Decision Support model for Crop selection through Analytical Hierarchy Process (AHP)

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ABSTRACT
The goal of this research is to investigate the process of choosing the best crop by using an Analytical Hierarchy Process as a decision-support model (AHP). To achieve the necessary goal, AHP is applied. The AHP is used to evaluate four different Crop and choose the best option. Based on days to maturity and pH, this model helps determine which Crop is best. The benefit analysis is calculated in order to get to a definitive conclusion. A consistency test is run to ensure the accuracy of all calculations. According to the Crop for the grow, the selection criteria and their evaluations can be modified.

Keywords: Analytical Hierarchy Process (AHP), CropSelection, Multi-Criteria Decision-Making.

1. INTRODUCTION

The art and science of developing the soil, growing crops, and raising livestock is known as agriculture. It involves preparing plant and animal items for human consumption and distributing them to marketplaces. Most of the food and textiles in the world are produced by agriculture.It is the primary source of income for many people and the base of the state's economy. It offers individuals jobs. It is an important source of income for the government and a way to generate foreign currency. Karnataka agricultural landscape is made up primarily of large steppes of drought-prone land and intermittent areas of irrigated land. As a result, the state's agricultural land is heavily resource constrained and subject to the moods of the monsoon season.

A plant or plant product that can be grown and harvested for income or food is referred to as a crop. Crops can be divided into six groups based on their intended use: food, feed, fiber, oil, ornamental, and industrial crops. Fruits and vegetables are collected from food crops for human use.the creation of crops with high water use efficiency (drought tolerance), high yields, early maturation, and high consumer appeal. creation of solutions that are ecologically friendly for the effective control of diseases and pests.

Around 3000 years ago, cucumber was first introduced in India. From there, it appears to have moved quickly to Western Asia and finally Southern Europe. The introduction of cucumber to South China and North China through the India-China border and the Silk Road, respectively, and its subsequent spread to East Asia.Within Karnataka the native cucumber type is typically grown in Dakshin Kannada, with Hassan and Chikkamgaluru providing the majority of the output.For cucumber plantations, a weed-free field is necessary. 3–4 ploughings must be completed before to planting in order to achieve fine tilth. To improve the field, FYM like animal waste is incorporated into the soil. Then, nursery beds with a width of 2.5m and placed 60 cm apart are created.Cucumbers are particularly significant economically because they have excellent nutritional, pharmacological, and health-promoting benefits. Cucumbers, which belong to the Cucurbitaceae plant family, have high numbers of the cancer-preventing, bitter-tasting nutrients cucurbitacin.

Okra is a warm-season crop known in Portuguese and Spanish as quiabo and quingombó. It originated in India, was domesticated by the Egyptians in the 12th century AD, and travelled to the United States via the slave trade in the 18th century. Along with many other countries, it is also quite well-liked in many regions of Brazil.Ladyfinger, sometimes referred to as bhindi in India, is nutrient-rich. It is regarded as a good source of calcium, potassium, carbohydrate, proteins, vitamins, enzymes, and a variety of other minerals. In both temperate and tropical regions, okra is a significant crop. The seeds may include antioxidants, which are essential for maintaining good health. Okra flour has a great deal of potential for usage in improving foods to add adequate nutrients for people whose daily nutritional demands aren't being met.

A flowery growing plant with a weak woody stem, tomatoes can reach heights of 1-3 m. The fruits of cultivated types of range in size from cherry tomatoes, which are around 1-2 cm in size, to beefsteak tomatoes, which are about 10 cm or more in diameter. The flowers are yellow. Tomatoes are the second-most significant vegetable crop. From 3.7 million acres, the current global production of fresh fruit is around 100 million tones. The growing season for tomatoes ranges from 90 to 150 days.It is grown for processed goods and fresh fruit. Vitamins, carotenoids, and phenolic compounds are just a few of the health-promoting substances found in tomatoes. In addition to being valuable economically and nutritionally, tomatoes have evolved into the standard for research on how fleshy fruits develop.

One of the most popular and frequently cultivated vegetables in India is the green bean. The young, green pods are prepared and consumed like a vegetable. Immature pods are sold whole, sliced, or French cut, in fresh, frozen, or canned form. With a higher yield than the bean and pea, it is also a significant crop grown.The best time to grow kidney beans is in the spring, between February and March, and in the Wheat crop, between May and June. In the final week of January, some farmers in Punjab plant kidney beans. Use a 45–60 cm between row and 10-15 cm between plant spacing for early variety.A good source of fiber is beans. That's significant because the majority of Americans don't consume the 25 to 38 g daily that are suggested. In addition to keeping you regular, fibre appears to be a defence against heart disease, high cholesterol, high blood pressure, and stomach problems. Each cup of navy beans contains roughly 19 grammes of fibre.

