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Assessment of the Climate-Smart Agriculture Interventions towards the Avenues of Sustainable Production–Consumption

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Abstract: In the current scenario, climatic adversities and a growing population are adding woes to the concerns of food safety and security. Furthermore, with the implementation of Sustainable Development Goal (SDG) 12 by the United Nations (UN), focusing on sustainable production–consumption, climatic vulnerabilities need to be addressed. Hence, in order to map the sustainable production–consumption avenues, agricultural practices need to be investigated for practices like Climate-Smart Agriculture (CSA). A need has arisen to align the existing agricultural practices in the developing nation towards the avenues of CSA, in order to counter the abrupt climatic changes. Addressing the same, a relation hierarchical model is developed which clusters the various governing criteria and their allied attributes dedicated towards the adoption of CSA practices. Furthermore, the developed model is contemplated for securing the primacies of promising practices for the enactment of CSA using the duo of the Analytical Hierarchical Process (AHP) and Fuzzy AHP (FAHP). The outcomes result in the substantial sequencing of the key attributes acting as a roadmap toward the CSA. This emphasizes the adoption of knowledge-based smart practices, which leaps from the current agricultural practices toward the CSA. Furthermore, by intensifying the utilization of the improved and resilient seed varieties and implying the fundamentals of agroforestry, we secure primacy to counter the adversities of the climate.

Keywords: climate change; climate smart agriculture; sustainability; AHP; FAHP; developing economy

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1. Introduction

The agriculture sector is highly impacted by the various vulnerabilities allied to the volatile climatic conditions [1]. Extensive dependency on traditional agricultural practices, the consumption of inorganic fertilizers, and the intensive usage of water for irrigation have put the scenarios of the utilization of natural resources, consumer health, and the environment under great risk [2]. Furthermore, the increased severity of the various climatic changes has added woes that directly affect the agricultural practices in India [3]. These changes include the decrease in the productivity of land, the irregular pattern of rainfall, and the increase in the average temperature, etc., which affect mainly the poor population [4]. In order to nurture the exponential growth of the population, avenues of production–consumption need to be reexamined for sustainability. Owing to the extremities bundled with the abruptness of climatic changes and their impact on responsible production–consumption patterns, they were enlisted in the Sustainable Development Goal (SDG) by the United Nations (UN) in the year 2015 [5]. They were enlisted as SDG12, which solely focuses on responsible production–consumption.

It is a fact that India's agricultural activities share nearly 18 percent of the total emission of greenhouse gases (GHG). In continuation of the same, it is predicted that by the year

2030, GHG emission is going to climb to 515 megatons of CO_2 equivalent ($MtCO_2e$) per year [6]. An inference can be grounded on the mentioned fact that places that are currently less prone to climatic susceptibilities are going to be vulnerable in the future. In response to the same, India has aimed to reduce the emission of GHG to half by 2050 [7], and by adopting various smart mitigation practices there is a potential to reduce emissions by 85.5 $MtCO_2e$ per year [6].

In order to achieve the goals of the sustainable development programs, sustainable production–consumption needs to be incorporated with the various agricultural practices [8]. This bundles the notions allied with the sustainability-based production of the various agricultural practices having strong compliances with the economic, social, and societal perspectives [9]. In place of the same, consumption patterns also need to be ramped with sustainability, in order to ensure food safety and security. Consequently, various environmental abruptions, economic distress, and societal disparities have slackened the production–consumption patterns [10]. In order to bridge the same, various agricultural practices need to be upgraded with the various field advancements, shifting agricultural production and its consumption towards sustainability [11]. Agricultural production should be smart enough to counteract the external vulnerabilities; similarly, the consumption volume should be reliable enough to nurture every section of society.

Even the government of India is keen to upscale the income of the farmers and other people who are allied with its supply chain in the journey from farm to fork. Along with this, it is consistently focusing on upscaling living standards, emphasizing the sustainable use of land, water, and other resources, keeping in view the needs of future generations [12]. Hence, various transformative actions need to be ramped up in the agriculture sector in order to meet SDG 13, which focuses entirely on combatting the climatic changes and their impact by enacting the issue within national policy and strategic development frameworks [13].

Nowadays, with the advancement in the domain of information and technology, agricultural practices need to be aligned with the goals of Industry 4.0 in order to tackle such climatic vulnerabilities. Among them, opting for Climate-Smart Agriculture (CSA) is widely seen to achieve these targets. It is a strategy that aims to increase the productivity of land, and the income of farmers, by reducing the emission of greenhouse gases and making crops more climate-resilient [14]. CSA has the potential to step closer to the avenues allied with the SDGs of the UN, especially those associated with food security and climate change [15]. As per the Food and Agriculture Organization (FAO), CSA is not a set of completely new practices but an innovative and integrated approach to tackle challenges such as food security, the increasing global average temperature, the reduction of the productivity of land, the depletion of resources, and the unpredictable nature of the monsoon because of climate change. However, there are a few constraints on the adoption of CSA technologies, some of which are a lack of knowledge, insufficient finance opportunities, and a lack of policies to push its implementation. There is a need for different practices which may be suitable for different kinds of soil, and climatic conditions which are also economically viable [16]. For India, which has so much diversity when it comes to soil types and climatic conditions, not one model of development can be suitable for all regions. There is a need to identify a set of suitable techniques that will yield results in specific conditions regarding which innovation and technology should be promoted in agriculture. The following research queries (RQs) are under consideration:

RQ1: How does the adoption of CSA practices turn the Sustainable Development Goals (SDG 12 and 13) of the United Nation from agenda to reality?
RQ2: How should the CSA-based interventions be enacted in diversified geographical regimes for sustainable production–consumption?
RQ3: How should we secure the primacy of the various smart adoptions in order to move CSA adoption in sustainable avenues?

The presented work aims to answer the mentioned RQs by considering insights gained from the geographical region of Bundelkhand situated in India. The region under consideration is extensively involved in the various agricultural practices.

2. Literature Insights

CSA comprises a set of interventions that help farmers to adjust their farming system towards the mitigation of the effects of extreme climatic events whilst also increasing their income and the productivity of their land [17]. It can be seen that through the implementation of CSA practices, the overall content of organic carbon stock, microbial population, and soil enzymes have increased, thereby increasing the soil fertility and enhancing the production of cereal systems [18]. Imran et al. [14] explored the various adopters of CSA practices allied with the cotton crop in the region of Pakistan. Pal et al. [19] reviewed the avenues for the deployment of the CSA practices in the drought-prone regions of India. Tong et al. [20] discussed the role of CSA practices in mitigating the effect of climate change on the production of rice in China. Khatri-Chhetri et al. [21] detailed the various techniques which are preferred by local farmers in different rainfall zones to combat uncertainty due to climate change. Imran et al. [22] found that access to credit, a good quality of groundwater, awareness about CSA practices, and the ownership of tube wells are some of the factors that improve resource-use efficiency. Raile et al. [23] theoretically reviewed the instances of the adoption of CSA practices in the region of Senegal by exploring the public and political perspectives bundled with them. Agricultural practices such as crop rotation and conservation tillage enhance the crop yield and tackle climatic interventions [14]. Jarial [24] assessed the various challenges allied with the deployment of the Internet of Things for the grounding of CSA-based practices. Jat et al. [18] assessed the various perspectives on the bundling of the CSA and sustainability in the region of the Indo-Gangetic region, which is majorly engaged in the production of rice and wheat.

Imran et al. [14] assessed the impact of CSA practices as an alternative to promote the sustainable production of the cotton crop. Hajimirzajan et al. [25] developed an integrated framework that blends the sustainability principles with the CSA practices for the grounding of the various strategies of the large-scale planning of crops. Abegunde et al. [26] reviewed the CSA practices based on production as the enabler of food security in South Africa. Jiskani et al. [27] evaluated the various factors acting as hurdles for the adoption of CSA practices toward sustainable production–consumption avenues. Hoek et al. [28] detailed the sustainable food systems and their allied factors governing sustainable production–consumption. García-Oliveira et al. [29] ramped up various solutions to promote sustainable production–consumption-based agri-food systems. Liu et al. [30] assessed the various barriers associated with sustainable food production–consumption in China by leveraging them towards the circular economy perspective. Cooreman-Algoed et al. [31] reviewed the customer perception of environmental sustainability-based production–consumption by considering a case study on chicken meat. Tidåker et al. [32] focused on the sustainable consumption of legumes. For the same, their environmental impact was considered in the journey from origin to market. Potter et al. [33] revealed the effects of the environmental sustainability labels on consumer choices, and posed them as an enabler of sustainable consumption. Hötzel and Vandresen [34] reviewed the Brazilian meat industry for the assessment of the various measures governing sustainable production–consumption.

Lipper et al. [35] reviewed the CSA as one of the enablers of food security. Chandra et al. [36] performed a systematic analysis which aimed to reveal the scenarios associated with the adoption of CSA practices in the context of developing nations. Westermann et al. [37] clustered the insights of the various case studies towards the deployment of CSA procedurals. Arslan et al. [38] detailed the adoption-based implication of the CSA in the agri-practices of Zambia. Totin et al. [39] unearthed the various institutional perspectives allied with the enactment of CSA practices. Partey et al. [40] modeled a CSA framework which aimed to overcome climate variability in West Africa, along with its adoption challenges. Shilomboleni et al. [41] reviewed the various political and economic challenges allied with the adoption of CSA practices in Africa. Sain et al. [42]

exercised a probabilistic cost and benefit analysis of CSA practices allied with the maize–bean-based production system. Kurgat et al. [43] explored the technological advancements befitting the CSA practices in Tanzania. Khatri-Chhetri et al. [20] developed a framework posing CSA adoption as the enabler of sustainability in agri-practices. Thornton et al. [44] secured the priorities of the CSA by incorporating spatially and temporally based timescales. Onyeneke et al. [45] reviewed the adoption perspectives in the farming activities of southeast Nigeria. Makate et al. [46] detailed the small farmer's perceptions of the CSA for making farming resilient with the help of climatic vulnerabilities. Sharma et al. [47] reviewed the various market disruptions allied with the production–consumption of agriproducts. Ouédraogo et al. [48] evaluated the actual and potential adoption rates of climate-smart agricultural technologies in developed infrastructure.

