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# Model for implementing sustainable agriculture based on good agricultural practice as a strategy for adapting to the impact of climate change

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**Abstract:** The aim of this research is to develop a strategy for implementing sustainable agriculture based on good agricultural practice as a strategy for adapting to the impacts of climate change. This research was conducted in the Kopeng area, Semarang Regency, Central Java, which is one of the areas in Indonesia that is rich in agricultural potential. Efforts to implement a sustainable agricultural model in Kopeng Village considering that the majority of agriculture in this area still relies on conventional agricultural techniques which have an impact on reducing land quality. The data analysis method used in this research is ANP (Analytic Network Process) which is a mathematical theory that allows decision making to deal with interrelated factors (dependence) as well as mathematical feedback. The results of the research show that the Sustainable Agriculture Implementation Model Based on Good Agricultural Practice as a Strategy for Adapting to the Impact of Climate Change in Kopeng Village requires attention to six criteria, including sustainable land management, efficient use of water, conservation of biodiversity, reduced use of chemicals, increased welfare farmer socio-economics, climate change adaptation and mitigation. The most prioritized criterion is sustainable land management. In the criteria for sustainable land management, there are three sub-criteria, including Crop Rotation, No-till land management and Use of land cover. Of the three sub-criteria, the sub-criteria that is most prioritized in the criteria for sustainable land management is crop rotation.
***Keywords:*** *Climate change, Good agricultural practice, Sustainable agriculture.*

## 1. Introduction

Sustainable development has been a guiding principle for all economic and political sectors since the United Nations Conference on Environment and Development in Rio in 1992. There is also broad consensus that it is an important goal for agriculture, and sustainable agriculture is seen as essential to global sustainability. Global climate change and population growth pose major challenges to food production [1, 2]. It is estimated that global food production needs to increase by 100-110% by 2050, which is much higher than previous predictions of around 70% for the same year [3]. As a result, from the production supply side, additional use of pesticides and fertilizers is required to stimulate and increase crop yields [4-6]. Based on FAO statistics (2020), the use of chemical pesticides in Indonesia reaches 1,597 tons per year. The low utilization efficiency of pesticides and chemical fertilizers has caused ecological damage and waste of resources [7, 8]. Therefore, there is an urgency to develop environmentally friendly strategies to increase the efficiency of pesticide and fertilizer use in the future.


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Intensive agriculture to increase food production requires the use of inputs such as environmentally friendly fertilizers and pesticides to reduce major pressure on the environment [9]. Organic fertilizers have been introduced as an alternative to chemical fertilizers with the aim of increasing soil fertility in sustainable agricultural crop production. Organic fertilizers consist of various types of free-living organisms that can convert nutrients from inaccessible forms to accessible forms through biological processes. This leads to better root system development and seed germination, increases soil fertility, inhibits the spread of pathogens, improves soil physical and chemical properties, and increases nutrient absorption by plants, thereby increasing agricultural production [10, 11]. Organic fertilizer generally includes manure, plant residues, green manure, and fungal microorganisms that stimulate plant growth [12]. In a sustainable agricultural system, the use of organic fertilizer is very important to increase production and maintain soil fertility in a sustainable manner [10, 13, 14].

To meet the demand for agricultural food in 2050, it is necessary to use environmentally friendly fertilizers and pesticides. This is important because current pest attacks have caused production losses of 20-95%, even causing puso and crop failure on a large scale [15]. Farmers often use chemical pesticides without paying attention to the target pest, and are inappropriate in type, dose, application method and frequency of use, which tends to be excessive. This condition can leave residue in soil and water, and be carried into agricultural products, thereby reducing environmental quality and endangering the health of humans and other living creatures [16]. In the long term, this situation can result in failure of agricultural production management through pest resurgence and increased pest resistance. Untung [17] proposed the concept of organic pest control to reduce dependence on chemical pesticides. Organic pesticides, including microbial pesticides, are environmentally friendly components. According to Schumann [18] organic pesticides contain organic compounds and antagonistic microbes that can inhibit or kill pests and plant diseases. Biopesticides contain organic compounds that are easily degraded in nature. In addition, organic pesticides are usually made from natural ingredients based on local resources, so they can function as the main pest control for food crops which is cheap, easy, leaves no residue and is environmentally friendly.