This study work attempts to address such difficult conditions and offer a resolution. For this investigation, four different crops with varying specification. The main objective of this study is to choose the best crop among these 4 crops that are currently growing. Six key factors are taken into consideration throughout the selecting process: I)Temperature, ii) Sowing depth, iii) Days to maturity, iv) pH, v) Vitamin A, vi) Fertilizers. The list of selected crop names and complete growing specifications is provided inTable-2.

Prathyusha Gollapudi et.al[7],Goal Programming approach to allocate the time and cost constraints in a construction project optimization problem.Kamal M.A, et, al.,[2] presents group decision-making using the AHP for project management. Praveen Kumara et, al.,[8] presented a weighted goal mixed integer programming model with a real size application to deal with Power Generation in Deregulated Markets.Vargas and Ricardo Viana,[11] presented principles and techniques of the analytic hierarchy process (AHP) in the prioritization and selection of projects in a portfolio. Praveena Kumara et, al.,[9] presented Goal programming model based on Analytic Hierarchy Process (AHP) for budget allocation planning in hospital administration. S.kim,[1], The selection criteria for gamification platforms to help management's systematic decision-making process.Maruthuret,al.,[3]presents To determine whether the Analytic Hierarchy Process (AHP) is practical and useful for choosing medications for type 2 diabetes.Natasya et,al.,[5]presented to Choose the Newest Smartphone Using Analytical Hierarchy Process was designed to help the consumer make a systematic selection of smartphone.Marjan Hummel et,al.,[6]presents the Healthcare organizations are increasingly using the analytical hierarchy process (AHP) as a technique for multi-criteria decision analysis.Paleieet,al.,[10]presented the reasons for selecting the right project to conduct business in various organizations. It presents several methods for evaluating and selecting projects. A special focus is on Analytical Hierarchy Process (AHP).Şahin et,al.,[4] presented the investigated an analytical hierarchy-based decision-support model for choosing a location for a new hospital.Ivan ArifulFathoni et.al.,[12] presented The number of outstanding students is a problem in determining the decision-making of outstanding students. One of the effective decision-making methods for solving problems in selecting outstanding students is the Analytical Hierarchy Process (AHP) method.

2. Data of the Problem

2.1 Analytic Hierarchy Process(AHP)

The stages of the AHP process are described. Each crop has a purpose and a set of objectives. They reflect the demands and desires of farmers. There are generally numerous options for meeting these needs and

desires. As a result, we create a number of situations in the form of grows. We need criteria to choose the best crop to grow. The best criteria are determined by farmers.

The technique begins with the creation of a hierarchy of criteria. The decision-making objective goal is at the highest level. Building a hierarchy of criteria and its sub criteria is what structuring crop criteria entails. Setting priorities among crops is easier when criteria are broken down into sub-criteria. The hierarchy of criteria represents the structure of the organization's strategy and key performance metrics while also allowing for the selection of crop based on their alignment with farmers objectives. Setting suitable and unambiguous criteria is the first issue when choosing among several strategically essential initiatives for our grows.When we choosecriteria, it is almost immediately clear that they are not equally important and that they are interrelated.

The next step is to assign weights to the previously selected criteria and, if required, split the overall criterion weight across sub criteria.advocate for a pairwise comparison approach to weighing, in which each criterion is compared to each other. Every hierarchic level (comparison of two components belonging to the same group within a hierarchy) and every level of the entire hierarchy is subjected to this pairwise comparison. As a result of this comparison, we can always focus on only two of the criteria at a time.This allows us to determine which criteria are more essential and which are less important for each combination, as well as the difference in importance between them.

When we prioritization the criteria, what technique is used to apply weights to criteria? We normally evaluate two criteria simultaneously and utilize a point framework going from 1 to 9. The pertinence of understanding that the human brain can precisely recognize and consider a couple of things at once is the scale's limitation. Table 1 contains the most dependable guidelines for assessing the pairings. We give the degree of dominance of one element over another in each pair. The exceptional predominance of one criterion over another is given a score of 9, while equality is given a rating of one. Record the reciprocal value if the second criterion is more significant than the first. As a result, we get values in the range of 1/9 to 9. This proportion appraisal approach has been exactly shown to be precise enough for vast majority of issues. A decrease in the balance of assessments would result from a more prominent variety of judgment. Utilize the weighted typical strategy to show up at the last decision. This might be determined by increasing the meaning of the model by the vulnerability level.

