



Driving factors for developing integrated farming: Multi-criteria decision-making analysis

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ABSTRACT

Integrated farming (IF) by temporal and spatial mixing of crops, livestock, fishery, and allied activities in a single farm, is considered a critical multifunctional option for smallholder farmers, who form the backbone of Indian agriculture, to ensure sustainable livelihoods, the productivity of agricultural enterprises, stability of farm income, food and nutritional security. However, the adoption of IF still remains low. To explore the critical factors of IF systems and prioritize them for stakeholders' decision-making and development of strategies, the current research was undertaken to integrate SWOT (Strengths, Weaknesses, Opportunities, and Threats) - AHP (Analytic Hierarchy Process) analysis. We used a multi-stage sampling to select 60 practicing IF adopters in West Bengal state of eastern India for the collection of pair-wise comparison data on 32 SWOT factors using a close-ended questionnaire and subjected to AHP analysis to understand the quantitative importance of each factor of SWOT. Results of the multi-criteria analysis showed the total priority weight of the opportunity component (0.450) was the highest, followed by strength (0.341), weakness (0.114), and threat components (0.095). Based on the global priority weight of all 32 SWOT factors, sustainable livelihood security² was the key driving factor (0.081) followed by promotion of organic farming (0.072), better risk management (0.063) and incorporation of high-value crops (0.063) of opportunity component. Increased farm production and productivity (0.058) and enhancement in income (0.055) of strength component also played as vital driving factors. There was no factor of weakness and threat components within the first 10 important factors. The insights of this study may help improve extension services to smallholder farmers for prioritizing strategies in the adoption process of IF. Additionally, it can also help policymakers to design targeted policies, remove barriers, foster innovation, and promote sustainable practices, contributing to food security and environmental sustainability.

Keywords: Analytic hierarchy process (AHP), Driving factors, Integrated farming (IF), Limiting factors, SWOT analysis, West Bengal

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The crop-livestock mixed farming system is an age-old tradition in India (Kumar *et al.* 2012). Different integrated farming (IF) models have been reported in the Indian context (Srivastava 2018). While the inequitable distribution of land holdings among 86% of small and marginal farmers, who are cultivating in 45% of area in India, makes the small and marginal farms the poverty hotspot of the country. IF can be suited for the development of small and marginal farms by providing increased food production, improved productivity, higher net income and employment and minimizing the cost of total farm production and risk as well (Ngatindriatun and Adzim 2022). Yet, adoption of IF in India remains low (Purnomo *et al.* 2021). Several types of drivers influence the adoption of IF including economic, environmental, and social (Hendrickson *et al.* 2008). Currently, there is paucity of information on what types of driving as well as limiting factors influence IF and priority wise at what extent these determine the performance of an IF in Indian context.

Earlier the SWOT analysis was applied to identify the internal and external key factors in integrated aqua farming system (Shefat *et al.* 2018). However, the SWOT analysis method cannot quantitatively evaluate the factors and cannot objectively compare the priority between factors (Genç *et al.* 2018). The AHP is a popular multiple-criteria decision-making quantitative technique (Dixon-Ogbechi and Adebayo 2020), applied to do a pairwise comparison of the factors and rank the influence of the factors and prioritize factors that influence decision-making based on the relative importance of the factors (Blagojevic *et al.* 2016). AHP methodology, proposed by Thomas L. Saaty is one of the analytic methods of complicated decisions (Saaty 1980). Quantitative SWOT analysis using the AHP method was first presented by Kurttila *et al.* (2000) which was named A-WOT. Other authors have used the A-WOT in their surveys (Shrestha *et al.* 2004) for prioritizing SWOT factors. The SWOT-AHP combination model is a powerful decision-making technique. Hence, the present study aimed to apply an integrated SWOT-AHP analysis for prioritizing the

practicing farmers' perceptions of the driving factors to develop an IF.

MATERIALS AND METHODS

The research was carried out in West Bengal state of eastern India. Multi-stage sampling was followed to select respondents for the study. Firstly, districts under six agro-climatic zones (ACZ), viz. Northern Hill Zone, Teri Zone, Old Alluvial Zone, New Alluvial Zone, Coastal Saline Zone and Undulating Red and Laterite Zone (Raman and Balaguru 1988) were selected. Secondly, blocks from a district in consultation with the District Agriculture Department and Krishi Vigyan Kendra (KVK) based on a greater number of IFs for developing the sampling frame were selected. Thirdly, for a selected block, we employed a two-stage stratified random sampling of villages under a block, followed by another random selection of IF adopters from a village. In this manner, a total of 60 IFs were selected.

