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Review Article

Analytical hierarchy process for sustainable agriculture: An overview

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REVIEW HIGHLIGHTS

- This study is the first of its kind to put together the literature review of analytical hierarchy process (AHP) applications for sustainable agriculture.
- The utility of MCDM techniques like AHP seems imperative for attaining SDG.

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Analytical hierarchy process

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ABSTRACT

United nation sustainable development goal two (UNSDG-2) aims to achieve the eradication of hunger along with the assurance of food security for all by 2030. This cannot be achieved without combining all forms of sciences including mathematics and statistics with agriculture practice to make agriculture sustainable. Agriculture has been considered the backbone of the economic systems of developing and developed countries. However, while practicing the activities, various conflicting issues incorporate and make the situation challenging for the agriculture industry in the decision-making process. Multi-criteria decision-making (MCDM) techniques can provide the optimal solution and they have proved to be viable in various complex decision-making problems of the real world like agriculture-related decision-making problems. They can help to find a suitable alternative for a particular complex situation. The analytical hierarchy process (AHP); a globally accepted method; has been a winning arc of the MCDM techniques. This article specifically reviews the application of AHP in various agriculture-related problems, the models used, the data sources used, and the overall precision attained using the different performance criteria of the past few years.

Specifications table

Subject area:	Mathematics and Statistics
More specific subject area:	*Multi-criteria decision-making*
Name and reference of original method:	N.A.
Name of the reviewed methodology:	*Analytical hierarchy process*
Keywords:	*Multi-criteria decision-making (MCDM); Pairwise comparison matrix (PCM); Analytical hierarchy process (AHP); Sustainable agriculture (SA)*
Resource availability:	*N.A.*
Review question:	*What is the analytical hierarchy process (AHP)?* *How is AHP playing a vital role in achieving United nation sustainable development goal 2 (UNSDG-2) through its applications in agriculture?*
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Method details

Agricultural decision problems are important from both economic and social point of view. Agriculture and allied sectors contribute around 25% of the GDP and about 70% of Indians are dependent on agriculture [1]. Therefore, agricultural planning plays a major role in the overall growth of any nation considering today's scenario. Due to the increasing world population, the demand for agricultural commodities has also increased. In order to achieve food security for all and make agriculture sustainable, planning and decision-making are the most crucial parts while dealing with agricultural problems like soil quality assessment, adopting a suitable irrigation method for a particular area, knowing the risk factors related to agriculture. The solution of these agriculture problems can only be obtain by the proper assessment of the methodology applied [2].

Sustainable agriculture (SA) is a wider term, which sustainably promotes farming-related practices to meet society's present food and textile-related needs without doing the compromise with future generation's ability to meet their same needs. Management of soil, water, crop, disease/pest and waste are the main components of sustainable farming [3].

Decision-making (DM) is a routine process in our day-to-day life challenges. Even a newborn brain has been trained to take some decisions since its birth. The most rapidly growing problem area in the world of DM is Multi Criteria Decision Making (MCDM). People engaged in DM from ancient times, and decisions were based on a single individual and a single criterion. However, as DM progressed, decisions were no longer based on a single individual and a single criterion, instead consider multiple people and multiple criteria, which help to search more accurate decision. Moreover, in the course of time, the process of DM has become challenging due to the continuously increasing complex nature of MCDM problems. MCDM problems can be assumed to be made up of five important components namely the goal, the available preferences and the alternatives, criteria, and the outcomes [4]. Complex decision-making is like a puzzle-like problem that in turn can lead to an inappropriate decision. MCDM techniques have been used to solve these complex decision-making problems. A perfect blend of mathematical knowledge and psychological aspect give birth to an MCDM technique, which has gained popularity due to its simpler application mechanism. However, in-depth knowledge of mathematics is a prerequisite as far as the development of a new MCDM technique is concerned. MCDM techniques help in reaching the optimal solution to these complex MCDM problems and had been widely accepted by researchers. Several methods for improving MCDM have been developed, including the analytic hierarchy process (AHP). MCDM techniques that can provide better insight now had been widely used in the field of agriculture as well. The flow chart of MCDM techniques is depicted in Fig. 1.

AHP is an MCDM technique, where the problem is first structured. This structure contains all the associated aspects either qualitative or quantitative and then it provides the weight to each elements considered [5]. The purpose of this article is solely to assess and critically analyze articles published in the field of SA decision-making using AHP as a methodology.

Analytical hierarchy process (AHP)

Thomas Saaty developed AHP in the year 1970 [5]. For the last forty years, it has been regarded as a widely used and accepted tool to deal with complex decision-making problems for various fields [6,7]. It provides support to the decision-makers so that they can select the best alternative that depends on multiple criteria and sub-criteria [8]. It reduces the complications by making a number of comparisons amongst the elements of the hierarchy. AHP helps to capture subjective as well as an objective outlook of associated problems. In addition, it also measures the consistency of the decisions obtained and thus reduces the prejudice against the decision.