Conceptually, the use of organic fertilizers and pesticides is an ideal choice to achieve sustainable agriculture, but implementation is often difficult. This research focuses on testing good practices in using organic fertilizers and pesticides through the circular economy concept in Kopeng Village, Semarang Regency, one of the largest agricultural producers in Central Java. The circular economy concept promotes those materials usually considered waste can be used as new resources of economic value. In essence, a circular economy is a system that focuses on the reuse, recycling and recovery of materials to achieve economic prosperity, environmental protection and social justice [19]. The environmental, social and economic benefits of a circular economy in this context include the use of organic fertilizer derived from processing cattle and rabbit waste, while organic pesticides are produced from community harvest waste. Circular agriculture in this research focuses on using minimal amounts of external input, closing nutrient cycles, regenerating soil, and minimizing environmental impacts [20]. If widely implemented, circular agriculture can reduce the resource requirements and ecological footprint of the agricultural sector [21]. This can also help reduce the use of chemical fertilizers and has the potential to reduce global CO2 emissions [22].

The implementation of a circular economy in the agricultural sector of Kopeng Village, Semarang Regency, is a promising strategy to save relevant resources and reduce the negative environmental impacts of agricultural activities, while improving economic performance [23, 24]. Circular agriculture is also more labor intensive than conventional agriculture, offering a strategy for stimulating the economy in rural areas. Thus, implementing circular agricultural practices can make an important contribution to food security [25]. Adaptation to climate change, including the use of organic fertilizers and pesticides through circular agriculture, is an important contribution to meeting demand for food crops by 2050 while maintaining the principles of sustainable agriculture.

## 2. Theoretical Framework

The debate regarding agricultural sustainability began in the 1950s and 1960s, when agriculture began to undergo transformation through the green revolution. Increases in crop varieties, changes in management, and use of agricultural inputs such as fertilizers and pesticides lead to increases in crop yields and food production. However, this progress also brings undesirable negative impacts, such as threats to natural resources and various forms of environmental degradation, including air and water pollution, soil depletion, and reduced biodiversity [10, 11]. In this context, environmental issues became more prominent, and alternative approaches to conventional agricultural practices began to be sought. Conventional farming is often described as unsustainable, so alternatives are considered more sustainable. This is where the concept of sustainable agriculture, as an alternative agricultural form or ideology, emerged [24]. The debate about sustainable agriculture received increasing attention after the Brundtland report which introduced the idea of sustainable development. This new perspective causes sustainable agriculture to be understood as a systemic concept. Since then, the meaning of sustainability in agriculture and the methods and indicators for assessing it have continued to be debated. This long tradition has resulted in numerous scientific analyzes and numerous publications.

Sustainable agriculture, as has been emphasized, is not a clear and well-defined concept that is easy to implement correctly. Each actor has its own understanding, both explicit and implicit, about what sustainable agriculture is [11]. However, this is not a weakness. On the contrary, many publications confirm that with appropriate adaptation, this diversity of understanding is essential for successful implementation. This doesn't mean we don't need to define sustainable agriculture, but we need to define it more precisely. Of course, we must differentiate analyzes based on their purpose. Methods for assessing and evaluating agricultural systems (empirical contributions) require a more detailed definition, which should include a goal-oriented vision or understanding.