A comprehensive review of the literature and focus group discussion (FGD) among the Subject Matter Specialists (SMSs) of the KVK, scientists from different institutes and farmers was made to identify different SWOT

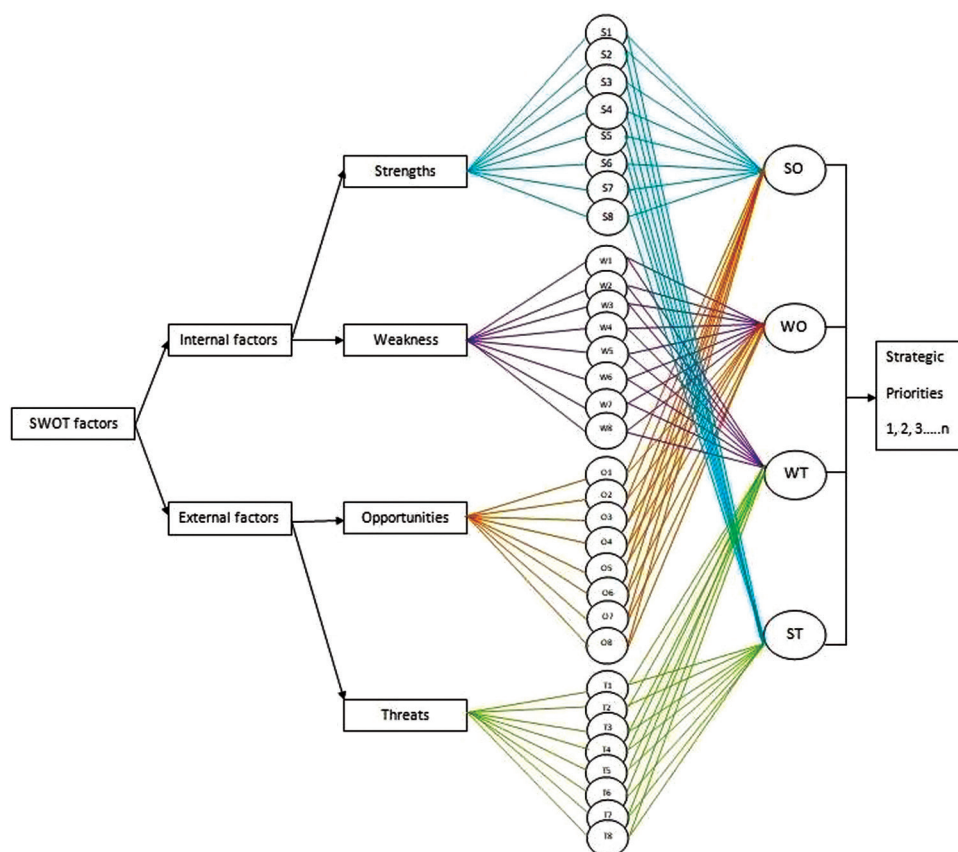


Fig. 1 The SWOT-AHP model which follows the following steps: (1) Building the SWOT analysis information through internal factors (Strengths and Weaknesses) and external factors (Opportunities and Threats); (2) Conducting a pairwise comparison of the SWOT factors with relative weights within every SWOT component; (3) Performing a pairwise comparison of the four SWOT components; (4) Using AHP analysis to prioritize each factor in the analysis; (5) Prioritizing and strategy formulation.

Table 1 Pairwise comparison scale (Saaty 1980)

Score	Definition
1	Equal importance of both factors
3	Moderate importance of one factor over another
5	Strong importance of one factor over another
7	Very strong importance of one factor over another
9	Extreme importance of one factor over another
2, 4, 6, 8	Intermediate value between two adjoining judgments

factors. An individual farm household operating on an IF was considered a primary sampling unit.