Agroforestry in CSA has the potential to enhance agricultural yields among small-holder farmers in the face of climate change [49]. It has been seen that by incorporating agroforestry within the Climate Smart Agriculture Project, the yield of maize crops in the drought-hit year increased by 20% for CSA program participation and 2% for the intensity of agroforestry fertilizer trees. Furthermore, it is recognizable that farmers with diverse income options, such as in the case of agroforestry, are less likely to be affected by changing weather patterns [50]. Taylor and Bhasme [51] reviewed the economic perspectives allied with the incorporation of agroforestry regarding the accomplishment of climate resilience. Partey et al. [52] assessed the technological impact of climate-smart agroforestry in the Sub-Saharan Africa region. Kimrao et al. [53] unfolded the multi-dimensional perspectives bundled with climate-smartness by relating the field advancements in the domain of agroforestry. Zerssa et al. [54] detailed the various challenges allied with the adoption of climate-smart agroforestry techniques by considering the concerns of small farmers in Ethiopia.

Motivational Traits

A plethora of the research literature findings heavily focused on the conceptual perspectives of the adoption of CSA-based agricultural practices. For the same, various studies incorporated regional diversities, widely clustered the deployment challenges, and reviewed the status of their implementation, etc. [54,55]. Among them, studies with theoretical working approaches are on the leading edge in comparison to empirical studies [56]. Insights from the research literature revealed that exploration of the adoption of CSA practices towards the avenues of sustainable production–consumption needs to be ramped up [57]. In continuation of the same, the presented work has seeded the development of the relation hierarchical model, which was further analyzed for pairwise comparison and internal consistency [58].

3. Model Development

In order to bridge the gap in the research literature, the presented work enacts the development of the hierarchical model which classifies the various governing perspectives of the CSA. The developed model seeds the insights gained from the research literature as well as from field practitioners. It comprises the five criteria which govern the twenty distinct attributes, which are further categorized based upon their compliance with the criteria under consideration. The considered criteria and their allied attributes are referred to the research literature, which is detailed further in Table 1. Furthermore, for the ease of understanding of the development, Figure 1 is developed.

Table 1. Details of the criteria and alternatives.

Criteria	Description	Attributes		Description
1. Soil smart (C1)	It is an approach to developing an optimized environment for the crop to grow in soil that has ample access to water, nutrients, and oxygen [59].	**1.1**	Crop Rotation (C11)	Method of growing crops in succession to enhance nutrient efficiency and control diseases [60].
		1.2	Bio-Fertilizers (C12)	Helps in maintaining soil health along with enhancing soil biodiversity [61].
		1.3	Conservation Tillage (C13)	Method to reduce degradation of soil while maintaining ecosystem stability [62].
		1.4	Drainage Management (C14)	Helps in achieving leaching requirements and increases irrigation water efficiencies [63].
2. Water smart (C2)	It focuses on enhancing the perspectives of water management in rain-fed and various irrigated agricultural systems [64].	**2.1**	Drip Irrigation (C21)	Reduces usage of water by minimizing the rate of evaporation and reduces leaching [65].
		2.2	Sprinkler Irrigation (C22)	Reduces water loss and increases yield of water uses per unit or irrigation efficiency [66].
		2.3	Rainwater Harvesting (C23)	Potential to mitigate the exploitation of groundwater and prevent water and food crises [67].
		2.4	Check Dams (C24)	Improves moisture, and reduces erosion activities [68].
3. Knowledge Smart (C3)	It bundles the perspectives allied with the sharing practices, technologies, and other filed advancements towards the enactment of CSA [69].	**3.1**	Livestock and Crop Insurance (C31)	An effective way to overcome the uncertainties of environmental and financial risk [70].
		3.2	Improved and Resilient Seeds (C32)	Ensures food security and adaptability to fight climate change [71].
		3.3	Seed and Fodder Banks (C33)	Preserve surplus fodder and seeds thus helping during times of food scarcity [72].
		3.4	Weather Based Crop Agro Advisory (C34)	Help farmers via the use of technology to prevent the loss of crops at times of abnormal weather conditions [73].
4. Livestock smart (C4)	It details the importance of various adaptation as well as mitigation strategies based on practices along the production–consumption supply chains [74].	**4.1**	Improved Feed for Animals on farm (C41)	Balanced nutrition increases livestock productivity and greenhouse emission [75].
		4.2	Promoting Hybridization (C42)	Ensures different species can adapt to different extreme conditions [76].
		4.3	Stocking Rate Management (C43)	Important to manage to ensure no soil erosion and water pollution [77].
		4.4	Disease Management among Animals (C44)	Ensures no loss of income, productivity, and effect on human health [78].
5. Carbon Smart (C5)	It is an approach to reducing greenhouse gas emissions from agricultural practices [79].	**5.1**	Agroforestry (C51)	Provides various environmental and financial services to the farmers [80].
		5.2	Fodder Management (C52)	The quality of forage directly impacts the net emission of GHG from farms [81].
		5.3	Digester for Bio Gas and manure (C53)	Potential to counteract the GHG emission due to the cultivation of crops [82].
		5.4	Custom Hiring Centre-Mechanization (C54)	Bring down the cost of cultivation and improve the quality of products while also reducing the carbon footprint [83].

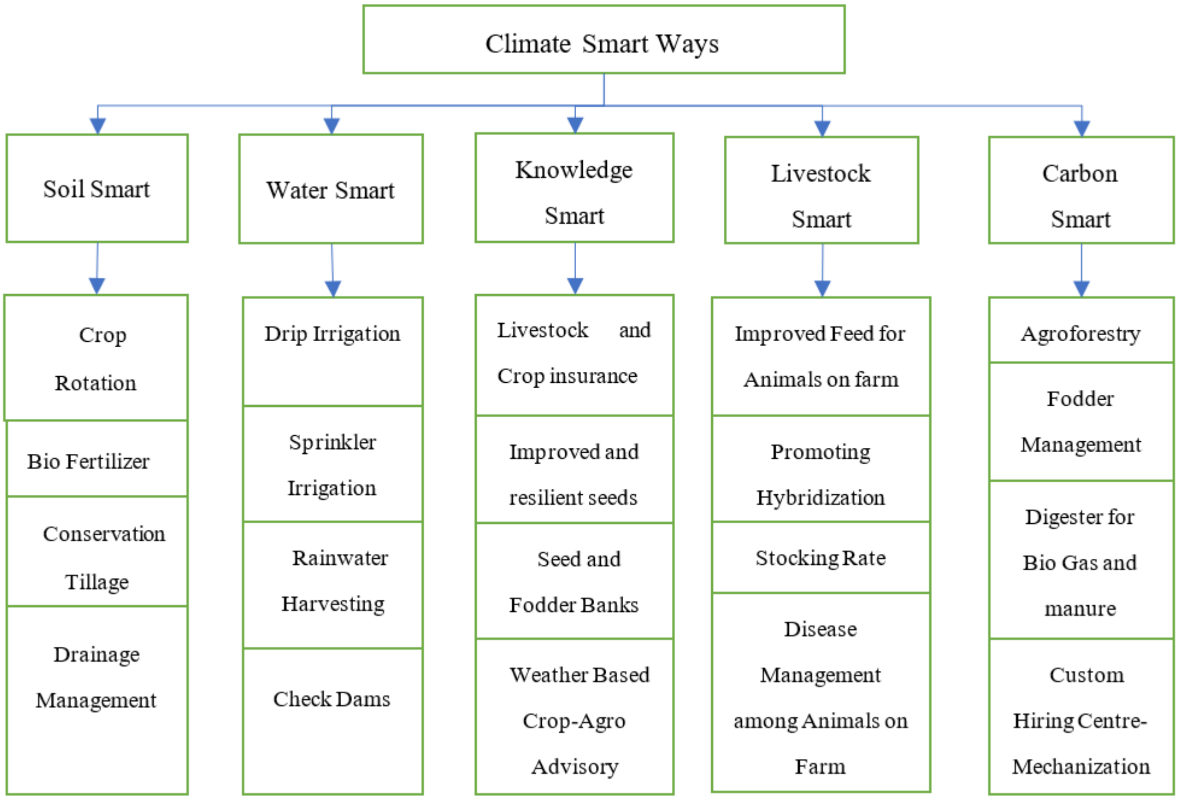

Figure 1. Proposed hierarchy-based model.

4. Research Methodology

The current study applies dual research methodologies, namely AHP and Fuzzy AHP (FAHP). The proposed methodology of the AHP outperforms in structured problems systematically by distinctly evaluating the weights of criteria and alternatives, and securing their primacy [84]. The implication of the AHP carves its way through problems structured hierarchically, from goal to alternatives [85]. Hierarchy glimpses the complexity allied with the inherent relationships, assessing its levels and comparing the elements. Owing to its versatility and consistency with the judgmental points, it is used in a wide range of multidisciplinary problems [86–93].

Firstly, a hierarchical model was developed using five broad criteria and twenty attributes. Initially, the gathered assessments were statistically validated for the dimensions of reliability and robustness by evaluating the Cronbach's alpha coefficient. Furthermore, in order to enrich the outcomes, a separate analysis for the criteria, sub-criteria, and attributes is exercised and detailed in Tables 2 and 3. For ease of understanding, the research methodology chosen in the presented work is diagrammed in Figure 2.

Table 2. Statistics for the criteria.

C_i	Criterion	Mean	SD
C_1	Economic	3.13	0.571
C_2	Environmental	4.13	0.730
C_3	Social	2.03	0.765
C_4	Human	2.80	0.887

Table 3. Statistics for the sub-criteria.

Criterion	Sub Criterion	Mean	SD
Economic	Timber Produce	4.03	0.809
	Non-Timber Produce	3.00	0.947
	Energy Saving	2.73	0.583
	Farm Income	3.77	0.679
	Tourism and Recreation	2.50	0.820
Environment	Soil Conservation	3.17	0.986
	Watershed Protection	3.90	0.845
	Carbon Sequestration	3.73	0.828
	Biodiversity Protection	2.70	1.088
	Air Quality	2.87	0.681
Social	Poverty Alleviation	3.47	0.819
	Shading Benefits	1.93	0.828
	Crop Failure	2.93	0.640
	Animal Husbandry	3.73	0.868
	Farm Output	3.37	0.718
Human	Employment Generation	3.72	0.841
	Organic Farming	2.07	0.923
	Food Security	3.28	0.960
	Living Standard	3.10	0.939
	Migration	3.41	0.907

Initially, the collected assessments were checked for the mean and standard deviation separately, to ensure that none of the criteria involved a redundant response. The same clustered assessments were statistically analyzed by the SPSS software. Its equivalent outputs are glimpsed in Table 2. It is important to check the collected responses for the mean and standard deviation values prior to their evaluation for the dimensions of reliability and robustness.

From Table 2, it can be deduced that the mean of the collected data for criteria C2 is the highest, which implies that the role of maintaining the ecological balance in any system is paramount to making it sustainable. Criterion C1 has the second-highest mean, which signifies the role economics plays in any system that is beneficial for everyone involved in the system. Other criteria—namely social and human—have lower means, with values of 2.03 and 2.80, respectively.