The approach of AHP is based on three important steps:

(1) The first step in AHP is to transform the multi-criteria decision-making problem into a hierarchy model. This model constitutes goal at the first level, criteria at the second level and alternatives at the third level. There must be at least these three levels in the hierarchy model though we can add other layers of sub-criteria between the criteria and the alternatives if required.

(2) The next step is to identify the importance of one criterion over another. Comparative judgements are made by constructing pairwise comparison between the n criteria and thus a matrix of order n is formed based on these comparisons. This matrix is always positive reciprocal in nature i.e all entries of the matrix are positive and $a_{ij} = \frac{1}{a_{ji}},\ i, j = 1, 2, \dots, n$. A scale is proposed by Saaty (Fig. 2) helps to find one-to-one correspondence between the set of alternatives and a subset of rational numbers $\{\frac{1}{9}, \frac{1}{8}, \frac{1}{7}, \frac{1}{6}, \frac{1}{5}, \frac{1}{4}, \frac{1}{3}, \frac{1}{2}, 1, 2, 3, 4, 5, 6, 7, 8, 9\}$, which represent the importance of of i^{th} alternative over the j^{th}alternative.

Suppose, we have n alternatives to be compared pairwise. If a_{ij} denotes the preference of i^{th} alternative over the j^{th}alternative, where $i,\ j = 1, 2, \dots, n$. Such pairwise comparisons are used to find the importance of one alternative over another in terms of each criterion. Then these relative preferences form a positive reciprocal matrix $A = [a_{ij}]$ of order n, where $a_{ii} = 1\ \forall i = 1, 2, \dots, n$ and $a_{ij} = \frac{1}{a_{ji}},\ i, j = 1, 2, \dots, n$. An $n \times n$ pairwise comparison matrix of order n can be represented as follows:

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ \frac{1}{a_{12}} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & \dots & a_{nn} \end{bmatrix} \tag{1}$$

(3) In the last step few calculations should be done to evaluate the priority vector (weights) and consistency of the judgements. Consistency index (CI) is used to evaluate consistency. If the CI is satisfactory then decision can be accepted otherwise the judgements should be repeated till the desired range of consistency is obtained.

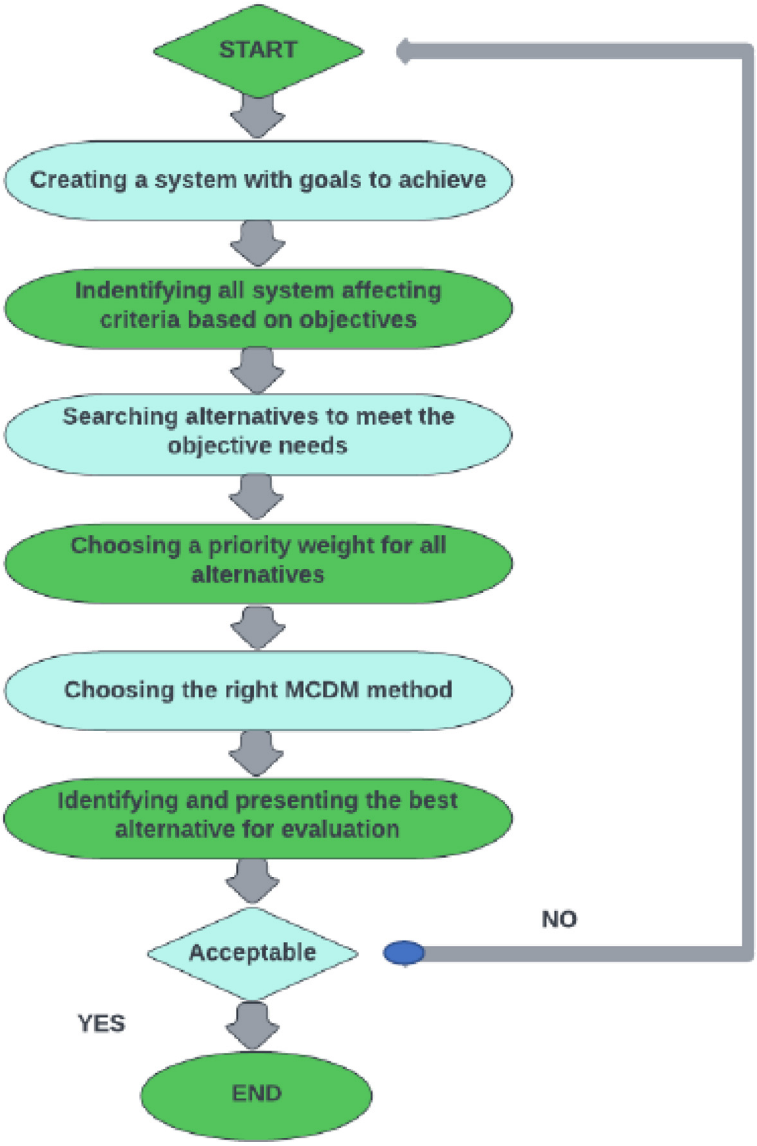

Fig. 1. Flow chart of MCDM.