The development of such a definition could be guided by the SAFA (Food and Agricultural Systems Sustainability Assessment) framework. Theoretical approaches do not require very detailed definitions. For this type of analysis, sustainable agriculture can be described as a concept that "describes a system" that is goal-oriented. Sustainable agricultural systems fulfill a diverse set of goals (multifunctional) and must persist over time. These principles and goals often compete with each other (corresponding to “competing goals” [20]. The goals include social, economic, and environmental issues, as well as the demands of current and future generations, demands global and local, as well as the demands of society, entrepreneurship (agriculture), and individuals (farmers). Sustainability is related to resource limitations, environmental degradation, and "long-term system performance".

Depending on the type of resource, the following principles should be followed: the recharge rate of renewable resources should be considered, and non-renewable resources should only be used judiciously. In general, the goal is good resource use efficiency. (Agro) ecosystems must be preserved, and their negative impacts avoided wherever possible. Sustainability also relates to the possibility of disruption, system resilience, and stability. This means that disruptions (e.g. drought, electricity shortages, floods, pests, and disease) to agricultural systems do not necessarily lead to destruction or significant failure in achieving goals. The main purpose Sustainable agriculture is about balancing multiple goals and finding the best compromise between competing or conflicting goals.

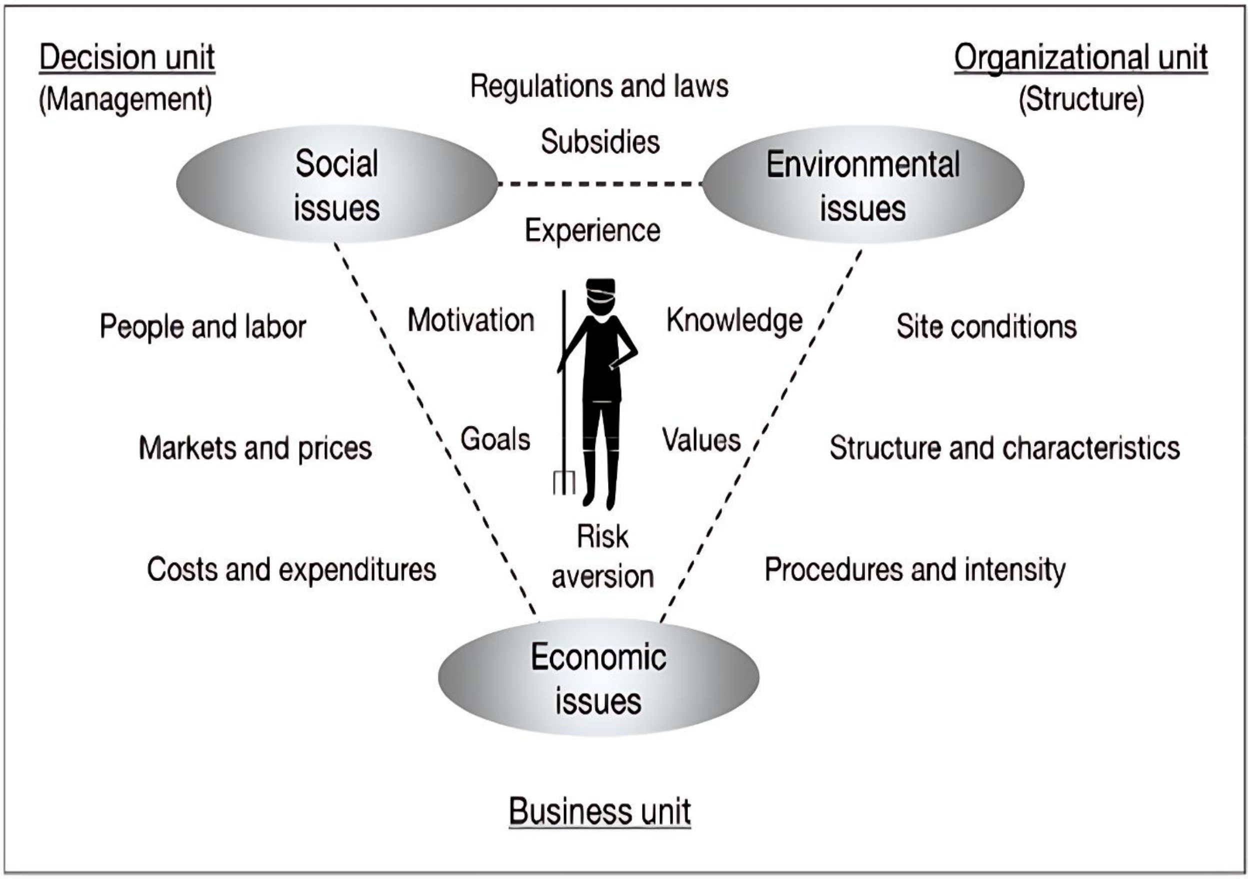


**Figure 1.**
Sustainable agriculture concept.

Scientists and researchers have varying motivations for considering sustainability in agriculture, and their goals may vary. Such motivations may include a desire to refine the theory behind sustainable agriculture, help define and increase understanding of sustainable agriculture, evaluate sustainability performance, and compare agricultural systems. However, the question is whether the efforts that have been made are sufficient to apply theory into practice. Some articles suggest that "theory and practice" should be integrated, support should be given to "practice-oriented research", and the transformation process towards sustainability in agriculture should be strengthened. Meanwhile, others propose increasing synergies between "agricultural policy, practice and research" and discuss "knowledge exchange" between science and practitioners [19]. In this context, it is important to discuss the relationship between science in sustainable agriculture and the process of applying theory in