The value of Cronbach's alpha was evaluated using IBM SPSS software and checked with standard acceptable values in order to check if the data is consistent. The generally accepted value of Cronbach's alpha lies in the range of $0.7 < \alpha < 0.95$ [94]. The results of the calculated Cronbach's alpha values for the criteria and sub-criteria are shown in Table 4.

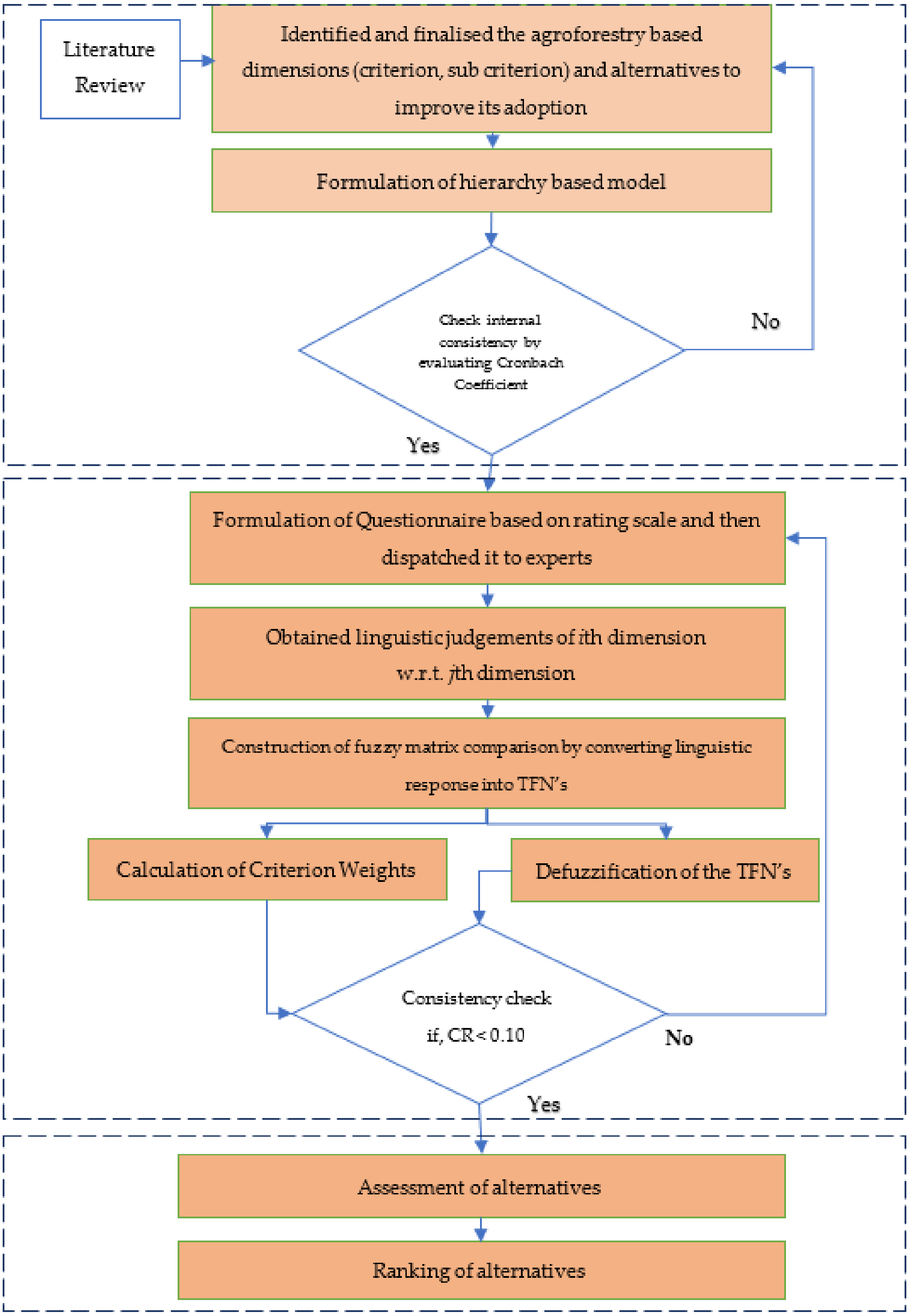

Figure 2. Research methodology.

Table 4. Reliability analysis of the criteria and cub-criteria of the proposed framework.

Criterion	Cronbach's Alpha	Sub Criterion	Cronbach's Alpha
Economic	0.768	Timber Produce	0.87
		Non-Timber Produce	
		Energy Saving	
		Farm Income	
		Tourism and Recreation	
Environment		Soil Conservation	0.872
		Watershed Protection	
		Carbon Sequestration	
		Biodiversity Protection	
		Air Quality	
Social		Poverty Alleviation	0.856
		Shading Benefits	
		Crop Failure	
		Animal Husbandry	
		Farm Output	
Human		Employment Generation	0.844
		Organic Farming	
		Food Security	
		Living Standard	
		Migration	

Hence, an inference can be made that the obtained value of the Cronbach's alpha coefficient is robust and reliable enough.

4.1. Analytic Hierarchy Process (AHP)

AHP is a multi-criteria decision-making tool that helps us to solve various complex problems by reducing them to a series of pairwise combinations and producing a result [94]. It ranks the alternatives and helps in selecting the most crucial alternative when the decision-maker has many alternatives to choose from. It is widely applied in hierarchical model analysis [95] to obtain a unidirectional relationship between different levels [96]. It can be used to deal with both qualitative and quantitative evaluation, and it can transform it into a multi-criteria ranking. It also incorporates a technique that can help in the checking of the consistency of decision-maker evaluation, and thus reduces the probability of bias in the decision-making process [97].

Initially, a hierarchical model was developed which comprises the set of criteria, sub-criteria, and alternatives relative to the goal under consideration. Furthermore, pairwise comparisons are constructed between the criteria, sub-criteria, and alternatives, respectively, based upon the rating values clustered in Table 5. A pairwise comparison among 'n' criteria was performed, and an $n \times n$ dimension matrix, A, was formulated: $A = \left(a_{ij}\right)_{n\ x\ n}$ where each element, a_{ij} (i, j = 1, 2, 3 . . . n), represents the pairwise comparison value of the i^{th} element relative to the jth element. The formula $n(n-1)/2$ gives the total number of pairwise comparisons when n criteria are considered. The matrix of pairwise comparison is represented in Equation (1).

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} \qquad a_{ii} = 1 \text{ for } i = j,\ a_{ji} = \frac{1}{a_{ij}} \text{ and } a_{ij} \neq 0. \tag{1}$$

Table 5. Rating values.

Equivalence	Rating Value
The comparison seems to be equally important	1
The comparison seems to be moderately more important	3
The comparison perceives to be very strongly important	5
The comparison poses a strong importance	7
The comparison is extremely important	9
Intermediaries	2, 4, 6, 8

In order to obtain the normalized pairwise comparison matrix, 'A_{norm}' can be obtained by making the sum of entries of each column equal to 1. Each entry of A_{norm} can be computed as shown in Equation (2).

$$\bar{a}_{ij} = \frac{a_{ij}}{\sum_{l=1}^{n} a_{lj}} \tag{2}$$

The final criteria weight is calculated by taking the average of all of the rows of A_{norm}, applying Equation (3):

$$w_j = \frac{\sum_{l=1}^{n} \bar{a}_{jl}}{n},\ w_j \text{ is the } n - \text{dimensional column vector} \tag{3}$$

At each stage, the consistency needs to be checked, as it is a very important factor. It requires the calculation of the largest eigenvalue of the matrix, λ_{max}, as shown in Equations (4) and (5), respectively:

$$\lambda_{max} = \frac{1}{n} \sum_{i=1}^{n} \frac{(Aw)_i}{w_i} \tag{4}$$

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{5}$$

The acceptable consistency ratio (CR) value is used to check the consistency degree by applying the formula detailed in Equation (6):

$$CR = \frac{CI}{RI} \tag{6}$$

where CI is the consistency index and RI is the random index of which the value depends upon the dimension of matrix A. If $CR < 0.1$, then the inconsistency degree for Matrix A is accepted, and the normalized weight w_j vector can be accepted as the weight of the elements.

4.2. Fuzzy Analytic Hierarchy Process (FAHP)

FAHP is an extension of Saaty's AHP in which fuzzy set theory is used. Extending the fundamentals of the fuzzy sets incorporates the vagueness and uncertainty allied with human judgment [98,99]. Hence, in order to tackle the decisional uncertainties, FAHP is implied in the proposed model for the assessment of the CSA practices. For the same thing, a triangular form of the membership function is given for each rating value, as shown in Figure 3 and Table 6.

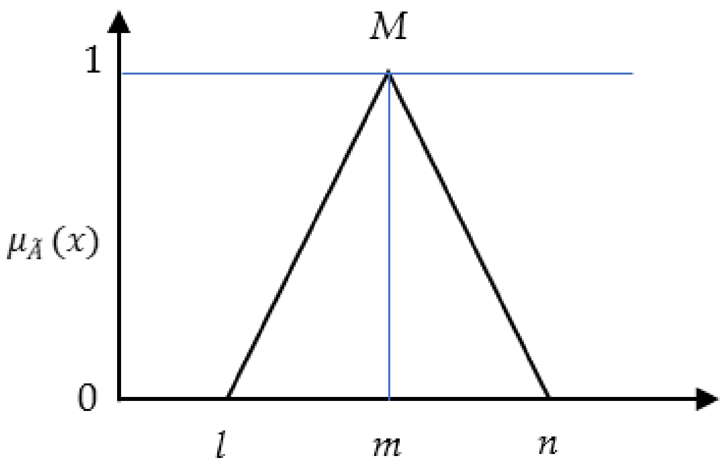

Figure 3. Triangular fuzzy number (TFN).

Table 6. Linguistic variables and TFN for the criteria and sub-criteria ratings.