In real world problem, it is not always possible to find the perfect judgments and hence, a consistent pairwise comparison matrix after performing the pairwise comparisons is needed [7]. Therefore, another important goal is to acquire a positive reciprocal matrix which is not very far from some consistent positive reciprocal matrix. If there are m criteria and $W = [w_1, w_2, \dots, w_m]^T$ is the corresponding weight vector then for a consistent pairwise comparison matrix A the following equation must always hold

$$A\ W = m \times W \tag{2}$$

This signifies that if m is the eigenvalue of A then W is the eigenvector associated with it. Also, a consistent pairwise comparison matrix has always rank one. Hence, the only nonzero and largest eigenvalue of A is m. AHP considers the eigenvector strategy to estimate the priority vector (weights). With the help of the eigenvector, the inconsistencies that occurred are being corrected, which is done by calculating W and correct eigenvector of matrix A.

$$A\ W = \ \lambda_{max}\ W \tag{3}$$

Where, $\lambda_{\max}$ denotes maximum eigenvalue of the pairwise comparison matrix A.

The eigenvector method is very useful to reach at the final and more consistent weights of the alternatives considered in the levels of the hierarchy. For an inconsistent matrix $\lambda_{max} > m$ and if $\lambda_{max} = m$ then matrix A must be consistent. Consistency ratio (CR), which

Intensity of importance	Definition
1	Equal importance
3	Moderate importance of one over another
5	Strong or essential importance of one over another
7	Very strong importance
9	Absolute importance
2,4,6,8	Intermediate values between two adjacent judgments
Reciprocals of above	If factor i has one of the above number assigned to it when compared to factor j, then j has the reciprocal value when compared with i.

Fig. 2. Fundamental nine point scale proposed by Saaty.

Table 1
Steps associated with AHP.

STEP-1 Formation of PCM $A = [a_{ij}]$	STEP-2 Evaluation of Normalised PCM $\bar{A} = [\overline{a_{ij}}]$	STEP-3 Evaluation of normalised Eigen vector $W = [w_1, w_2, w_3]^T$	STEP-4 Evaluation of Principal Eigen value	STEP-5 Consistency Ratio (CR)
$A = \begin{bmatrix} 1 & a_{12} & a_{13} \\ \frac{1}{a_{12}} & 1 & a_{23} \\ \frac{1}{a_{13}} & \frac{1}{a_{23}} & 1 \end{bmatrix}$ where, $a_{12}, a_{13}, a_{23} \in S$	$A = \begin{bmatrix} \overline{a_{11}} & \overline{a_{12}} & \overline{a_{13}} \\ \overline{a_{21}} & \overline{a_{22}} & \overline{a_{23}} \\ \overline{a_{31}} & \overline{a_{32}} & \overline{a_{33}} \end{bmatrix}$ $\overline{a_{ij}} = \frac{a_{ij}}{\sum_{k=1}^{3} a_{kj}}$	$w_i = \frac{\sum_{k=1}^{3} \overline{a_{ik}}}{3}$	$\lambda_{max} = \sum_{j=1}^{3} (\sum_{i=1}^{3} \overline{a_{ij}}) w_j$	$CR = \frac{CI}{RI}$ where, $CI = \frac{(\lambda_{max} - n)}{n-1}$ and RI is random index.

evaluates the measure of inconsistency in the judgements, is defined as

$$CR = \frac{CI}{RI} = \frac{\lambda_{max} - m}{RI * (m-1)} \tag{4}$$

where, RI is termed as a random index by Saaty, which is the average of consistency indices (CI) of the matrices of the same order. The acceptable upper bound of consistency ratio is 0.10. If the consistency ratio is above 0.10, then the decision maker needs to revise his/her decisions. The various steps associated with AHP are defined in a simpler way in Table 1.