practice. Publications on science and research in sustainable development suggest that tasks required in the implementation process, such as the creation of useful knowledge systems, may not be as relevant in science and research. Other authors pushed to address the "gap between research and practice" or criticized the lack of information flow between scientists, practitioners, and policymakers, and the difficulties this creates. Different perspectives on the relationship between research (knowing) and practice (doing) also exist. Some authors distinguish between "basic research", "use-inspired research", and "pure applied research", as well as "practice-oriented" and "basic research-oriented" work. In other words, not all scientific contributions to sustainable agriculture necessarily involve direct implementation.

## 3. Methods

This research was conducted in the Kopeng area, Semarang Regency, Central Java, which is one of the areas in Indonesia that is rich in agricultural potential. Efforts to implement a sustainable agricultural model in Kopeng Village considering that the majority of agriculture in this area still relies on conventional agricultural techniques which have an impact on reducing land quality. Apart from that, climate change which is currently occurring has also had an impact on reducing agricultural productivity in Kopeng Village. The data used in this research is primary data sourced from keypersons consisting of academics, government, farmers, NGOs, the general public and other stakeholders. Keyperson selection was carried out using a purposive sampling technique.

The data analysis method used in this research is ANP (Analytic Network Process) which is a mathematical theory that allows decision making to deal with interrelated factors (dependence) as well as mathematical feedback. In the ANP method there is interaction and feedback from elements in the cluster (inner dependence) and interaction between clusters (outer dependence). Comparisons in ANP are made between elements in components or clusters for each interaction in the network. ANP has three axioms which form the basis of its theory, axioms or postulates function to strengthen a statement whose truth can be seen without the need for evidence. According to these axioms are:

### *3.1. Reciprocal*

If activity X has a level of importance 6 times greater than activity Y then activity Y is 1/6 of activity X.

### *3.2. Homogeneity*

This axiom states that if the elements to be compared do not have too large a difference, this will result in greater judgment errors. The scales used in AHP and ANP are different from the scales used in general Likert scales (1 to 5). The ANP scale has a larger range, namely 1 to 9 even. The following is the scale used in ANP.