Fuzzy Number	Linguistic Variables	TFN
9	Extreme importance	(8, 9, 10)
8	Very strong to Extreme importance	(7, 8, 9)
7	Very strong importance	(6, 7, 8)
6	Strong to very strong importance	(5, 6, 7)
5	Strong importance	(4, 5, 6)
4	Moderate to strong importance	(3, 4, 5)
3	Moderate importance	(2, 3, 4)
2	Equal to moderate importance	(1, 2, 3)
1	Equal importance	(1, 1, 1)

For the fuzzy set $\widetilde{A}$ in a universe of discourse X with a set of elements, x is represented by a membership function $\mu_{\widetilde{A}}(x)$ in which each element 'x' in 'X' is mapped to a real number in the interval [0, 1]. If $\widetilde{a}$ is a triangular fuzzy number (TFN) then it is represented in fuzzy theory by a triplet (l, m, u). The membership function can be defined as shown in Equation (7) and visualized in Figure 4.

$$\mu_{\widetilde{A}}(x) = \begin{cases} 0, & x < l \\ \frac{x-l}{m-l}, & l \leq x \leq m, \\ \frac{u-x}{u-m}, & m \leq x \leq u \\ 0, & x > u \end{cases} \quad (7)$$

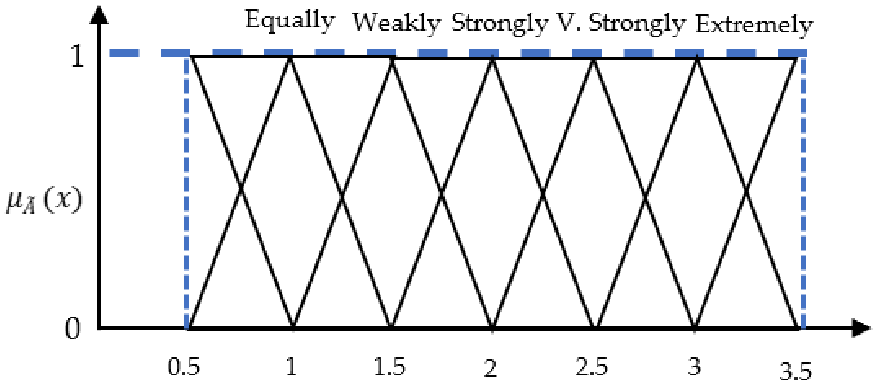

Figure 4. TFN membership plots.

The opinions of various field experts, collected in linguistic terms, are converted into the corresponding TFN. Assuming 'n' elements, the pairwise comparison of element i with element j gives an $n \times n$ fuzzy matrix containing fuzzy numbers $\widetilde{a}_{ij}$. The developed decision matrix is shown in Equation (8):

$$A = \begin{bmatrix} A_{11} & \cdots & A_{1n} \\ \vdots & \ddots & \vdots \\ A_{n1} & \cdots & A_{nn} \end{bmatrix}$$

where A_{ij} denotes the importance of the ith element with regard to the jth element and

$$\widetilde{a}_{ij}(1,\ 1,\ 1)\ for\ i = j\ and\ \widetilde{a}_{ij} = \frac{1}{\widetilde{a}_{ji}}\ for\ i \neq j \tag{8}$$

The geometric mean of the fuzzy comparison value is calculated for each criterion I, and each criterion is evaluated by the opting methodology shown in Equation (9).

$$\widetilde{r}_i = \widetilde{a}_{i1} \times \ldots\ldots\ldots \times \widetilde{a}_{in}{}^{\frac{1}{n}} \tag{9}$$

where $\widetilde{a}_{in}$ is a fuzzy value of the pairwise comparison of criterion i to n. Furthermore, the weights allied with the fuzzy numbers are evaluated by normalization. For the particular i criterion, its fuzzy weight is evaluated by applying the formula shown in Equation (10):

$$w_{i=}\widetilde{r}_i\ \times (\widetilde{r}_1 + \cdots + \widetilde{r}_n)^{-1}\ where\ \widetilde{r}_i = \widetilde{a}_{i1} \times \ldots\ldots\ldots \times \widetilde{a}_{in}{}^{\frac{1}{n}} \tag{10}$$

It is necessary to check the CR. For this, the obtained fuzzy weights are converted into crisp numbers by using the graded mean integration method. According to this approach, a fuzzy no. $\widetilde{A} = (l,\ m,\ u)$ can be transformed into a crisp value by using the following equation:

$$P\left(\widetilde{A}\right) = A = \frac{l + 4m + u}{6} \tag{11}$$

After obtaining the matrix in the crisp form, the CR can be checked.

4.3. Numerical Illustration

The developed hierarchical framework is analyzed by the methodologies of AHP and FAHP. Assessments are gained by using the nine-point rating scale, which seeds the development of the pairwise comparison matrix, as shown in Table 7. Furthermore, the presented work is enumerated with insights into the agriculture-rich area of the Bundelkhand region of India.

Table 7. Pairwise comparison matrix for the criteria.

	Soil Smart	Water Smart	Knowledge Smart	Livestock Smart	Carbon Smart
Soil Smart	1	1/3	1/5	2	1/3
Water Smart	3	1	2	2	2
Knowledge Smart	5	1/2	1	5	3
Livestock Smart	1/2	1/2	1/5	1	1/4
Carbon Smart	3	1/2	1/3	2	1

Because the gained assessments are subjective, their consistency is checked distinctly with the AHP and FAHP, based upon which the weights are evaluated and finalized. The matrix for pairwise comparison for the sub-attributes of the criteria Soil Smart (C1), Water Smart (C2), Knowledge Smart (C3), Livestock Smart (C4), and Carbon Smart (C5) is shown in Tables 8–12, respectively.

Table 8. Criterion 1-based comparisons.

	C11	C12	C13	C14
C11	1	3	5	1
C12	1/3	1	4	1/3
C13	1/5	1/4	1	1/3
C14	1	3	3	1

Table 9. Criterion 2-based comparisons.

	C21	C22	C23	C24
C21	1	5	3	7
C22	1/5	1	1/3	2
C23	1/3	3	1	6
C24	1/7	1/2	1/6	1

Table 10. Criterion 3-based comparisons.

	C31	C32	C33	C34
C31	1	1/5	4	1/2
C32	5	1	6	3
C33	1/4	1/6	1	1/5
C34	2	1/3	5	1

Table 11. Criterion 4-based comparisons.

	C41	C42	C43	C44
C41	1	3	4	2
C42	1/3	1	1	1/3
C43	1/4	1	1	1/5
C44	1/2	3	5	1

Table 12. Criterion 5-based comparisons.

	C51	C52	C53	C54
C51	1	5	6	3
C52	1/5	1	3	1/3
C53	1/6	1/3	1	1/4
C54	1/3	3	4	1

Based on the pairwise comparison matrix, local and global weights depicting the importance of the criteria and sub-attributes are calculated by the methodology of AHP.

Determination of Weight Using FAHP

In order to compare the weights of criteria obtained via AHP with FAHP, and to remove the vagueness generated due to human judgments, the evaluation of the weights is performed by FAHP, for which the questionnaire was prepared using the fuzzy linguistic scale as shown in Table 4. After that, a pairwise comparison matrix for the criteria was established by summarizing the data into corresponding TFN, which are shown in Table 13.

Table 13. TFN-based pairwise comparison matrix for the criteria.

	Soil Smart	Water Smart	Knowledge Smart	Livestock Smart	Carbon Smart
Soil	(1, 1, 1)	(1/4, 1/3, 1/2)	(1/6, 1/5, 1/4)	(1, 2, 3)	(1/4, 1/3, 1/2)
Water	(2, 3, 4)	(1, 1, 1)	(1/3, 1/2, 1)	(1, 2, 3)	(1, 2, 3)
Knowledge	(4, 5, 6)	(1, 2, 3)	(1, 1, 1)	(3, 4, 5)	(2, 3, 4)
Livestock	(1/3, 1/2, 1)	(1/3, 1/2, 1)	(1/5, 1/4, 1/3)	(1, 1, 1)	(1/3, 1/2, 1)
Carbon	(2, 3, 4)	(1/3, 1/2, 1)	(1/4, 1/3, 1/2)	(1, 2, 3)	(1, 1, 1)

Matrix for the pairwise comparison of the sub-attributes of five criteria: Soil Smart (C1), Water Smart (C2), Knowledge Smart (C3), Livestock Smart (C4), and Carbon Smart (C5) is shown in Tables 14–18.

Table 14. Pairwise comparison matrix of alternatives for criterion C1.

	C11	C12	C13	C14
C11	(1, 1, 1)	(2, 3, 4)	(4, 5, 6)	(1, 1, 1)
C12	(1/4, 1/3, 1/2)	(1, 1, 1)	(3, 4, 5)	(1/4, 1/3, 1/2)
C13	(1/6, 1/5, 1/4)	(1/5, 1/4, 1/3)	(1, 1, 1)	(1/4, 1/3, 1/2)
C14	(1, 1, 1)	(2, 3, 4)	(2, 3, 4)	(1, 1, 1)

Table 15. Pairwise comparison matrix of alternatives for criterion C2.

	C21	C22	C23	C24
C21	(1, 1, 1)	(4, 5, 6)	(2, 3, 4)	(6, 7, 8)
C22	(1/6, 1/5, 1/4)	(1, 1, 1)	(1/6, 1/5, 1/4)	(1, 2, 3)
C23	(1/4, 1/3, 1/2)	(2, 3, 4)	(1, 1, 1)	(5, 6, 7)
C24	(1/8, 1/7, 1/6)	(1/3, 1/2, 1)	(1/6, 1/6, 1/5)	(1, 1, 1)

Table 16. Pairwise comparison matrix of alternatives for criterion C3.

	C31	C32	C33	C34
C31	(1, 1, 1)	(1/6, 1/5, 1/4)	(3, 4, 5)	(1/3, 1/2, 1)
C32	(4, 5, 6)	(1, 1, 1)	(5, 6, 7)	(2, 3, 4)
C33	(1/5, 1/4, 1/3)	(1/7, 1/6, 1/5)	(1, 1, 1)	(1/6, 1/5, 1/4)
C34	(1, 2, 3)	(1/4, 1/3, 1/2)	(4, 5, 6)	(1, 1, 1)

Table 17. Pairwise comparison matrix of alternatives for criterion C4.

	C41	C42	C43	C44
C41	(1, 1, 1)	(2, 3, 4)	(3, 4, 5)	(1, 2, 3)
C42	(1/4, 1/3, 1/2)	(1, 1, 1)	(1, 1, 1)	(1/4, 1/3, 1/2)
C43	(1/5, 1/4, 1/3)	(1, 1, 1)	(1, 1, 1)	(1/6, 1/5, 1/4)
C44	(1/3, 1/2, 1)	(2, 3, 4)	(4, 5, 6)	(1, 1, 1)

Table 18. Pairwise comparison matrix of alternatives for criterion C5.

	C51	C52	C53	C54
C51	(1, 1, 1)	(4, 5, 6)	(5, 6, 7)	(2, 3, 4)
C52	(1/6, 1/5, 1/4)	(1, 1, 1)	(2, 3, 4)	(1/4, 1/3, 1/2)
C53	(1/7, 1/6, 1/5)	(1/4, 1/3, 1/2)	(1, 1, 1)	(1/5, 1/4, 1/3)
C54	(1/4, 1/3, 1/2)	(2, 3, 4)	(3, 4, 5)	(1, 1, 1)

Based upon the pairwise comparison rendered distinctly for the criteria and alternatives, FAHP is implied for the evaluation of the weights by implying a set of formulations detailed in Equations (7)–(11).