So, we can say that AHP addresses the subjective and objective components of DM by simplifying complex choice issues to a series of pairwise comparisons and afterwards synthesizing the results. AHP helps in this regard such as resource allocation, selecting the best alternatives, planning, and resolving conflicting and subjective criteria. AHP structures a problem into a hierarchy, starting with the goal, moving on to criteria and sub-criteria, and finally to alternatives, with a relationship analysis between the goal, criteria, and alternatives. AHP applications encompass a wide range of disciplines including Renewable Energy, Sustainable Manufacturing, Natural Hazards, Environmental Pollution, Landfill waste management and many others, which lies explicitly or implicitly under the theme of SD. But, the subjective nature of the AHP method, dependency on human emotions for numerical judgements, consistency issues associated with judgement in the AHP and high computational requirement etc. are the main limitation of AHP. Here in this article we solely focused on the applications of AHP for SA.

Collecting the information

In this paper, we present applications of AHP in agriculture covering the decision areas viz. selection, assessment, management, identification and evaluation. This article is based on 72 articles from the "Scopus and Web of Science" database. Articles have been searched in the academic databases Science Direct and Web of Science (WoS). In addition to this, google scholar and UPES Library utilized as a significant search engine. Following combination of keyword utilized for searching articles through mentioned search engines: AHP + sustainable agriculture.

Fig. 3 depicts the number of article published on AHP applications in SA on year on year basis versus the total number of times they cited in a particular year. While Fig. 4 demonstrate the number of publications in a specific WoS journal's category.

Applications of AHP in agriculture

AHP has been applied to different wings related to sustainability [9–16]. However, the ever-increasing world population and meeting their food demand is a major concern in recent years, which is leading to unethical agricultural practices such as excessive

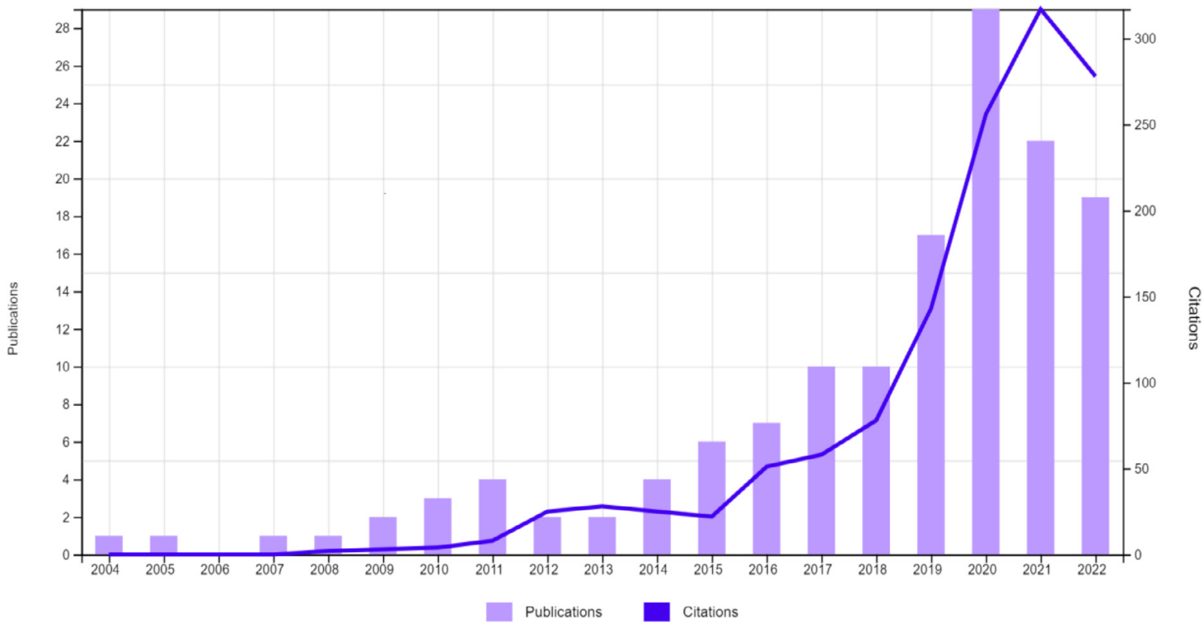

Fig. 3. Publications over time vs times cited.