The specific steps of the AHP process. Each crop has its purpose and its goals. They represent farmers needs and wants. There are usually several possibilities to fulfil these needs and wants. Therefore, we prepare several scenarios in the form of crops. To select best crop to grow we need criteria.

The fore most step in the process is to develop a norms hierarchy. Decision making goal is the higher level in the process. Structuring crop norms defines constructing order of norms and its sub norms. Changing Structuring norms to sub norms benefits farmer to set priorities among crops. Norms hierarchy reproduces the structure of organizational strategy and significant performance indicators and provides an opportunity to choose a crop with respect to its arrangement with grows aims. The primary task when an important crop selected for our land is to establish proper and clear norms. When we select a norm, it clearly shows that they are not equally significant and are interrelated.

The second step involves assigning weights to earlier selected norms and, wherever is required dividing total criterion weight among sub norms.suggested pair wise comparison method to weighting, wherein every criterion is compared with every other criterion. This process of comparison is carried out at each level of hierarchy and for every level of the whole hierarchy. Such comparison permits that one constantly focuses on two of the norms at the time. This way one can found that each combination, which norms are more significant and which norms are less significant and also significant difference between them.

The AHP approach is used in this study to identify the best crop to grow. In this section, we reviewed the six criteria that were picked from the hierarchy technique for each Crop. I)Temperature, ii) Sowing depth, iii) Days to maturity, iv) pH, v) Vitamin A, vi) Fertilizers All of the aforementioned factors were evaluated with the primary goal of selecting the best crop for grow in mind. The goal of this research was to improve an effective decision-making approach and apply it to crop qualifying and final selection utilizing different criteria.

Table 1. Scale rating of AHP pair wise comparison between the two parameters.

Scale Rating	Preferences agree (Meaning)	Reciprocal
1	Equally Important	1
2	Equally Moderately Important	½
3	Moderately Important	1/3
4	Very Important	¼
5	Strongly very important	1/5
6	Highly Important	1/6

7	Strongly Important	1/7
8	Very Strongly Important	1/8
9	Excessively important	1/9

2.2 Pair Wise and Consistency

AHP assists with assessment measures by providing a useful approach for examining evaluation consistency and minimizing any arguments in decision-making. This structure is separated into suitable levels of detail, knowing that the more criteria that are provided, the less significant each particular criterion becomes. It also aids to establish decision problem relevant qualities such as objectives and selection criteria between the top and bottom levels. The relative weights of each item are then determined at the appropriate level. The total of all criteria should be one.

According to experience with the Analytical Hierarchy Process, Table -2 describes the procedures for the function Object prequalification problem for the assumption forcrop to grow. It depicts an illustrative case for which crop A, B, C, and D would want to be prequalified. The hierarchy problem might be seen and analyzed using the AHP techniques that were provided.

Table 2. Corp details

Crop	Temperature (in °C)	Sowing depth (in inches)	Days to maturity	pH	Vitamin A (in IU)	Fertilizers need	Crop names
A	20-30	0.25	90-110 days	5.5-7.5	833	high	Tomato
B	16-30	1-1.5	45-50 days	6.0-7.5	108	medium	Green beans
C	20-32	0.5	45-50 days	6.0-7.5	716	average	Okra (Lady finger)
D	16-32	0.5	45-50 days	5.5-7.5	96	average	Cucumber