5. Results and Discussion

In this study, a comparative analysis of the AHP and FAHP was used to determine the key parameters and practices for achieving the goal of CSA. Using AHP, the local weight (LW) and global weight (GW) of the criteria were calculated, and are shown in Table 19.

Table 19. Summary of the evaluation of the AHP criterion weight.

Attribute	LW	Sub Attribute	LW	GW
Soil Smart	0.0937	Crop Rotation	0.3920	0.0367
		Vermicomposting and Mulching	0.1755	0.0164
		Conservation Tillage	0.0788	0.0073
		Drainage Management	0.3535	0.0331
Water Smart	0.3198	Drip Irrigation	0.5567	0.1781
		Check Dams	0.1059	0.0338
		Sprinkler Irrigation	0.2779	0.0889
		Rainwater Harvesting	0.0593	0.0189

Table 19. *Cont.*

Attribute	LW	Sub Attribute	LW	GW
Knowledge Smart	0.3433	Livestock and Crop insurance	0.1488	0.0511
		Improved and resilient seeds varieties	0.5519	0.1895
		Seed and Fodder Banks	0.0583	0.0200
		Weather-Based Crop-Agro Advisory	0.2409	0.0189
Livestock Smart	0.0782	Improved Feed for Animals on the farm	0.4462	0.0349
		Promoting Hybridization	0.1175	0.0092
		Stocking Rate Management	0.0981	0.0076
		Disease Management among Animals	0.3381	0.0265
Carbon Smart	0.1648	Agroforestry	0.5517	0.0909
		Fodder Management	0.1279	0.0210
		Digester for Bio Gas and manure	0.0649	0.0107
		Custom Hiring Centre- Mechanization	0.2553	0.0421

Furthermore, in order to enrich the analysis and capture the various uncertainties in the decision-making process, the developed model is assessed using the methodology of FAHP, which yields the evaluation of the local and global weight of the various attributes of the CSA-based adoptions. The outcomes of the FAHP are summarized in Table 20.

Table 20. Summary of the evaluation of the FAHP criterion weight.

Attribute	LW	Sub Attribute	LW	GW
Soil Smart	0.0886	Crop Rotation	0.4090	0.0362
		Vermicomposting and Mulching	0.1742	0.0154
		Conservation Tillage	0.0764	0.0067
		Drainage Management	0.3601	0.0319
Water Smart	0.3080	Drip Irrigation	0.5725	0.1763
		Check Dams	0.1098	0.0338
		Sprinkler Irrigation	0.2833	0.0872
		Rainwater Harvesting	0.0607	0.0187
Knowledge Smart	0.3404	Livestock and Crop insurance	0.1515	0.0516
		Improved and resilient seeds varieties	0.5693	0.1938
		Seed and Fodder Banks	0.0564	0.0192
		Weather-Based Crop-Agro Advisory	0.2529	0.0861
Livestock Smart	0.0709	Improved Feed for Animals on the farm	0.4648	0.0330
		Promoting Hybridization	0.1228	0.0087
		Stocking Rate Management	0.0992	0.0070
		Disease Management among Animals	0.3562	0.0252
Carbon Smart	0.1918	Agroforestry	0.5708	0.1095
		Fodder Management	0.1259	0.0241
		Digester for Bio Gas and manure	0.0648	0.0124
		Custom Hiring Centre- Mechanization	0.2655	0.0509

For a better understanding of the distinct outcomes of the proposed methodology, a plot is provided in Figure 5, which compares the weights of the sub-attributes of the CSA-based adoption regarding the promotion of sustainable production–consumption patterns.

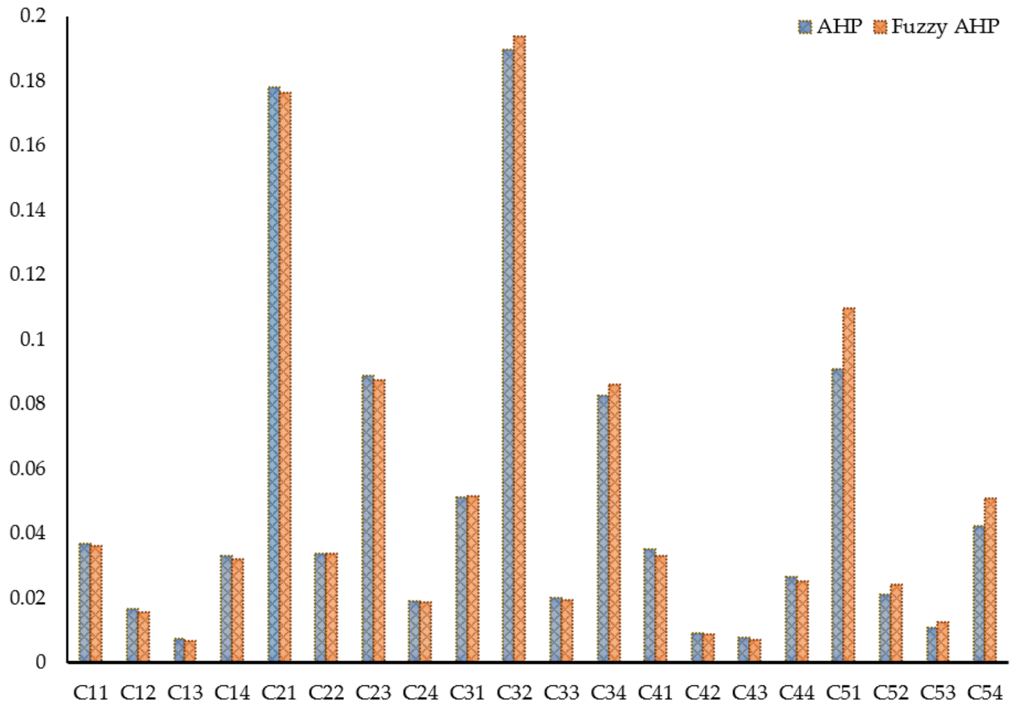

Figure 5. Summary of the comparison of the weights of the sub-attributes.

An inference can be made from the developed plots of the sub-attributes that improved and resilient seed varieties empower the enactment of the CSA-based practices. Using the improved seed varieties ensures the remarkable production volumes that are reliable enough to nurture the consumption needs of the masses. Improved seeds have better yields and less water and fertiliser utilization, which safeguards the natural resources and brings us a step closer to sustainability. Furthermore, implying drip irrigation for agricultural practices evokes the optimum utility of the water resources, rather than the direct pumping of groundwater. Such initiatives bring us a step closer to the avenues of sustainable production. The effective management of the land and water resources can be achieved by using agro forestry-based practices. These use the agricultural land cultivation of the trees and shrubs into the crop, and develop animal farming for social, economic, and environmental benefits. They incorporate financial flexibility and diversity, underpinning the notions of sustainable production–consumption.

Most agricultural practices are susceptible to weather vulnerabilities and pest attacks, which distort the mapping of the supply and demand patterns. Often, instances come into light when the low yield of the crops results in the high pricing of its constituent products and hampers their availability in the market. Hence, the mechanism allied with the weather-based crop-agro advisory should be strengthened. It is intended to reduce the pre- and post-harvest losses and curtail the wastage of manpower, materials, and allied resources. Furthermore, in order to cope with the same, the insurance of the crops and livestock needs to be ensured, which provides the necessary assistance and secures the dimension of food safety. In order to cater to the needs of the spawning population, traditional agricultural practices need to be enveloped by CSA-based activities. This ensures the mechanization of the existing practices and aligns them with the various field advancements of information technology. Such initiatives are necessary in order to balance production–consumption volumes and facilitate better traceability across the agri-food supply chains.

In order to manage soil fertility and prevent the depletion of its nutrient value, crop rotation patterns should be induced as part of CSA. This intervenes in the intentional combination of the various crops to be sown throughout the year, ensuring the financial benefits after a regular short interval of time, and fixes the nutrients in the soil. It promotes the optimum usage of the land, water, and other allied resources, advancing toward sustainable production–consumption. Furthermore, strengthening the irrigation means and ensuring drain management, improving the feeds for livestock, setting up the fodder banks, promoting the hybridization of the agricultural activities, and enhancing the CSA measures are also crucial for revamping the CSA measures. It can be inferred that CSA deployment is key to the promotion of sustainable production–consumption in the journey from farm to fork. The presented work enacted the duo of AHP and FAHP for the assessment of the attributes and sub-attributes of CSA adoption for the leveraging of the benefits of sustainable production–consumption. A distinct assessment of the criteria weights allied with the developed model is detailed in Table 21, and for greater understanding, the same plots are provided in Figure 6.

Table 21. Comparison of the AHP and FAHP results.

Methodology	C1	C2	C3	C4	C5
AHP	0.0937	0.3198	0.3433	0.0782	0.1648
FAHP	0.0886	0.3080	0.3404	0.0709	0.1918

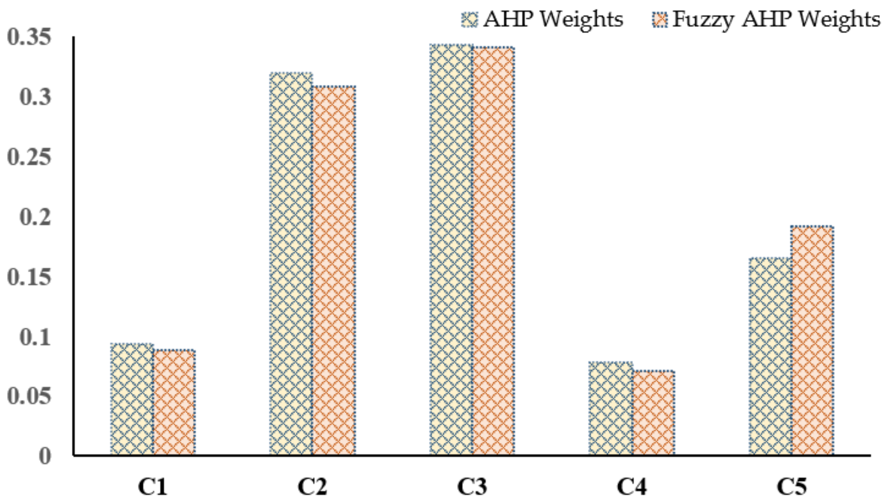

Figure 6. Comparison of the AHP- and FAHP-based criteria weights.