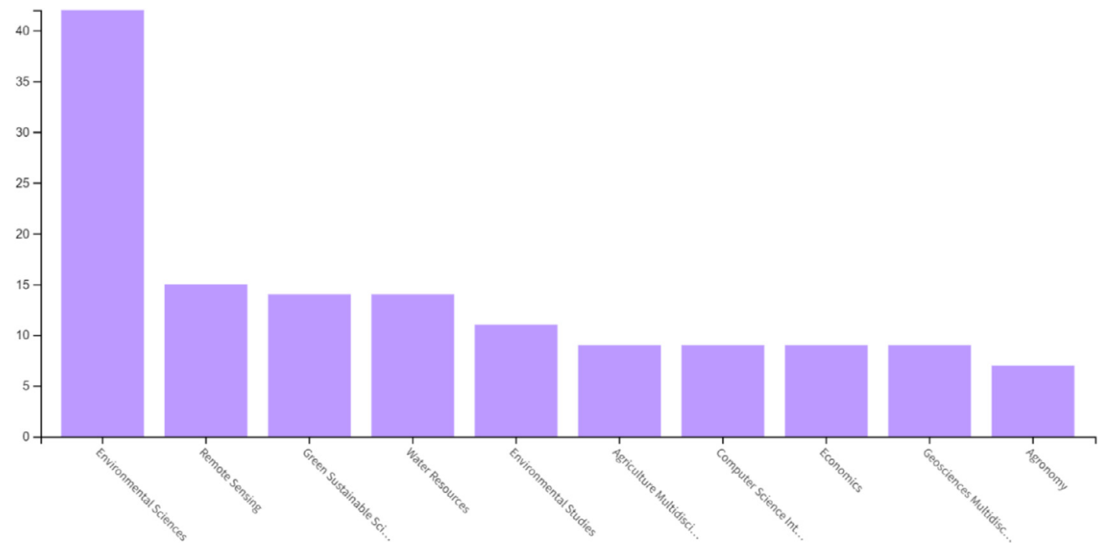

Fig. 4. Number of publications in a specific WoS journal's category.

use of chemicals and fertilizers. Intense pressure of increasing agriculture production to ensure food for all lead to massive fertilizer utilization that in turn results in soil pollution [17–20]. Hence, causing damage to the theme of a sustainable environment and also creating lots of health issues.. As an alternative, organic farming [21] may play an important part in socioeconomic development and help people to become self-sufficient. As organic farming is possible under certain climatic and environmental circumstances, so correct site selection of soil for farming [22], and the study of soil health is important [23–29]. Consideration of varied climatic, topological environment, socio-economic and geophysical limiting factors must be assessed with decision-making process for better crop yield [30,31]. AHP with the integration of GIS-based MCDM technique is utilized for land suitability analysis (LSA), managing the watershed for farming, and soil health analysis [32–35].

Alphonce [36] suggested the potential application of AHP in agricultural decisions in developing countries. Subdivisions preferred were subsistent farming in developing countries. He explained the process by the mean of a case study in which a farmer has to allocate a portion of the field to the food crops. They introduced resource allocation criteria and sub-criteria (s.cr) in this problem and applied AHP for determining the location of the village store, selection between subsistence farming and cash crop production, etc. in total, and determination of the crop production technology.

Karami [37] analyzed different parts for the selection of appropriate irrigation methods by forming groups. Four groups were formed with the help of cluster analysis. The alternatives for each of the group was border, basin and sprinkler irrigation. Based on these, nine important criteria were considered. After that different groups made the decision. A conclusion that came out was that the priority of the irrigation methods differed with respect to the groups. Later, the consistencies of all four groups were measured. The overall findings by the different groups after applying the AHP method indicated that in 74% of cases the experts agreed with the group decision but at the same time questioned the consistency of the decision made by 26% of the farmers of the group.

Rezaei-Moghaddam and Karami [38] has evaluated the appropriate sustainable agricultural development model for Iran. The two models selected were Ecological Modernization (EM) and De-Modernization (DM). Many organizations and groups participated in the decision-making. Each group analyzed and weighted the models accordingly. For the selection of criteria and implementation of AHP, various groups participated, were interviewed and they came out with nine criteria. The overall findings indicated that the ecological criteria was the most important criteria for sustainable agricultural in Iran and concluded that the EM-based sustainable agricultural development model has the highest priority.

To rank the set of productive alternatives for central south Chile, data has been collected from the farmers for various commodities based on farmer decision risk level [39]. The next task performed was to relatively rank the four different risk factors. Four criteria were considered. The results obtained by AHP after the operation showed that price and variability of the cost was the most important with not much difference in the weight given to the climate which was the least important factor. However, this study also concluded that according to the different geographical regions the weights given to different criteria or alternatives vary.

For ranking, the best management practices (BMPs) for the Saginaw river watershed various factors were considered [40]. All three criteria severed different spots for the allocation of the BMP and were ranked onethird while ranking in the AHP. Along with this, three scenarios were compared in the study. First was the comprehensive approach in which environmental, economic, and social aspects were considered together. Next was the traditional approach in which both environmental and economic aspects were considered. And in the last, only the environmental aspect was considered. They found that in the first scenario only strip-cropping was selected on all the CSAs at the sub-basin level, whereas the strip-cropping and residue management was selected after applying the AHP on the watershed outlet. In the second scenario, strip-cropping was eliminated by the BMP's both at the sub-basin and watershed outlet levels. Finally, in the third scenario, native grass was the least preferable BMP and concluded that 50% CSAs selected strip-cropping whereas the remaining 50% of CSAs selected native grass and residue management as equal priority.