Primary data were collected on 60 IFs using field observations and face-to-face interviews with a close-ended questionnaire. The questionnaire facilitated the responses against all possible pair-wise comparisons among the SWOT factors using a comparison scale (Table 1) developed by Saaty (1980, 2008). The participants were asked to evaluate whether the factors in the pair were equally important or whether one was more important than the other and thus each participant scored in the pair-wise comparison scale. The data obtained from the pairwise comparisons were used to obtain a priority value for each factor.

We used the pair-wise comparison data of SWOT factors for AHP analysis to understand the quantitative importance of each component and each SWOT factor. The SWOT-AHP model is shown in Fig. 1. The AHP methodology envisages the following steps (Saaty, 2000 and 2008).

Step 1: Establishing the hierarchical structure: With respect to the study, the composition of the hierarchy started from a complex problem and decomposed into main components, and these main components were decomposed furthermore into factors and then pairwise comparisons between factors were made to establish a hierarchy.

Step 2: Constructing the pair-wise comparison matrix: A pairwise comparison was conducted to determine priority. It calculated weights for each factor by taking the largest eigenvector of the order in a matrix. Each element in an upper level was used to compare the elements in the level below with respect to it. This work was done by pair-wise comparison two by two and through dedicating numeral scores which showed priority and majority between two decision elements. The relative priority value of each factor within each SWOT component was calculated and then represented in a matrix as depicted in equation 1

$$A = (a_{ij}) = \begin{bmatrix} 1 & W_1/W_2 & \dots & W_1/W_n \\ W_2/W_1 & 1 & \dots & W_2/W_n \\ \vdots & \vdots & \ddots & \vdots \\ W_n/W_1 & W_n/W_2 & \dots & 1 \end{bmatrix} \quad (1)$$

where each element in a_{ij} , quotient of the criteria weights. In this matrix, the element $a_{ij} = 1/a_{ji}$ and thus, when $i = j$, $a_{ij} = 1$.

The next step was to normalize the matrices to find the relative weights across the right eigenvector (w) that corresponded to the largest eigenvalue (λ_{max}) as shown in equation 2:

$$Aw = \lambda_{max} w \quad (2)$$

During the pair-wise comparison of the decision factors by the decision-makers, some inconsistencies might occur. In a situation where A contained inconsistency, the estimated priorities were obtained using the matrix as shown in Equation 1 as the input for the eigenvalue technique expressed in equation 3 (Saaty 1980).

$$(A - \lambda_{max} I)q = 0 \quad (3)$$

In equation 3, λ_{max} was the largest eigen factor of matrix A of size n ; q was the correct eigenfactor, and I represented the identity matrix of size n .

Step 3: Calculating the consistency index: Inconsistency might arise when λ_{max} deviated from n due to inconsistent pair-wise comparisons. It was therefore required that matrix A be tested for the degree of consistency among pair-wise comparison using the Consistency Index (CI) as registered in equation 4 (Saaty 1980):

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (4)$$

where n , Number of existing items in the judgment matrix problem.

Step 4: Calculating the consistency ratio: Since CI was dependent on n , a Consistency Ratio (CR) was calculated to ensure the consistency of the evaluation using equation 5 (Saaty 1980). The comparison was considered consistent if $CR < 0.10$.

$$CR = \frac{CI}{NI} \quad (5)$$

Step 5: Prioritization and strategy formulation: The AHP methodology steps were once implemented for each SWOT component and then the priority weights for all four SWOT components were obtained. Further, the local priority weights of the factors for each SWOT component were estimated using AHP. Finally, the global priority weights of all the factors of SWOT components were calculated by repeating all these steps of AHP to figure out the final ranking of all factors and identify the major drivers of practicing IF by the farmers.

RESULTS AND DISCUSSION

Identification of SWOT factors: A total of 32 SWOT factors were identified affecting the performance of IF in West Bengal. These 32 factors comprised of eight factors in each SWOT component are presented in Table 2.

SWOT analysis, described by Learned *et al.* (1969), is one of the key tools for addressing complex strategic situations by decision-making. The strengths and weaknesses are associated with internal organizational factors, while opportunities and threats cover an external environment in which the entity operates (Helms and Nixon 2010).