An inference can be made that among all of the criteria, the Knowledge Smart (C3) criterion has been given the utmost importance, followed by Water Smart, Carbon Smart, Soil Smart, and Livestock Smart. Because, in recent times, the characteristics of the decision-maker, information, and probable deviation is integrated into the decision-making process, a comparison of the results obtained via the AHP with FAHP becomes necessary. It can be seen that although the trend is the same in both AHP and FAHP, the criterion weights obtained are different. The maximum deviation is seen for the criterion Carbon Smart.

The most weighted criterion is Knowledge Smart, which clearly shows that, in the future, information technology is going to play a vital role. The second-most important criterion is Water Smart, which shows the concern of experts and farmers regarding the judicious use of water. Water scarcity is prevalent in many parts of the world, and is going to worsen even more in the coming future. Therefore, drip irrigation technology, which makes the most efficient use of the water available, has been given high importance. The rainwater harvesting method—in which the water is stored in man-made ponds or tanks—has also been given high importance, and can help farmers cope with the changing monsoon patterns. This will also promote production–consumption in the tough times of water scarcity.

Agroforestry is chosen above all else because it can help in facing climate change in multidimensional ways. It has the potential to enhance soil fertility by supplementing organic content in the soil in the form of plant litter, increasing the rainwater holding capacity, minimizing the erosion of soil by reducing runoff, and most importantly, proliferating the farmer's income. Other carbon-smart practices such as custom hiring centers can help reduce the carbon footprint and also help farmers to use modern equipment and technologies in their field. This can help play a revolutionary role in transforming agriculture from traditional to modern sustainable agriculture, emphasizing sustainable and responsible production–consumption.

The criteria Carbon Smart and Livestock Smart—in which crop rotation and improved feed for farm animals have been given utmost priority, respectively—have their environmental benefits. Crop rotation can help the soil recover its lost nutrients, and is critical for maintaining the health of the soil. Improvements in feed for animals on the farm can help reduce the emission of GHG, as the diet of animals is directly linked to the greenhouse gases they emit. This is even more important because a quarter of all GHG emissions occur because of food production–consumption.

6. Conclusions

The presented study aimed to move traditional agricultural practices toward the advancements of climate-smart agriculture. Various climatic abruptions and prevailing weather uncertainties due to the large scale of globalization and industrialization have posed a threat to the nurturing of the spawning populations across the globe. Hence, the need has arisen for a shift toward sustainable production–consumption patterns and an upgrade of the existing agricultural activities close to CSA. For the same, a relational hierarchical model was developed in this work, which was further analyzed for the various pairwise comparisons and internal consistency by the methodology of the AHP, and validated by FAHP. The contemplation of the proposed model resulted in the securing of the primacy of the various attributes and sub-attributes of the CSA.

It is evident from the obtained results for enacting the CSA-based practices that improved seed varieties featuring resilience should be utilized, and more emphasis should be placed on the knowledge-based smart practices mentioned in the developed framework. Using the improved seed varieties improves the utility of the land, promises crop yields, and strengthens the economic, social, and societal perspectives responsible for the sustainable production–consumption patterns. Furthermore, opting for the various water-smart adoptions and rendering the measures for promoting drip irrigation, ensuring proper drain management, and regulating the water for irrigation by creating check dams would be wise. Agricultural activities extensively utilize groundwater, but its replenishment rate is quite low in comparison to its consumption rate. Hence, in order to safeguard the interests of society and promote equity, sustainable production–consumption measures need to be taken.

Furthermore, the developed framework revealed that some of the ideas—like seed and fodder banks and custom hiring center mechanization—were identified to have the potential to bring about a significant change in the rural economy of the country while also ensuring the country meets its SDGs. In a continuation of this, the same agroforestry-based practices should be ramped up towards the adoption of the CSA protocols in agricultural practices. Agroforestry is seen as a promising alternative for aggregating and sustaining production in the agricultural sector while also ameliorating the deleterious effects of food production—consumption on the environment. Sustainable development via the adoption of scientific agroforestry interventions has tremendous potential to meet several objectives of the SDGs. Furthermore, adopting the agroforestry-based CSA is an enabler of carbon smart-based interventions. These interventions aim to reduce the carbon footprint generated from the various agricultural activities and the allied course of the production–consumption volumes.

Agroforestry and fodder management have the potential to meet the demands of raw materials that are currently imported, with examples being timber and medicinal herbs. Without transforming agriculture, it is impossible to preserve the biodiversity on this planet, and climate-smart interventions could prove to be the transformation that the agriculture sector desperately needs. The outcome of the study points out some effective techniques which can be useful for decision-makers at various levels. Based on this study, policy-makers, district agricultural departments, agricultural research institutions, and non-government organizations can determine appropriate investment decisions on high-weighted techniques that will have a constructive impact on the current and future context of social, economic, and environmental development in the agriculture sector, stepping closer towards sustainable production–consumption.

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References

1. Rao, C.S.; Kareemulla, K.; Krishnan, P.; Murthy, G.R.K.; Ramesh, P.; Ananthan, P.S.; Joshi, P.K. Agro-ecosystem based sustainability indicators for climate resilient agriculture in India: A conceptual framework. *Ecol. Indic.* **2019**, *105*, 621–633. [CrossRef]
2. Zulfiqar, F.; Thapa, G.B. Determinants and intensity of adoption of "better cotton" as an innovative cleaner production alternative. *J. Clean. Prod.* **2018**, *172*, 3468–3478. [CrossRef]
3. Srinivasarao, C.H.; Rao, K.V.; Gopinath, K.A.; Prasad, Y.G.; Arunachalam, A.; Ramana, D.B.V.; Chary, G.R.; Gangaiah, B.; Venkateswarlu, B.; Mohapatra, T. Agriculture contingency plans for managing weather aberrations and extreme climatic events: Development, implementation and impacts in India. *Adv. Agron.* **2020**, *159*, 35–91. [CrossRef]
4. Falco, C.; Galeotti, M.; Olper, A. Climate change and migration: Is agriculture the main channel? *Glob. Environ. Change* **2019**, *59*, 101995. [CrossRef]
5. Chuang, Y. Climate variability, rainfall shocks, and farmers' income diversification in India. *Econ. Lett.* **2019**, *174*, 55–61. [CrossRef]
6. Sapkota, T.B.; Vetter, S.H.; Jat, M.L.; Sirohi, S.; Shirsath, P.B.; Singh, R.; Jat, H.S.; Smith, P.; Hillier, J.; Stirling, C.M. Cost-effective opportunities for climate change mitigation in Indian agriculture. *Sci. Total Environ.* **2019**, *655*, 1342–1354. [CrossRef] [PubMed]
7. Bhattacharya, A. Global climate change and its impact on agriculture. In *Changing Climate and Resource Use Efficiency in Plants*; Academic Press: Cambridge, MA, USA, 2019; pp. 1–50. [CrossRef]
8. Barber, J. Mapping the movement to achieve sustainable production and consumption in North America. *J. Clean. Prod.* **2007**, *15*, 499–512. [CrossRef]
9. Garcia-Herrero, I.; Hoehn, D.; Margallo, M.; Laso, J.; Bala, A.; Batlle-Bayer, L.; Fullana, P.; Vazquez-Rowe, I.; Gonzalez, M.J.; Durá, M.J.; et al. On the estimation of potential food waste reduction to support sustainable production and consumption policies. *Food Policy* **2018**, *80*, 24–38. [CrossRef]
10. Almuflih, A.S.; Sharma, J.; Tyagi, M.; Bhardwaj, A.; Qureshi, M.R.N.M.; Khan, N. Leveraging the Dynamics of Food Supply Chains towards Avenues of Sustainability. *Sustainability* **2022**, *14*, 6958. [CrossRef]
11. Sharma, J.; Tyagi, M.; Bhardwaj, A. Assessment of the Challenges Obstructing Performance of Indian Food Supply Chain Dynamics. In *Recent Advances in Operations Management Applications*; Springer: Singapore, 2022; pp. 365–376. [CrossRef]
12. Haque, M.I.; Khan, M.R. Impact of climate change on food security in Saudi Arabia: A roadmap to agriculture-water sustainability. *J. Agribus. Dev. Emerg. Econ.* **2020**, *12*, 1–18. [CrossRef]