Land suitability for agriculture is critical information in the growth and future planning of agriculture [41]. Based on this, a land suitability evaluation for agriculture was undertaken in order to assist decision-makers and agricultural development planners in determining how proper or acceptable it is forcertain use of land in a specific place that is more suited for a specific agriculture use. Strategies contributed to this were RS-GIS, Fuzzy-logic and the application of multi-Criteria Evaluation using the AHP methodology. From the searches conducted it is clear that AHP has been used widely throughout management and decision support systems [41].

A study on AHPbased selection of ethical model for sustainable agricultural development in Iran has been conducted in 2016 [42]. The hierarchy was constructed containing three alternatives named utilitarian-based model, rights-based model and virtue-based model. Nine criteria had also been taken into consideration. On applying the AHP, the result so obtained indicated that resilience of agricultural systems, supportive policies and self-reliance, and equity were the most important criteria for Iran in sustainable agricultural development. At the end, two strategies were outlined for developing a macro-ethics approach.

Food or raw materials have been a major concern to meet the needs of agricultural commodities for Ethiopia [43]. It seems that the basin that was structured for its suitability; which depends upon the amount, location and degree; was not properly examined as the literature review and other past resources were considered. Therefore, to meet the need of the people of Ethiopia, numbers of agricultural land suitable evaluation criteria were identified. These criteria's were examined properly on a GIS platform and their relative weights were evaluated by the AHP method. On the analysis, it was found that 53.8% of the basin land was highly suitable for the agriculture purpose and 23.2% was moderately suitable and trough these regions of the basin having high suitability and high susceptibility for land degradation and soil erosion were identified.

Ali et al. [44] helped the government of Ghana (GoG) for the implementation of the new programs aim for food and jobs (PFJ) which was done with the help of SWOT analysis i.e., strengths, weaknesses, opportunists, and threats. The government of Ghana made a goal in line with Millennium Development Goals (MDG) to reduce the poverty and malnourishment in that region. Further, with the help of AHP the criteria were prioritized. As per the results favorable environmental conditions were the highest strength followed by agricultural land availability. Inadequate financial services were termed as the weakest followed by over-resilience on climate conditions. Export potential relative to agricultural material was identified as the highest opportunity followed by one district one factory (1D1F). Negative unwelcome of climate change was considered to be the main threat followed by the import of food products. The limitation of this study was that only 10 people were interviewed to examine or meet the need of the complete region.

Thapa and Murayama [45] performed the assimilation or integration of GIS and AHP for pre-urban agriculture planning which prevailed in very interesting decision scenarios to the decision-makers. The research was conducted at the Hanoi peri-urban area by integrating RS, GIS and AHP and 46% of the arable land was available for the optimum development to be obtained by that area. Five parameters namely land, soil, road linkage, water resource linkage and market linkage are used and data was collected from various organizations. These five parameters were scaled as very good, good, fair and unnamable as per the strength. The AHP methodology was applied to study the parameter's relative priority. The result concluded that 32% of the province's arable land is very good, while only 12 and 2% parts of the province's arable land are good and fair respectively for the peri-urban agriculture.

There are many monetary valuation methods available to the DM but these methods have certain limitations.. Therefore, theDM preferred choosing the MCDA technique to proceed with their research under process. It is very less likely for the DM to adopt the very shortcuts by focusing irrationally on a single attribute [46]. A study was done by Duke and Aull-Hyde [47] regarding public

Table 2
Few more agricultural applications of AHP based on decision area.