**Table 1.**
Scales in ANP.

| Description | Level of importance | Explanation |
|---|---|---|
| Very much greater influence/level of influence | 9 | Evidence that favors one element over another element has a high degree of probability of affirmation |
| Between grades 7-9 | 8 | A compromise value between two adjacent values |
| Very much greater influence/level of importance | 7 | One element is superior to the other elements, and is dominantly demonstrated in practice |
| Between 5-7 | 6 | A compromise value between two adjacent values |
| Greater influence/level of importance | 5 | Experience and judgment strongly favor one element over another |
| Between 3-5 | 4 | A compromise value between two adjacent values |
| Slightly greater influence/level of importance | 3 | Experience and judgment slightly favor one element over another |
| Between 1-3 | 2 | A compromise value between two values that are close |
| The same magnitude of influence/level of importance | 1 | The two elements being compared have the same important contribution to the goal |

The stages of research using the Analytic Network Process (ANP) are as follows:

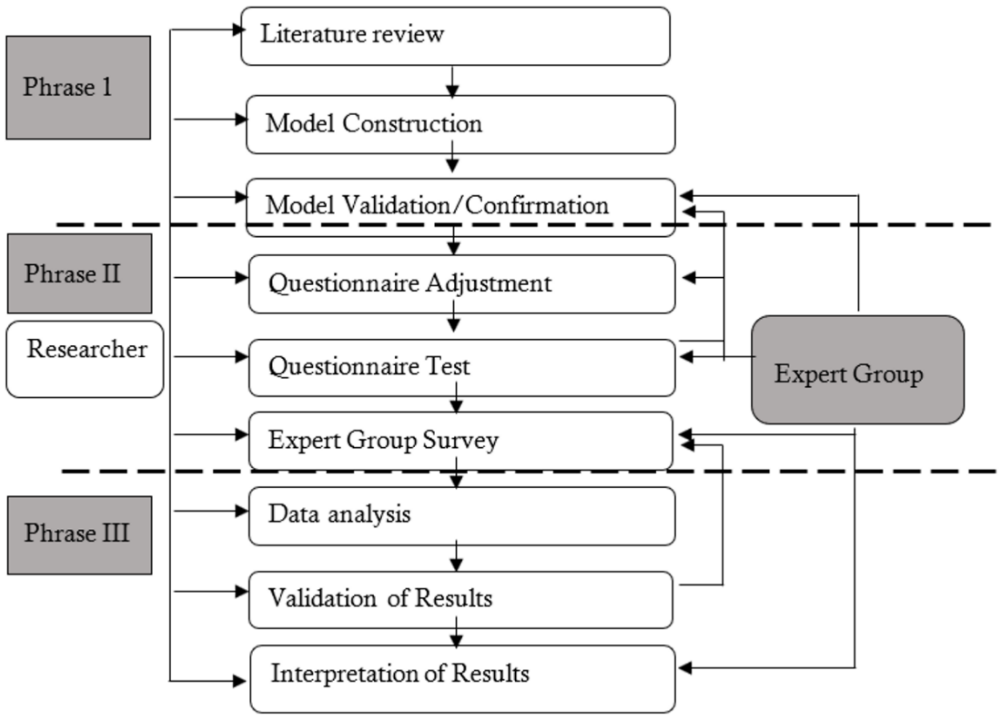


**Figure 2.**
ANP stages.

The stages of analysis using the Analytic Network Process (ANP) are explained in the following image:

Step 1: ANP Network Generation

Based on ANP methodology, the temporary facility layout decision problem can be transformed into a network structure, which is established according to the links and interdependencies between the factors considered in the evaluation problem. Different kinds of relationships between the factors are incorporated into the network.

Step 2: Pairwise Comparisons

Based on the generated temporary facility layout decision network structure, the relative importance of clusters and elements are required for final evaluation. In order to derive priorities, pairwise comparisons are conducted between clusters and elements according to the relationships and interdependencies.

For an $n \times n$ pairwise comparison matrix, the total number of pairwise comparisons that should be performed is $n \times (n-1)/2$, where n is the total number of elements required to be compared. Moreover, within the matrix, a reciprocal value can be automatically calculated and assigned for reverse comparison. The pairwise comparison number aij should meet the following equation:

$aij \times aji = 1$

where aij is the pairwise comparison number, which is calculated by the value of fundamental scale

Step 3: Consistency Check

Through the derived comparison matrices, the eigenvectors of the matrices are obtained, which represent the weights of the elements. The local priority vector is computed as Equation:

$Aw = \lambda max$

where A is defined as the matrix of pairwise comparison values; w is the priority vector, which is called the principal eigenvector; and$\lambda$max is the maximum or principal eigenvalue of matrix A.