Table 2 SWOT factors under SWOT components in IF of West Bengal

Factor	Positive	Negative
	Component 1: Strengths	Component 2: Weaknesses
	S1 Enhancement in income	W1 Intensive water requirement
	S2 Ensure women participation and additional employment opportunity	W2 Limited knowledge and skill of the farmers
	S3 Increased farm production and productivity	W3 Over/ extra burden towards women family members
Internal	S4 Effective utilization of farm by-products (resource recycling)	W4 Resistance in adoption
	S5 Year-round food availability	W5 Complexity in farm management
	S6 Lower dependency on external input	W6 Higher labour engagement
	S7 Multiple species biodiversity	W7 Small and fragmented land
	S8 Dietary diversity	W8 Perfection towards specialized farming
	Component 3: Opportunities	Component 4: Threats
	O1 Climate-resilient farming practices	T1 Natural calamity
	O2 Better risk management	T2 Lack of technical support (like custom hiring centres, suitable farm inputs)
	O3 Sustainable livelihood security	T3 Market threat-volatile price
External	O4 Promotion of organic farming	T4 Limited access to credit
	O5 Use of high-end technology (IoT, IT, Remote sensing)	T5 Greater capital start-up cost
	O6 Agro-tourism	T6 Agro-ecological region-specific limitations
	O7 Exploration of innovation potential	T7 Migration of family labour
	O8 Incorporation of high-value crops	T8 Biotic stress (like disease pest parasite pathogen infestation)

Global prioritization of all SWOT factors under four components of SWOT analysis: Table 3 shows the global priority weights of all SWOT factors along with their respective overall rank. Sustainable livelihood security was the key driving factor with an overall (global) priority weight of 0.081 among all factors followed by promotion of organic farming (0.072) of opportunity component as the second main driving factor in practising IF.

The practicing farmers believed that promotion of organic farming could be an important opportunity because of the resource recycling among farm enterprises and reduced dependency of the external inputs like chemical fertilizers. An IF was found to promote sustainable agriculture (Herridge *et al.* 2019) as well as organic farming (Morris and Winter 1999). Both better risk management (0.063) and incorporation of high-value crops (0.063) of the opportunity component registered as the third important factor. An IF provides better risk management (Faria Correa *et al.* 2019) and an opportunity for incorporation of high-value crops (Bhargavi *et al.* 2019). Increased farm production and productivity and enhancement in income of the strength component emerged as 4th and 5th vital driving factors with the overall (global) priority weights of 0.058 and 0.055, respectively. The practicing farmers probably perceived that IF helped them to utilize each piece of land which accelerated per unit of land production and productivity by utilizing their own resources, thus leading to enhanced farm income. Dadabhau and Kisan (2013) reported an increase in economic yield per unit area per unit time by virtue of

the intensification of crop and allied enterprises. An IF with agricultural crops, horticultural crops, forest trees, fodder, cattle, goats, fisheries, vermicomposting etc. could double the income of the farmers (Basavanneppa and Gaddi 2020).

None of the factors of the weakness and threat components featured in the first 10 factors. Higher labour engagement (0.019), intensive water requirement (0.018), greater capital start-up cost (0.016), both market threat-volatile price (0.015) and limited knowledge and skill of the farmers (0.015) ranked 12th, 13th, 14th and 15th, respectively in overall (global) prioritization of all factors. The farmers expressed the engagement of more labour (Purnomo *et al.* 2021) and requirement of intensive water (Pandey *et al.* 2019) to maintain different enterprises in an IF round the year. The initial financial constraints (Pandey *et al.* 2019) as well as the marketing problem (Rathore *et al.* 2019) appeared as the limitations to adopting the IF. Poor education, lack of knowledge and skill of the farmers have been identified as the limiting factors for low adoption of IF (Rathore *et al.* 2019).

Drawing on Ajzen's (1991) Theory of planned behaviour (TPB), we observe that a farmer's attitude and social norms, coupled with their perceived behavioural control is linked to their intention to practice IF. If a farmer holds a positive attitude about IF, his practice of IF is positively judged by fellow farmers, and he/she perceives the practice of IF as less difficult or achievable, the intention of practising IF will be strong. Although our study does not intend to employ TPB, we assume SWOT-AHP to explore

Table 3 Global prioritization of all factors under four components of SWOT analysis for decision making in practicing IF in West Bengal

