	a_{45}	a_{46}	a_{47}	a_{48}
		CRITERIA							
		C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
	Weights	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8
Alternatives	A1	a_{11}	a_{12}	a_{13}	a_{14}	a_{15}	a_{16}	a_{17}	a_{18}
	A2	a_{21}	a_{22}	a_{23}	a_{24}	a_{25}	a_{26}	a_{27}	a_{28}
	A3	a_{31}	a_{32}	a_{33}	a_{34}	a_{35}	a_{36}	a_{37}	a_{38}
	A4	a_{41}	a_{42}	a_{43}	a_{44}	a_{45}	a_{46}	a_{47}	a_{48}

Table 2 Saaty's 9-point scale for pairwise comparison in AHP (Saaty 1980)

Intensity of Importance	Definition	Explanation
1	Equal Importance	Judgment favors both criteria equally.
3	Moderate Importance	Judgment slightly favors one criterion
5	Strong Importance	Judgment strongly favors one criterion.
7	Very Strong Importance	One Criterion is favored strongly over the another
9	Absolute / Extreme Importance	There is evidence affirming that one criterion is favored over another
2,4.6,8	Immediate values between above scale values	Absolute Judgment cannot be given and a compromise is required
Reciprocals of the above	If element i has one of the none zero numbers assignment when compared with activity j. j has the reciprocal value when compared to i	A reasonable assumption

The scores of both criteria and the alternatives were given based on managerial judgments using the AHP scale. Table 3, shows the resulting weights for the criteria based on pairwise comparisons. Pairwise comparisons defines the relative importance of one item to the other in meeting the decision goal. $\frac{n^2 - n}{2}$, where n=8, the number of comparisons = 28 in the decision matrix. The Business Performance Management (BPMSG) analytical hierarchy process priority software was then used to calculated the weights of the both the criteria and alternatives**.** Consistent in the judgments are measured using the Consistency Ratio proposed by Saaty. Consistency ratio is measured as the division of Consistency Index comparison over Random Consistency Ratio. In formula; CR = CI / RI. The value of the Consistency ratio is accepted if it is less or equal to 10%.

The criteria weights in Table 3 below were used to generate the percentage weights of the decision criteria in Table 4. From the results in Table 4 below, market risk was ranked first with the highest percentage of 32.1% followed by Financial risk with 20.7%, through to the political risk been ranked as the lowest agricultural supply chain risk with 3.5%. The resulting weights are based on the principal eigenvector of the decision matrix with CR =7.3%. The higher the percentage, the greater the impact on the agricultural sector.

Table 3 Weights for the criteria based on Saaty's9-pointpairwise comparisons scale

CRITERIA	Market Risk	Financial Risk	Biological Risk	Weather Risk	Logistical Risk	Operational Risk	Political Risk	Policy Risk
Market Risk	1	3	5	3	3	7	5	2
Financial Risk		1	5	2	1	3	7	5
Biological Risk			1	1	1	1	5	1
Weather Risk				1	1	2	2	1
Logistical Risk					1	2	7	3
Operational risk						1	2	2
Political Risk							1	1
Policy Risk								1

Table 4 Resulting Weights for the criteria based on Eigenvector

CRITERIA	1	2	3	4	5	6	7	8	Priority	Rank
1 Market Risk	1	3.00	5.00	3.00	3.00	7.00	5.00	2.00	32.1%	1
2 Financial Risk	0.33	1	5.00	2.00	1.00	3.00	7.00	5.00	20.7%	2
3 Biological Risk	0.20	0.20	1	1.00	1.00	1.00	5.00	1.00	8.2%	5
4 Weather Risk	0.33	0.50	1.00	1	1.00	2.00	2.00	1.00	9.0%	4
5 Logistic Risk	0.33	1.00	1.00	1.00	1	2.00	7.00	3.00	13.6%	3
6 Operational Risk	0.14	0.33	1.00	0.50	0.50	1	2.00	2.00	6.6%	6
7 Political Risk	0.20	0.14	0.20	0.50	0.14	0.50	1	1.00	3.5%	8
8 Policy Risk	0.50	0.20	1.00	1.00	0.33	0.50	1.00	1	6.3%	7

The decision maker compared each pair of the categories in the agricultural sector (alternatives) including crops, livestock, forestry and logging and fishing with respect to the decision criteria including market, financial, biological, weather, logistical, operational, political and policy risk. The weight of these alternatives in relation to each criteria is shown in Table 5, 6, 7 to 12. Also, the computation of the overall weights of the alternatives in relation to the decision criteria is presented in Table 13.

Table 5 Weights of alternatives in context of Market

Alternatives	1	2	3	4	Priority	Rank
1 Crops	1	2.00	5.00	2.00	45.8%	1
2 Livestock	0.50	1	2.00	3.00	28.3%	2
3 Forestry and Logging	0.20	0.50	1	1.00	11.9%	4
4 Fishing	0.50	0.33	1.00	1	14.1%	3

Table 6 Weights of alternatives in context of Financial Risk

Alternatives	1	2	3	4	Priority	Rank
1 Crops	1	5.00	3.00	7.00	59.8%	1
2 Livestock	0.20	1	2.00	3.00	19.4%	2
3 Forestry and Logging	0.33	0.50	1	2.00	13.9%	3
4 Fishing	0.14	0.33	0.50	1	7.0%	4