13. Sharma, J.; Tyagi, M.; Bhardwaj, A. Parametric review of food supply chain performance implications under different aspects. *J. Adv. Manag. Res.* **2020**, *17*, 421–453. [CrossRef]
14. Imran, M.A.; Ali, A.; Ashfaq, M.; Hassan, S.; Culas, R.; Ma, C. Impact of climate smart agriculture (CSA) through sustainable irrigation management on Resource use efficiency: A sustainable production alternative for cotton. *Land Use Policy* **2019**, *88*, 104113. [CrossRef]
15. Newell, P.; Taylor, O.; Naess, L.O.; Thompson, J.; Mahmoud, H.; Ndaki, P.; Rurangwa, R.; Teshome, A. Climate smart agriculture? Governing the sustainable development goals in Sub-Saharan Africa. *Front. Sustain. Food Syst.* **2019**, *3*, 55. [CrossRef]
16. Suganthi, A.; Nikita, S.A.; Kousika, J.; Bhuvaneswari, K.; Sridharan, S. Determination of thiamethoxam residues in banana stem and fruit through LC-MS/MS. *Environ. Monit. Assess.* **2018**, *190*, 1–8. [CrossRef] [PubMed]
17. Waaswa, A.; Oywaya Nkurumwa, A.; Mwangi Kibe, A.; Ngeno Kipkemoi, J. Climate-Smart agriculture and potato production in Kenya: Review of the determinants of practice. *Clim. Dev.* **2022**, *14*, 75–90. [CrossRef]
18. Jat, H.S.; Choudhary, M.; Kakraliya, S.K.; Gora, M.K.; Kakraliya, M.; Kumar, V.; Poonia, T.; Mcdonald, A.J.; Jat, M.L.; Sharma, P.C.; et al. A Decade of Climate-Smart Agriculture in Major Agri-Food Systems: Earthworm Abundance and Soil Physico-Biochemical Properties. *Agronomy* **2022**, *12*, 658. [CrossRef]
19. Pal, B.D.; Kapoor, S.; Saroj, S.; Jat, M.L.; Kumar, Y.; Anantha, K.H. Adoption of climate-smart agriculture technology in drought-prone area of India–implications on farmers' livelihoods. *J. Agribus. Dev. Emerg. Econ.* 2021; *ahead of print*. [CrossRef]
20. Tong, Q.; Swallow, B.; Zhang, L.; Zhang, J. The roles of risk aversion and climate-smart agriculture in climate risk management: Evidence from rice production in the Jianghan Plain, China. *Clim. Risk Manag.* **2019**, *26*, 100199. [CrossRef]
21. Khatri-Chhetri, A.; Aggarwal, P.K.; Joshi, P.K.; Vyas, S. Farmers' prioritization of climate-smart agriculture (CSA) technologies. *Agric. Syst.* **2017**, *151*, 184–191. [CrossRef]
22. Imran, M.A.; Ali, A.; Ashfaq, M.; Hassan, S.; Culas, R.; Ma, C. Impact of Climate Smart Agriculture (CSA) practices on cotton production and livelihood of farmers in Punjab, Pakistan. *Sustainability* **2018**, *10*, 2101. [CrossRef]
23. Raile, E.D.; Young, L.M.; Sarr, A.; Mbaye, S.; Raile, A.N.; Wooldridge, L.; Sanogo, D.; Post, L.A. Political will and public will for climate-smart agriculture in Senegal: Opportunities for agricultural transformation. *J. Agribus. Dev. Emerg. Econ.* **2019**, *9*, 44–62. [CrossRef]
24. Jarial, S. Internet of Things application in Indian agriculture, challenges and effect on the extension advisory services—A review. *J. Agribus. Dev. Emerg. Econ.* 2022; *ahead of print*. [CrossRef]
25. Hajimirzajan, A.; Vahdat, M.; Sadegheih, A.; Shadkam, E.; El Bilali, H. An integrated strategic framework for large-scale crop planning: Sustainable climate-smart crop planning and agri-food supply chain management. *Sustain. Prod. Consum.* **2021**, *26*, 709–732. [CrossRef]
26. Abegunde, V.O.; Sibanda, M.; Obi, A. Effect of climate-smart agriculture on household food security in small-scale production systems: A micro-level analysis from South Africa. *Cogent Soc. Sci.* **2022**, *8*, 2086343. [CrossRef]
27. Jiskani, I.M.; Cai, Q.; Zhou, W.; Lu, X.; Shah, S.A.A. An integrated fuzzy decision support system for analyzing challenges and pathways to promote green and climate smart mining. *Expert Syst. Appl.* **2022**, *188*, 116062. [CrossRef]
28. Hoek, A.C.; Malekpour, S.; Raven, R.; Court, E.; Byrne, E. Towards environmentally sustainable food systems: Decision-making factors in sustainable food production and consumption. *Sustain. Prod. Consum.* **2021**, *26*, 610–626. [CrossRef]
29. García-Oliveira, P.; Fraga-Corral, M.; Pereira, A.G.; Prieto, M.A.; Simal-Gandara, J. Solutions for the sustainability of the food production and consumption system. *Crit. Rev. Food Sci. Nutr.* **2022**, *62*, 1765–1781. [CrossRef] [PubMed]
30. Liu, Y.; Wood, L.C.; Venkatesh, V.G.; Zhang, A.; Farooque, M. Barriers to sustainable food consumption and production in China: A fuzzy DEMATEL analysis from a circular economy perspective. *Sustain. Prod. Consum.* **2021**, *28*, 1114–1129. [CrossRef]
31. Cooreman-Algoed, M.; Boone, L.; Taelman, S.E.; Van Hemelryck, S.; Brunson, A.; Dewulf, J. Impact of consumer behaviour on the environmental sustainability profile of food production and consumption chains—A case study on chicken meat. *Resour. Conserv. Recycl.* **2022**, *178*, 106089. [CrossRef]
32. Tidåker, P.; Potter, H.K.; Carlsson, G.; Röös, E. Towards sustainable consumption of legumes: How origin, processing and transport affect the environmental impact of pulses. *Sustain. Prod. Consum.* **2021**, *27*, 496–508. [CrossRef]
33. Potter, C.; Bastounis, A.; Hartmann-Boyce, J.; Stewart, C.; Frie, K.; Tudor, K.; Bianchi, F.; Cartwright, E.; Cook, B.; Rayner, M.; et al. The effects of environmental sustainability labels on selection, purchase, and consumption of food and drink products: A systematic review. *Environ. Behav.* **2021**, *53*, 891–925. [CrossRef]
34. Hötzel, M.J.; Vandresen, B. Brazilians' attitudes to meat consumption and production: Present and future challenges to the sustainability of the meat industry. *Meat Sci.* **2022**, *192*, 108893. [CrossRef]
35. Lipper, L.; Thornton, P.; Campbell, B.M.; Baedeker, T.; Braimoh, A.; Bwalya, M.; Caron, P.; Cattaneo, A.; Garrity, D.; Henry, K.; et al. Climate-smart agriculture for food security. *Nat. Clim. Change* **2014**, *4*, 1068–1072. [CrossRef]
36. Chandra, A.; McNamara, K.E.; Dargusch, P. Climate-smart agriculture: Perspectives and framings. *Clim. Policy* **2018**, *18*, 526–541. [CrossRef]
37. Westermann, O.; Förch, W.; Thornton, P.; Körner, J.; Cramer, L.; Campbell, B. Scaling up agricultural interventions: Case studies of climate-smart agriculture. *Agric. Syst.* **2018**, *165*, 283–293. [CrossRef]
38. Arslan, A.; McCarthy, N.; Lipper, L.; Asfaw, S.; Cattaneo, A.; Kokwe, M. Climate smart agriculture? Assessing the adaptation implications in Zambia. *J. Agric. Econ.* **2015**, *66*, 753–780. [CrossRef]

39. Totin, E.; Segnon, A.C.; Schut, M.; Affognon, H.; Zougmoré, R.B.; Rosenstock, T.; Thornton, P.K. Institutional perspectives of climate-smart agriculture: A systematic literature review. *Sustainability* **2018**, *10*, 1990. [CrossRef]
40. Partey, S.T.; Zougmoré, R.B.; Ouédraogo, M.; Campbell, B.M. Developing climate-smart agriculture to face climate variability in West Africa: Challenges and lessons learnt. *J. Clean. Prod.* **2018**, *187*, 285–295. [CrossRef]
41. Shilomboleni, H. Political economy challenges for climate smart agriculture in Africa. *Agric. Hum. Values* **2020**, *37*, 1195–1206. [CrossRef]
42. Sain, G.; Loboguerrero, A.M.; Corner-Dolloff, C.; Lizarazo, M.; Nowak, A.; Martínez-Barón, D.; Andrieu, N. Costs and benefits of climate-smart agriculture: The case of the Dry Corridor in Guatemala. *Agric. Syst.* **2017**, *151*, 163–173. [CrossRef]
43. Kurgat, B.K.; Lamanna, C.; Kimaro, A.; Namoi, N.; Manda, L.; Rosenstock, T.S. Adoption of climate-smart agriculture technologies in Tanzania. *Front. Sustain. Food Syst.* **2020**, *4*, 55. [CrossRef]
44. Thornton, P.K.; Whitbread, A.; Baedeker, T.; Cairns, J.; Claessens, L.; Baethgen, W.; Bunn, C.; Friedmann, M.; Giller, K.E.; Herrero, M.; et al. A framework for priority-setting in climate smart agriculture research. *Agric. Syst.* **2018**, *167*, 161–175. [CrossRef]
45. Onyeneke, R.U.; Igberi, C.O.; Uwadoka, C.O.; Aligbe, J.O. Status of climate-smart agriculture in southeast Nigeria. *GeoJournal* **2018**, *83*, 333–346. [CrossRef]
46. Makate, C.; Makate, M.; Mango, N.; Siziba, S. Increasing resilience of smallholder farmers to climate change through multiple adoption of proven climate-smart agriculture innovations. Lessons from Southern Africa. *J. Environ. Manag.* **2019**, *231*, 858–868. [CrossRef] [PubMed]
47. Sharma, J.; Tyagi, M.; Bhardwaj, A. Exploration of COVID-19 impact on the dimensions of food safety and security: A perspective of societal issues with relief measures. *J. Agribus. Dev. Emerg. Econ.* **2021**, *11*, 452–471. [CrossRef]
48. Ouédraogo, M.; Houessionon, P.; Zougmoré, R.B.; Partey, S.T. Uptake of climate-smart agricultural technologies and practices: Actual and potential adoption rates in the climate-smart village site of Mali. *Sustainability* **2019**, *11*, 4710. [CrossRef]
49. Amadu, F.O.; Miller, D.C.; McNamara, P.E. Agroforestry as a pathway to agricultural yield impacts in climate-smart agriculture investments: Evidence from southern Malawi. *Ecol. Econ.* **2020**, *167*, 106443. [CrossRef]
50. Lopez-Ridaura, S.; Frelat, R.; van Wijk, M.T.; Valbuena, D.; Krupnik, T.J.; Jat, M.L. Climate smart agriculture, farm household typologies and food security: An ex-ante assessment from Eastern India. *Agric. Syst.* **2018**, *159*, 57–68. [CrossRef]
51. Taylor, M.; Bhasme, S. Between deficit rains and surplus populations: The political ecology of a climate-resilient village in South India. *Geoforum* **2021**, *126*, 431–440. [CrossRef]
52. Partey, S.T.; Zougmoré, R.B.; Ouédraogo, M.; Thevathasan, N.V. Why promote improved fallows as a climate-smart agroforestry technology in sub-Saharan Africa? *Sustainability* **2017**, *9*, 1887. [CrossRef]
53. Kimaro, A.A.; Sererya, O.G.; Matata, P.; Uckert, G.; Hafner, J.; Graef, F.; Sieber, S.; Rosenstock, T.S. Understanding the multidimensionality of climate-smartness: Examples from agroforestry in Tanzania. In *The Climate-Smart Agriculture Papers*; Springer: Cham, Switzerland, 2019; pp. 153–162. [CrossRef]
54. Zerssa, G.; Feyssa, D.; Kim, D.G.; Eichler-Löbermann, B. Challenges of smallholder farming in Ethiopia and opportunities by adopting climate-smart agriculture. *Agriculture* **2021**, *11*, 192. [CrossRef]
55. Branca, G.; Arslan, A.; Paolantonio, A.; Grewer, U.; Cattaneo, A.; Cavatassi, R.; Lipper, L.; Hillier, J.; Vetter, S. Assessing the economic and mitigation benefits of climate-smart agriculture and its implications for political economy: A case study in Southern Africa. *J. Clean. Prod.* **2021**, *285*, 125161. [CrossRef]
56. Prestele, R.; Verburg, P.H. The overlooked spatial dimension of climate-smart agriculture. *Glob. Change Biol.* **2020**, *26*, 1045–1054. [CrossRef] [PubMed]
57. Barasa, P.M.; Botai, C.M.; Botai, J.O.; Mabhaudhi, T. A Review of Climate-Smart Agriculture Research and Applications in Africa. *Agronomy* **2021**, *11*, 1255. [CrossRef]
58. Harvey, C.A.; Chacón, M.; Donatti, C.I.; Garen, E.; Hannah, L.; Andrade, A.; Bede, L.; Brown, D.; Calle, A.; Chará, J.; et al. Climate-smart landscapes: Opportunities and challenges for integrating adaptation and mitigation in tropical agriculture. *Conserv. Lett.* **2014**, *7*, 77–90. [CrossRef]
59. Bai, X.; Huang, Y.; Ren, W.; Coyne, M.; Jacinthe, P.A.; Tao, B.; Hui, D.; Yang, J.; Matocha, C. Responses of soil carbon sequestration to climate-smart agriculture practices: A meta-analysis. *Glob. Change Biol.* **2019**, *25*, 2591–2606. [CrossRef] [PubMed]
60. Patle, G.T.; Kumar, M.; Khanna, M. Climate-smart water technologies for sustainable agriculture: A review. *J. Water Clim. Change* **2020**, *11*, 1455–1466. [CrossRef]
61. Li, J.; Xia, E.; Wang, L.; Yan, K.; Zhu, L.; Huang, J. Knowledge domain and emerging trends of climate-smart agriculture: A bibliometric study. *Environ. Sci. Pollut. Res.* **2022**, 1–20. [CrossRef]
62. Molieleng, L.; Fourie, P.; Nwafor, I. Adoption of Climate Smart Agriculture by Communal Livestock Farmers in South Africa. *Sustainability* **2021**, *13*, 10468. [CrossRef]
63. Maraseni, T.; An-Vo, D.A.; Mushtaq, S.; Reardon-Smith, K. Carbon smart agriculture: An integrated regional approach offers significant potential to increase profit and resource use efficiency, and reduce emissions. *J. Clean. Prod.* **2021**, *282*, 124555. [CrossRef]
64. Agrimonti, C.; Lauro, M.; Visioli, G. Smart agriculture for food quality: Facing climate change in the 21st century. *Crit. Rev. Food Sci. Nutr.* **2021**, *61*, 971–981. [CrossRef] [PubMed]