Table 3. General Analytical Hierarchy Process Model

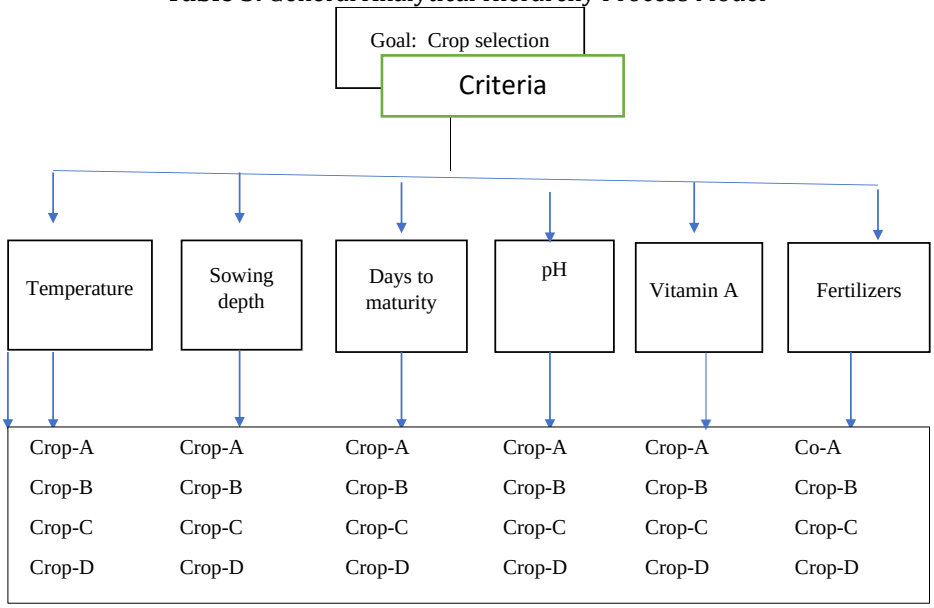

Table 4. Normalized Pair-Wise Matrix. Normalizing the matrix means to divide each element in every column by the sum of that column

	Temperature	Sowing depth	Days to maturity	pH	Vitamin A	Fertilizers
Temperature	1	0.33	0.2	0.11	0.14	3
Sowing depth	3	1	0.33	0.14	0.33	3
Days to maturity	5	3	1	0.2	0.2	3

pH	9	7	5	1	3	7
Vitamin A	7	3	5	0.33	1	9
Fertilizers	0.33	0.33	0.33	0.14	0.11	1
SUM	25.33	14.66	11.86	1.92	4.78	26

Table 5.

	Temperature	Sowing depth	Days to maturity	pH	Vitamin A	Fertilizers	Criteria Weights (AVG)
Temperature	0.039	0.023	0.017	0.057	0.029	0.115	0.047
Sowing depth	0.118	0.068	0.028	0.073	0.069	0.115	0.079
Days to maturity	0.197	0.205	0.084	0.104	0.042	0.115	0.125
pH	0.355	0.477	0.422	0.521	0.628	0.269	0.445
Vitamin A	0.276	0.205	0.422	0.172	0.209	0.346	0.272
Fertilizers	0.013	0.023	0.028	0.073	0.023	0.038	0.033

Table 6. Each criterion Pairwise Comparison Matrix and Normalization Matrix (crop), A:- Crop-1; B:- Crop-2; C:- Crop-3; D:- Crop-4

Pairwise Comparison Matrix					Normalization Matrix					AVG
Temperature	A	B	C	D	Temperature	A	B	C	D	
A	1	2	0.125	0.166	A	0.065	0.143	0.086	0.023	0.079
B	0.5	1	0.166	0.2	B	0.032	0.071	0.114	0.027	0.061
C	8	6	1	6	C	0.516	0.429	0.686	0.815	0.611
D	6	5	0.166	1	D	0.387	0.357	0.114	0.136	0.248
Sum	15.5	14	1.457	7.366						

$\lambda_{max} = 4.0048$,Consistency Index$CI = 0.0016, RI = 0.9$,Consistency Ratio$(CR) = 0.0017 < 0.1$,the degree of consistency is satisfactory (the judgments are acceptable)

Pairwise Comparison Matrix					Normalization Matrix					AVG
Vitamin A	A	B	C	D	Vitamin A	A	B	C	D	
A	1	0.166	5	0.125	A	0.066	0.023	0.412	0.013	0.129
B	6	1	6	0.166	B	0.395	0.136	0.495	0.018	0.261
C	0.200	0.167	1	8	C	0.013	0.023	0.082	0.861	0.245
D	8	6	0.125	1	D	0.526	0.818	0.010	0.108	0.366
SUM	15.200	7.333	12.125	9.291						

$\lambda_{max} = 3.951$,Consistency Index$CI = 0.016, RI = 0.9$,Consistency Ratio$(CR) = 0.018 < 0.1$,the degree of consistency is satisfactory (the judgments are acceptable)

Pairwise Comparison Matrix					Normalization Matrix					AVG
Sowing depth	A	B	C	D	Sowing depth	A	B	C	D	Weights
A	1	0.330	0.166	3	A	0.163	0.031	0.013	0.322	0.133
B	3	1	6	0.111	B	0.490	0.095	0.480	0.012	0.269
C	6	0.167	1	5	C	0.980	0.016	0.080	0.537	0.403
D	0.333	9	0.200	1	D	0.054	0.857	0.016	0.107	0.259
Sum	10.333	10.497	7.366	9.111						