Table 7 Weights of alternatives in context of Biological Risk

Alternatives	1	2	3	4	Priority	Rank
1 Crops	1	2.00	7.00	5.00	54.9%	1
2 Livestock	0.50	1	3.00	2.00	24.9%	2
3 Forestry and Logging	0.14	0.33	1	0.50	7.5%	4
4 Fishing	0.20	0.50	2.00	1	12.7%	3

Table 8 Weights of alternatives in context of Weather Risk

Alternatives	1	2	3	4	Priority	Rank
1 Crops	1	5.00	9.00	5.00	65.4%	1
2 Livestock	0.20	1	3.00	1.00	14.9%	2
3 Forestry and Logging	0.11	0.33	1	0.50	6.3%	4
4 Fishing	0.20	1.00	2.00	1	13.4%	3

Table 9 Weights of alternatives in context of Logistical Risk

Alternatives	1	2	3	4	Priority	Rank
1 Crops	1	4.00	5.00	5.00	59.6%	1
2 Livestock	0.25	1	3.00	1.00	17.5%	2
3 Forestry and Logging	0.20	0.33	1	0.50	8.1%	4
4 Fishing	0.20	1.00	2.00	1	14.8%	3

Table 10 Weights of alternatives in context of Operational Risk

Alternatives	1	2	3	4	Priority	Rank
1 Crops	1	5.00	7.00	3.00	59.7%	1
2 Livestock	0.20	1	3.00	1.00	16.4%	3
3 Forestry and Logging	0.14	0.33	1	0.50	7.3%	4
4 Fishing	0.33	1.00	2.00	1	16.6%	2

Table 11 Weights of alternatives in context of Political Risk

Alternatives	1	2	3	4	Priority	Rank
1 Crops	1	1.00	0.33	0.50	14.1%	4
2 Livestock	1.00	1	0.33	2.00	20.3%	2
3 Forestry and Logging	3.00	3.00	1	3.00	48.5%	1
4 Fishing	2.00	0.50	0.33	1	17.1%	3

Table 12 Weights of alternatives in context of Policy Risk

Alternatives	1	2	3	4	Priority	Rank
1 Crops	1	1.00	0.33	0.50	13.6%	3
2 Livestock	1.00	1	0.33	0.50	13.6%	3
3 Forestry and Logging	3.00	3.00	1	3.00	49.5%	1
4 Fishing	2.00	2.00	0.33	1	23.2%	2

Table 13 Computation of overall alternative weights in relation to the decision criteria

Criteria / Alternatives	Market Risk	Financial Risk	Biological Risk	Weather Risk	Logistical Risk	Operational Risk	Political Risk	Policy Risk	WEIGHT
Crops	0.147	0.124	0.045	0.059	0.081	0.039	0.001	0.001	0.509
Livestock	0.091	0.040	0.020	0.013	0.024	0.011	0.001	0.001	0.215
Forestry and Logging	0.038	0.029	0.001	0.001	0.011	0.001	0.017	0.031	0.143
Fishing	0.045	0.014	0.010	0.012	0.001	0.011	0.001	0.015	0.120

DISCUSSIONS AND MANAGERIAL IMPLICATIONS

The market risk was identified to be the most important criterion with the overall priority weight of 32.1% followed by a weight of 20.7%, 13.6%, 9.0%, 8.2%, 6.6%, 6.3% and 3.5% for financial, logistic, weather, biological, operational, policy and political risk respectively (Table 4). The overall weight of the alternatives (crops, livestock, forestry and logging and fishing) in relation to the criteria are 50.9%, 21.5%, 14.3% and 12% respectively (Table 13).

The results indicate that, the agricultural sector in Ghana is immensely affected by the market risk. This means that, demand related risk such as disruptions in the distribution network, fluctuations in demand, fluctuations in the prices of inputs and output, changes in market demands, changes in food safety requirements among others and supply related risk such as delayed and distorted information, sales promotions, order batching, price fluctuations and rationing, or shortage gaming highly affect the agricultural sector in Ghana. Secondly, financial risk such as insufficient financial support, fluctuations in exchange and rates also affect the chain significantly. Moreover, logistic risk such as inventory management of perishable products, farm planning, and food distribution management, meaningfully affect the chain.

Weather, biological, operational, policy and political risk does not strongly affect the agricultural supply chain. Furthermore, the alternative (crops) is highly influenced by the agricultural supply chain risk. This implies that the crops faces numerous risks and this could in turn affect the agricultural sector negatively. Livestock was identified as the alternative that was affected significantly by agricultural supply chain risk after crops. Forestry and logging and fishing followed respectively.

CONCLUSION

The paper has contributed by applying Analytic Hierarchy Process in the agricultural sector in Ghana. It also revealed the degree to which each category in the agricultural sector is affected by the supply chain risk in Ghana. A further empirical study of using an MCDM method to investigate the mitigation strategies for the above agricultural supply chain risks will be beneficial to government, policy makers, participants in the chain and also investors in the country.

LIMITATIONS OF THE STUDY

The geographical location of Ghana explains the relevant agricultural supply chain risk that affect the agricultural sector and the extent to which it affects crops, livestock, forestry and logging and fishing. The application of this study is geographically biased thus the results of this study could only be applied to a location of similar environmental settings as in Ghana. Secondly, results are limited to the agricultural industry. A future research to investigate the of agricultural supply chain risk in other countries using other MCDM methods could also broaden the scope of this study area.

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