Refs.	Decision area	Measure Focus	Country origin	Criteria considered	Technique used
Xue et al. [62]	Assessment	To determine the utility and sensitivity of Meta-soil AHP's health assessment.	China	Physical (3 s.cr), Biological (4 s.cr), Chemical (7 s.cr)	Meta-AHP
Mishra et al. [63]	Selection/ identification	Identifying ideal zones for organic agricultural growth in Uttarakhand, India.	India	DFR, Geology, SL, DFS, soil, LULC	AHP, GIS
Pramanik [64]	Assessment	Suitable land analysis in Darjeeling district's hilly areas for the agriculture purpose.	India	soil characteristic (5 s.cr), SL (5 s.cr), aspect (5 s.cr), LULC (6 s.cr), soil moisture (5 s.cr), DFS (5 s.cr), Geology (5 s.cr), DFR(5 s.cr), elevation (5 s.cr)	AHP, GIS
Kahsay et al. [65]	Evaluation / assessment	In semi-arid northern Ethiopia, examine suitability of the soil for sorghum crop production.	Ethiopia	Soil (24 s.cr), climate (3 s.cr), topography (2 s.cr)	AHP, GIS
Feizizadeh and Blaschke [66]	Evaluation	Efficient use of soil resources for agricultural output.	Iran	SL, fertility, temperature, ground water capacity, elevation, aspect, pH, precipitation	AHP
Akinci et al. [67]	Selection	Identification of appropriate sites for agricultural usage.	Turkey	Soil type (7 s.cr), land use capability class (5 sub-criteria), SL (6 s.cr), elevation (6 s.cr), land use capability subclass (5 s.cr), soil depth (5 s.cr), aspect (4 s.cr), erosion (4 s.cr), Other soil properties (4 s.cr)	AHP, GIS
Roy and Saha [68]	Selection	In the Hinglo river basin, indicate the acceptable land area for rice production.	Pakistan	Temperature, relief, geology, DFR, precipitation, SL, water resources, texture, pH, (10)micro nutrients, depth of ground water	AHP, GIS
Raza et al. [69]	Illustration	Delineation of Suitable Rice Cultivation Sites in Pakistan's Punjab Province.	Pakistan	EC (electrical conductivity), drainage, ripening, flowering, tillering, pH, soil type, milky dough, panical primoda, leaf emergency	AHP, Remote sensing, GIS
Kazemi and Akinci [70]	Evaluation	Investigate rain fed farming performance potential of Iran's Golestan Province.	Iran	soil organic carbon, LULC, pH, soil texture, SH, elevation, precipitation, SL, temperature, erosion, electrical conductivity	AHP, GIS
Bagdanavičiūtė et al. [71]	Selection	Provisional zebra mussel farming in a eutrophic lagoon ecosystem: a site selection strategy focusing largely towards restoration.	-	Suspended materials, ice cover, depth, marine protected region, state border protected areas, current velocity & stability, DFS, accessibility, bottom sediment's, chlorophyll, residence time, salinity	GIS, AHP
Maleki et al. [72]	Assessment	In Iran and other comparable locations, a unique analytical methodology was used to assess land suitability for saffron farming.	Iran	Soil (3 s.cr), Climate (5 s.cr), topography (3 s.cr)	AHP, MCA, GIS

preferences for land preservation in Delaware, USA using AHP. In this study, the most important aim was to reach on an agreement for decisions and priorities in an indistinguishable manner by using Delphi exercises.

Climate-resilient agriculture is a hot topic for researchers. A conceptual framework for this in India using AHP and Weighted sum model (WSM) is presented by Rao et al. [48]. An AHP tree was formed by the evolution of the hierarchy of decision criteria leading to alternative courses. The AHP was used to figure out the relative weights of "choice criteria" and relative ratings (priorities) of "options". Qualitative facts and the usage of knowledgeable judgments have been applied to derive these weights and ratings. Prioritization of the options was completed primarily based on the ratings obtained. A basic framework by using AHP for the climate change adaptation and a conceptual model for Climate Risk Management Package for Agriculture (CRiMPA) was presented.

Bhattarai and Kathmandu [49] presented diffusion of AHP in Nepal-focused utility studies and dissemination activities in the course of ten years between 2003 and 2013. It was found that energy, water and surroundings associated hassles have mainly attracted for the utility of AHP in Nepal.

Reclaimed water reuse for an arid zone to recharge aquifers contributes to reduce strain on traditional water [50]. The purpose behind this AHP based study was to find and rank the appropriate sites for recharging aquifers with the use of reclaimed water primarily by combining multi-criteria analyzes along with the geospatial analysis. Seven constraints were selected to perceive the best regions for aquifer recharge. A vector spatial layer was acquired and the possible regions were delineated with the aid of using