$\lambda_{max} = 3.951$,Consistency Index$CI = 0.061, RI = 0.9$,Consistency Ratio$(CR) = 0.068 < 0.1$,the degree of consistency is satisfactory (the judgments are acceptable)

Pairwise Comparison Matrix					Normalization Matrix					AVG
Fertilizers	A	B	C	D	Fertilizers	A	B	C	D	Weights
A	1	0.166	0.5	5	A	0.137	0.016	0.029	0.381	0.141
B	6	1	0.111	7	B	0.819	0.097	0.006	0.533	0.364
C	2	9	1	0.125	C	0.273	0.873	0.058	0.010	0.304
D	0.200	0.142	8	1	D	0.027	0.014	0.468	0.076	0.146
Sum	9.200	10.308	9.611	13.125						

$\lambda_{max} = 4.385$,Consistency Index$CI = 0.0161, RI = 0.9$,Consistency Ratio$(CR) = 0.017 < 0.1$,the degree of consistency is satisfactory (the judgments are acceptable)

Pairwise Comparison Matrix					Normalization Matrix					AVG
Days to maturity	A	B	C	D	Days to maturity	A	B	C	D	Weights
A	1	0.33	0.2	1	A	0.100	0.032	0.032	0.098	0.065
B	3	1	0.111	8	B	0.300	0.096	0.018	0.784	0.299
C	5	9	1	0.2	C	0.500	0.861	0.158	0.020	0.385
D	1.000	0.125	5	1	D	0.100	0.012	0.792	0.098	0.251
Sum	10.000	10.455	6.311	10.2						

$\lambda_{max} = 4.004$,Consistency Index$CI = 0.0012, RI = 0.9$,Consistency Ratio$(CR) = 0.0014 < 0.1$,the degree of consistency is satisfactory (the judgments are acceptable)

Pairwise Comparison Matrix					Normalization Matrix					AVG
pH	A	B	C	D	pH	A	B	C	D	Weights
A	1	3	0.2	6	A	0.100	0.287	0.032	0.588	0.252
B	0.33	1	0.111	0.125	B	0.033	0.096	0.018	0.012	0.040
C	5	8	1	5	C	0.500	0.765	0.158	0.490	0.478
D	0.166	0.111	5	1	D	0.017	0.011	0.792	0.098	0.229
Sum	6.496	12.111	6.311	12.125						

$\lambda_{max} = 3.968$,Consistency Index$CI = 0.0106, RI = 0.9$,Consistency Ratio$(CR) = 0.0117 < 0.1$,the degree of consistency is satisfactory (the judgments are acceptable)

Table 7. Pair wise comparison matrix.

	Temperature	Sowing depth	Days to maturity	pH	Vitamin A	Fertilizers
Temperature	1	0.33	0.2	0.11	0.14	3
Sowing depth	3	1	0.33	0.14	0.33	3
Days to maturity	5	3	1	0.2	0.2	3
pH	9	7	5	1	3	7
Vitamin A	7	3	5	0.33	1	9
Fertilizers	0.33	0.33	0.33	0.14	0.11	1
SUM	25.33	14.66	11.86	1.92	4.78	26

Table 8. Normalized Pair-Wise and average values of thematrixpriority vector.

	Temperature	Sowing depth	Days to maturity	pH	Vitamin A	Fertilizers	AVG
Temperature	1	0.33	0.2	0.11	0.14	3	0.046
Sowing depth	3	1	0.33	0.14	0.33	3	0.078
Days to maturity	5	3	1	0.2	0.2	3	0.124
pH	9	7	5	1	3	7	0.444
Vitamin A	7	3	5	0.33	1	9	0.271
Fertilizers	0.33	0.33	0.33	0.14	0.11	1	0.032

Table 9. Consistency ratio calculation

	Temperature	Sowing depth	Days to maturity	pH	Vitamin A	Fertilizers	SUM
Temperature	0.039	0.023	0.017	0.057	0.029	0.115	0.281
Sowing depth	0.118	0.068	0.028	0.073	0.069	0.115	0.472
Days to maturity	0.197	0.205	0.084	0.104	0.042	0.115	0.748
pH	0.355	0.477	0.422	0.521	0.628	0.269	2.672
Vitamin A	0.276	0.205	0.422	0.172	0.209	0.346	1.630
Fertilizers	0.013	0.023	0.028	0.073	0.023	0.038	0.198