65. Sharma, J.; Tyagi, M.; Bhardwaj, A. Parametric assessment of temperature monitoring trends in food supply chain performance system. In *Optimization Methods in Engineering*; Springer: Singapore, 2021; pp. 169–184. [CrossRef]
66. Jouni, H.J.; Liaghat, A.; Hassanoghli, A.; Henk, R. Managing controlled drainage in irrigated farmers' fields: A case study in the Moghan plain, Iran. *Agric. Water Manag.* **2018**, *208*, 393–405. [CrossRef]
67. Levidow, L.; Zaccaria, D.; Maia, R.; Vivas, E.; Todorovic, M.; Scardigno, A. Improving water-efficient irrigation: Prospects and difficulties of innovative practices. *Agric. Water Manag.* **2014**, *146*, 84–94. [CrossRef]
68. Das, P.; Neelima, A. An overview of approaches for content-based medical image retrieval. *Int. J. Multimed. Inf. Retr.* **2017**, *6*, 271–280. [CrossRef]
69. Senyolo, M.P.; Long, T.B.; Blok, V.; Omta, O. How the characteristics of innovations impact their adoption: An exploration of climate-smart agricultural innovations in South Africa. *J. Clean. Prod.* **2018**, *172*, 3825–3840. [CrossRef]
70. Hassanli, A.M.; Beecham, S. Criteria for Optimizing Check Dam Location and Maintenance Requirements. Ph.D. Thesis, University of South Australia, Centre for Water Management and Reuse, Adelaide, SA, Australia, 2013.
71. Celia, M.; Adrian, D.; Christian, D. Crop Insurance Program of the PCIC: Integrative Report from the Five Case Regions in the Philippines. 2017. Available online: www.econstor.eu (accessed on 20 May 2020).
72. Kansiime, M.K.; Mastenbroek, A. Enhancing resilience of farmer seed system to climate-induced stresses: Insights from a case study in West Nile region, Uganda. *J. Rural. Stud.* **2016**, *47*, 220–230. [CrossRef]
73. Venugopalan, V.K.; Prabhakar, M.; Gopinath, K.A.; Pankaj, P.K.; Rao, C.S. Community Fodder Banks for addressing forage shortage in rainfed areas. *Indian Farm.* **2016**, *66*, 21–25.
74. Ebara, M.; Fukuda, H.; Saisho, H. The copper/zinc ratio in patients with hepatocellular carcinoma. *J. Gastroenterol.* **2003**, *38*, 104. [CrossRef] [PubMed]
75. Bhattacharyya, P.; Pathak, H.; Pal, S. Livestock and Aquaculture Management for Climate-Smart Agriculture. In *Climate Smart Agriculture*; Springer: Singapore, 2020; pp. 113–127. [CrossRef]
76. Adesipo, A.; Fadeyi, O.; Kuca, K.; Krejcar, O.; Maresova, P.; Selamat, A.; Adenola, M. Smart and climate-smart agricultural trends as core aspects of smart village functions. *Sensors* **2020**, *20*, 5977. [CrossRef] [PubMed]
77. Savian, J.V.; Schons, R.M.T.; de Souza Filho, W.; Zubieta, A.S.; Kindlein, L.; Bindelle, J.; Bayer, C.; Bremm, C.; de Faccio Carvalho, P.C. 'Rotatinuous' stocking as a climate-smart grazing management strategy for sheep production. *Sci. Total Environ.* **2021**, *753*, 141790. [CrossRef] [PubMed]
78. Kelly, A.M.; Renukdas, N.N. Disease management of aquatic animals. In *Aquaculture Health Management*; Academic Press: Cambridge, MA, USA, 2020; pp. 137–161. [CrossRef]
79. Current, D.; Lutz, E.; Scherr, S.J. The costs and benefits of agroforestry to farmers. *World Bank Res. Obs.* **1995**, *10*, 151–180. [CrossRef]
80. Rendón-Huerta, J.A.; Pinos-Rodríguez, J.M.; Kebreab, E. Animal nutrition strategies to reduce greenhouse gas emissions in dairy cattle. *Acta Univ.* **2018**, *28*, 34–41. [CrossRef]
81. Meyer-Aurich, A.; Schattauer, A.; Hellebrand, H.J.; Klauss, H.; Plöchl, M.; Berg, W. Impact of uncertainties on greenhouse gas mitigation potential of biogas production from agricultural resources. *Renew. Energy* **2012**, *37*, 277–284. [CrossRef]
82. Sharma, J.; Jayant, A. An Intelligent Simulation based case study of Indian Micro Small Medium Enterprise (MSME) of farm equipment manufacturing. *J. Phys. Conf. Ser.* **2019**, *1240*, 012030. [CrossRef]
83. Liu, Y.; Eckert, C.M.; Earl, C. A review of fuzzy AHP methods for decision-making with subjective judgements. *Expert Syst. Appl.* **2020**, *161*, 113738. [CrossRef]
84. De FSM Russo, R.; Camanho, R. Criteria in AHP: A systematic review of literature. *Procedia Comput. Sci.* **2015**, *55*, 1123–1132. [CrossRef]
85. Sharma, J.; Jayant, A. Modelling, Simulation and Optimization of Product Flow in a Multi-products Manufacturing Unit: A Case Study. In *Operations Management and Systems Engineering*; Springer: Singapore, 2019; pp. 185–214. [CrossRef]
86. Jafari, S.; Aghel, M.; Sohani, A.; Hoseinzadeh, S. Geographical preference for installation of solar still water desalination technologies in Iran: An analytical hierarchy process (AHP)-based answer. *Water* **2022**, *14*, 265. [CrossRef]
87. Solangi, Y.A.; Longsheng, C.; Shah, S.A.A. Assessing and overcoming the renewable energy barriers for sustainable development in Pakistan: An integrated AHP and fuzzy TOPSIS approach. *Renew. Energy* **2021**, *173*, 209–222. [CrossRef]
88. Sharma, J.; Jayant, A.; Tyagi, M. Simulation based design of Production and Multi echelon supply chain network for job shop manufacturing environment: A Case Study. *J. Phys. Conf. Ser.* **2019**, *1240*, 012066. [CrossRef]
89. Lyu, H.M.; Zhou, W.H.; Shen, S.L.; Zhou, A.N. Inundation risk assessment of metro system using AHP and TFN-AHP in Shenzhen. *Sustain. Cities Soc.* **2020**, *56*, 102103. [CrossRef]
90. Jayant, A.; Sharma, J. A comprehensive literature review of MCDM techniques ELECTRE, PROMETHEE, VIKOR and TOPSIS applications in business competitive environment. *Int. J. Curr. Res.* **2018**, *10*, 65461–65477.
91. Dong, Q.; Cooper, O. An orders-of-magnitude AHP supply chain risk assessment framework. *Int. J. Prod. Econ.* **2016**, *182*, 144–156. [CrossRef]
92. Adebanjo, D.; Laosirihongthong, T.; Samaranayake, P. Prioritizing lean supply chain management initiatives in healthcare service operations: A fuzzy AHP approach. *Prod. Plan. Control.* **2016**, *27*, 953–966. [CrossRef]
93. Tyagi, M.; Kumar, P.; Kumar, D. Permutation of fuzzy AHP and AHP methods to prioritizing the alternatives of supply chain performance system. *Int. J. Ind. Eng.* **2015**, *22*, 729–752.

94. Saaty, T.L. What is the analytic hierarchy process. In *Mathematical Models for Decision Support*; Springer: Berlin/Heidelberg, Germany, 1988; pp. 109–121. [CrossRef]
95. Sharma, J.; Tyagi, M.; Panchal, D.; Bhardwaj, A. Dimensions Modelling for Reliable Indian Food Supply Chains. In *Reliability and Risk Modeling of Engineering Systems*; Springer: Cham, Switzerland, 2021; pp. 133–150. [CrossRef]
96. Wang, Z.; Ran, Y.; Chen, Y.; Yu, H.; Zhang, G. Failure mode and effects analysis using extended matter-element model and AHP. *Comput. Ind. Eng.* **2020**, *140*, 106233. [CrossRef]
97. Tyagi, M.; Kumar, P.; Kumar, D. A hybrid approach using AHP-TOPSIS for analyzing e-SCM performance. *Procedia Eng.* **2014**, *97*, 2195–2203. [CrossRef]
98. Tyagi, M.; Kumar, P.; Kumar, D. Assessment of CSR based supply chain performance system using an integrated fuzzy AHP-TOPSIS approach. *Int. J. Logist. Res. Appl.* **2018**, *21*, 378–406. [CrossRef]
99. Qureshi, M.R.N.; Singh, R.K.; Hasan, M. Decision support model to select crop pattern for sustainable agricultural practices using fuzzy MCDM. *Environ. Dev. Sustain.* **2018**, *20*, 641–659. [CrossRef]