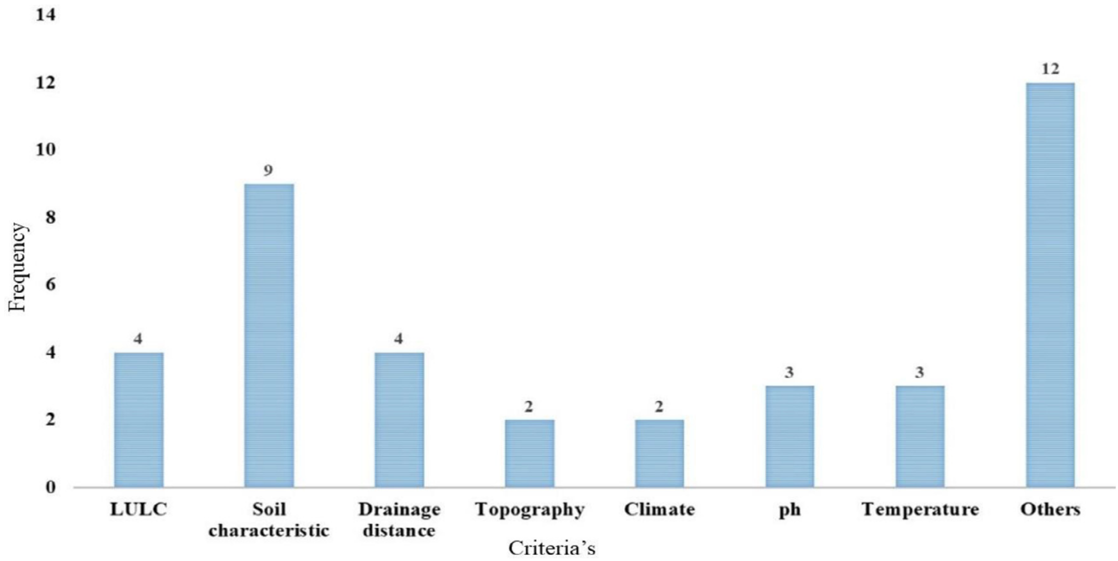

Fig. 5. Frequency distribution of important agriculture criteria.

an intersection operator. For the ranking of these regions, three main criteria were identified from which twelve sub-standards were derived. All of them were prepared in a selection hierarchy shape and weighted by the usage of Saaty pairwise comparison matrices.

AHP can play vital role in groundwater-related decision-making problems [51,52]. In three regions of Uttar Dinajpur District, West Bengal, India, the ground water levels have been decreased due to the intensive use of agricultural practices [53]. The three regions considered in the study done by Biswas et al. [53], were Goalpokhar 1, Goalpokhar 2, and Karandighi blocks to determine groundwater resource potential map using AHP. The map was compiled by using ten thematic layers (criteria's) which include geomorphology, slope, geology, land use/land cover, rainfall, slope curvature, drainage density, the modified normalized difference water index, topography wetness index and soil type. On comparing the criteria pairwise and calculating the weights of the elements in it, geomorphology was considered the most prioritized element followed by a slope. Sub categories were also evaluated and weights were assigned to each of the criteria. The ground water potential map was then validated. The whole region was then categorized into five categories. The results concluded that Goalpokhar 1 and 2 are more permeable lithology, which is suitable for storage of groundwater.

To increase the micronutrient concentrations in staple crops by the application of fertilizer is a vital strategy for limiting iodine deficiency disorders [54,55]. A combination of SWOT and AHP was employed in 2016 for examining the fertilizer use in Uganda and for prioritizing the iodine biofortification technology from the stakeholder analysis point of view [56,57].

Microbial activities and physical properties of soil get altered due to frequent wetting and drying of rice fields. The soil quality of central plains of Chhattisgarh was evaluated and AHP based Soil quality index was developed by Kumar et al [58]. Soil quality indicators, which are taken into consideration, were phosphorous, zinc, soil organic carbon, mean weight diameter and available water content.

Identification of Iran's Haraz Mountains landslide-prone locations done by Pourghasemi et al. [59] by using Fuzzy-AHP method. Slope degree, Topographic witness Index(TWI), Aspect, slope length, altitude, stream power index(SPI), plan curvature, DFF, Lithology, DFR, LULC, DFS were main criteria considered. Azarafza et al. [60] and Althuwaynee et al. [61] have also used AHP for landslide susceptibility assessment.

More description of some other research articles related to the agricultural application of AHP is presented in Table 2.

According to the aforementioned review done in the agricultural sector, soil characteristics (including depth, contents, kinds, and qualities) found to be the most commonly employed criteria. LULC (Land Use/ Land Cover) and drainage distance appear to be the second and third most essential factor. Additional frequently used criteria are also demonstrated in Fig. 5. Other criteria in Fig. 5 includes Suspended materials, ice cover, micro-nutrients, depth of ground water, precipitation etc.

There is still a huge scope of applicability of various MCDM techniques for SA as it still has various complex and unexplored dimension where MCDM techniques can play the role of a change maker.

Conclusion

This study aims to provide the critical analysis and review of the applications of AHP in agriculture with an aim to help in attaining the sustainability in agriculture by the mean of a MCDM technique named AHP. It is an adaptable technique and can be applied alone or in combination with other tools to agriculture related decision-making problems. Based on the finding one can conclude that almost all of the decision area related to the application of AHP in agriculture are being discussed here. It can also be concluded that such kind of study require the greater attention of researchers, scientists and policy makers related to the field of agriculture in order to achieve the intended Sustainable Development Goals (SDG).

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Declaration of Competing Interest

The authors of this article declare that they have no conflict of interests.

Data availability

No data was used for the research described in the article.

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