Table 10. Ratio of weighted sum value and criteria weights

	SUM	AVG	SUM /AVG
Temperature	0.281	0.046	6.105
Sowing depth	0.472	0.078	6.049
Days to maturity	0.748	0.124	6.030
pH	2.672	0.444	6.018
Vitamin A	1.630	0.271	6.014
Fertilizers	0.198	0.032	6.180
AVG			6.066

3. Consistency Ratio

- Calculate the consistency index (CI):$(CI) = \frac{(\lambda_{max} - n)}{(n-1)}$ The smaller the CI, the smaller the deviation from the consistency is.
- Calculate the appropriate value of n by comparing the consistency index with the random index used in decision making. If $\left(\frac{CI}{RI}\right) < 0.10$, the degree of consistency is satisfactory, but if $\left(\frac{CI}{RI}\right) > 0.10$, conclude that there exists inconsistencies and the AHP may not give meaningful results.

The consistency ratio for each criterion at the same level was calculated as follows:

Determine the Consistency Index$(CI) = \frac{(\lambda_{max} - n)}{(n-1)}$

Where λ_{max} is the average of Sum / WeightsColumn.

n is the number of Criteria,

Random Consistency index table:

Size of Matrix	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Average of Sum / Weights Column

$$\lambda_{max} = \frac{(6.105 + 6.049 + 6.030 + 6.018 + 6.014 + 6.180)}{6} = 6.066$$

Consistency Index$(CI) = \frac{(6.066 - 6)}{(6-1)}$

Consistency Index$(CI) = 0.0132$

Consistency Ratio $(CR) = \frac{CI}{RI} = \frac{0.0132}{1.24} = 0.0106$

Consistency Ratio $(CR) = 0.0106$

The result is within the acceptable range because the value of the consistency ratio is less than 0.10.

3.1. Complete priority vector

The complete priorities were determined by multiplying the priority vectors of the criteria by the priorities for each alternative decision for each objective.

Table 11. Total priority vector with critical weights

Temperature	Sowing depth	Days to maturity	pH	Vitamin A	Fertilizers
0.046	0.078	0.124	0.444	0.271	0.032

Table 12. Alternatives priority vector (A- Crop; B-Crop; C-Crop; D-Crop)

	Temperature	Sowing depth	Days to maturity	pH	Vitamin A	Fertilizers
A	0.079	0.133	0.065	0.252	0.129	0.141
B	0.061	0.269	0.299	0.040	0.261	0.364
C	0.611	0.403	0.385	0.478	0.245	0.304
D	0.248	0.259	0.251	0.229	0.366	0.146

Priority vector for Crop -A:
$0.079 + 0.133 + 0.065 + 0.252 + 0.129 + 0.141 = 0.133$
Priority vector for Crop -B:
$0.061 + 0.269 + 0.299 + 0.040 + 0.261 + 0.364 = 0.216$
Priority vector for Crop -C:
$0.611 + 0.403 + 0.385 + 0.478 + 0.245 + 0.304 = 0.404$
Priority vector for Crop -D:
$0.248 + 0.259 + 0.251 + 0.229 + 0.366 + 0.146 = 0.250$

RESULTS

The crop is now ranked according to their overall priorities, based on the table of values. The best crop was C (Crop-C). A, B, C and D specifying that C is the best crop to grow for performing sensitivity analysis, the decision-maker can check the accepting of this decision on the overall priorities of crop by demanding altered values for his comparison decisions.
Hence, we can observe that AHP considers individual aspects of all the criteria as well as alternatives and combines them to give the final score.

CONCLUSION

The AHP procedure is utilized in a variety of decision-making situations. We have chosen to show you how AHP evaluates and selects the best crop. AHP is capable of expediting the development of crops growing. The major strength of AHP is its methodical approach in multiple phases, as well as its capacity to reduce function object subjectivity when deciding between growing options. AHP also has a number of flaws when it comes to crop selection. The first flaw is that it overlooks the fact that certain decisions might have negative consequences. The second constraint is that all criteria must be fully disclosed and accounted for at the start of the selection process, as per AHP. It also permits the crop more influential farmer to cheer for their own initiatives while obstructing the open selection process. The procedure is not only difficult to comprehend, but it also necessitates some mathematical work.
The goal of this paper is to use AHP as a decision-making approach that allows for the consideration of multiple criteria to select the best crop for grow.

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