Components and their factors	Priority of the factors under each component	Overall (global) priority of each factor	Overall Rank
<i>Component 1: Strength ($\lambda_{MAX}=8.11$; Consistency Index (CI)= 0.017; Consistency Ratio (CR)= 0.012)</i>			
Enhancement in income	0.16	0.055	V
Ensure women participation and additional employment opportunity	0.12	0.041	VIII
Increased farm production and productivity	0.17	0.058	IV
Effective utilization of farm by-product (resource recycling)	0.14	0.048	VII
Year-round food availability	0.1	0.034	X
Lower dependency on external input	0.09	0.031	XI
Multiple species biodiversity	0.11	0.038	IX
Dietary diversity	0.1	0.034	X
<i>Component 2: Weakness ($\lambda_{MAX}=8.097$; Consistency Index (CI)= 0.014; Consistency Ratio (CR)= 0.010)</i>			
Intensive water requirement	0.16	0.018	XIII
Limited knowledge and skill of the farmers	0.13	0.015	XV
Over/extra burden towards women family members	0.09	0.010	XX
Resistance in adoption	0.09	0.010	XX
Complexity in farm management	0.13	0.015	XV
Higher labour engagement	0.17	0.019	XII
Small and fragmented land	0.1	0.011	XIX
Preference towards specialized farming	0.12	0.014	XVI
<i>Component 3: Opportunity ($\lambda_{MAX}=8.16$; Consistency Index (CI)= 0.024; Consistency Ratio (CR)= 0.017)</i>			
Climate resilient farming practices	0.12	0.054	VI
Better risk management	0.14	0.063	III
Sustainable livelihood security	0.18	0.081	I
Promotion of organic farming	0.16	0.072	II
Uses of high-end technology (IoT, IT, Remote sensing)	0.06	0.027	XII
Agro-tourism	0.09	0.041	VIII
Exploration of innovation potential	0.12	0.054	VI
Incorporation of high-value crops	0.14	0.063	III
<i>Component 4: Threat ($\lambda_{MAX}=8.050$; Consistency Index (CI)= 0.008; Consistency Ratio (CR)= 0.006)</i>			
Natural calamity	0.13	0.012	XVIII
Lack of technical support (like custom hiring centers, suitable farm inputs)	0.11	0.010	XX
Market threat-volatile price	0.16	0.015	XV
Limited access to credit	0.11	0.010	XX
Greater capital start-up cost	0.17	0.016	XIV
Agro-ecological region-specific limitations	0.09	0.009	XXI
Migration of family labour	0.09	0.009	XXI
Biotic stress (like disease pest parasite pathogen infestation)	0.14	0.013	XVII

factors which form the basis of farmers' attitude towards the perceived benefits (strength and opportunity) of IF and provide insights about behavioural control (weakness and threat). That means SWOT-AHP does not only direct use about the relative weights that farmers assign to individual SWOT elements but also suggests farmers' behaviour and

the possible points of interventions to reinforce desirable behavior (the adoption and practice of IF).

Conclusion and policy implications

It can be concluded that the highest preference of the farmers was on the external positive factors of opportunity

component, the policy for increasing the adoption of IF might be set towards sustainable livelihood security; promotion of organic farming; better risk management and incorporation of high-value crops. The internal positive factors of strength component, such as increased farm production and productivity; enhancement in income would also be considered with due importance in policy-making strategy for motivating the farmers to adopt IF. Although less important, the limiting factors under weaknesses and threats components might be helpful in formulating mitigation strategies for mainstreaming IF in the natural resource management plans. Policymakers may leverage insights into driving factors to replicate successful integrated farming initiatives on a larger scale. This will help in scaling up pilot projects, disseminating best practices, and fostering collaboration among stakeholders to promote the widespread adoption of integrated farming practices. In essence, identifying driving factors for developing IF will provide policymakers with a roadmap for designing targeted policies, removing barriers, fostering innovation, and promoting sustainable agricultural practices that contribute to broader policy goals related to food security, environmental sustainability, and rural development. The present SWOT-AHP analysis ranked the driving as well as limiting factors which would be useful in prioritizing strategies for the adoption process of IF. The results obtained from this research would help decision-makers and extension programme planners to realize the complexity of the real world in which the farmers and farm families operationalized IF.

Ethical statement

In beginning, the farmers were discussed about objectives of study and its probable outcomes. With this background, they were asked to provide their consent. Farmers consented to be part of this study anonymously and have shared their knowledge and information allowing research team to share the key findings in digital and non-digital forms.

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