After the local priority vectors are derived, the consistency is verified through a consistency index (CI) and a consistency ratio (CR). Lack of consistency in the pairwise comparisons indicates lack of understanding of the problem by the layout planners, which is caused by wrong decisions. The consistency ratio is acceptable if it is less than 0.1. The CI and CR are defined as Equation:

CR = CI/RI

with CI = (λmax−n)/(n−1) (3) where CR represents the consistency ratio; CI represents the consistency index; RI represents the random index; and n is the size of matrix A.

Step 4: Super matrix and Global Priority Calculation

Through pairwise comparisons, the relative importance is obtained. However, this is not enough for demonstration of the differences between clusters and elements. Therefore, the super matrix, as shown in Equation:

$$W = \begin{array}{c} \\ C_1 \\ C_2 \\ \vdots \\ C_n \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} W_{11} & W_{12} & \cdots & W_{1n} \\ W_{21} & W_{22} & \cdots & W_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ W_{n1} & W_{n2} & \cdots & W_{nn} \end{bmatrix} \end{array}$$

In order to derive the weighted super matrix, normalization is required to be conducted on the unweighted super matrix. The normalized weighted super matrix W can be calculated by multiplying the unweighted super matrix W shown in Equation and the weighting matrix.

## 4. Results and Discussion

Effort Sustainable agricultural development requires a mix of strategies that cover various aspects/criteria from upstream to downstream. To determine the priority of each aspect, it is necessary to calculate the weights to see which aspects should be prioritized to develop sustainable agriculture. This research has six aspects/criteria in a sustainable agricultural development strategy, namely sustainable land management, efficient water use, biodiversity conservation, reducing the use of chemicals, increasing the socio-economic welfare of farmers, adapting and mitigating climate change. Each criterion has sub-criteria. To determine the priority of each criterion, calculations are carried out using the Analytic Network Process (ANP) method. ANP is a powerful synthetic method for combining judgment and data (combining judgment data) to determine choices effectively and predict data accurately (rank options and predict outcomes).

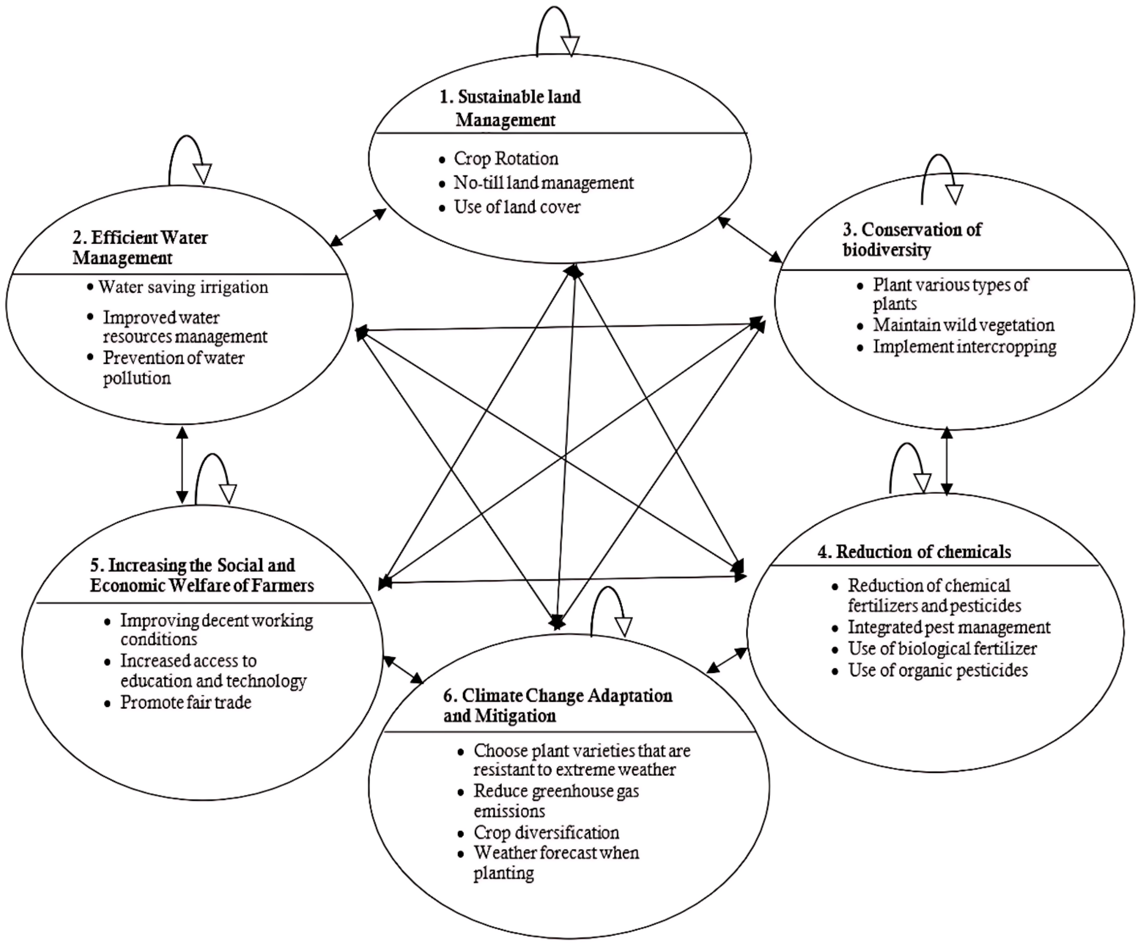


**Figure 3.**
Conceptual Framework for Sustainable Agriculture-Based Implementation Strategy *Good Agricultural Practice.*

Based on Figure 1 above, it can be seen that the conceptual framework in the strategy for implementing sustainable agriculture based on good agricultural practice focuses on six criteria. Each criterion has several supporting sub-criteria. Figure 3 also shows that there is a relationship between nodes in one cluster which is indicated by an upward curved line (loop) in a cluster/criterion. This is called the inner dependence relationship. Apart from that, there is a direct relationship between several clusters which is called outer dependence.

### *4.1. Pairwise Comparison Matrix between Nodes (Inner Dependence)*

The pairwise comparison matrix for inner dependence is obtained from the relationship between nodes (sub criteria) in the cluster (criteria). Where the relationship between nodes in one cluster will form a curved line above the criteria or is called a loop. Inner dependence relationships can occur as in Figure 3. Based on the ANP analysis for sustainable land management criteria, the following results were obtained:

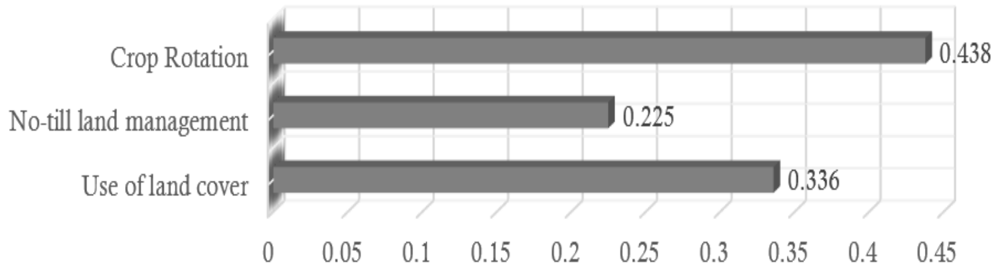


**Figure 4.**
Sustainable land management.

Based on Figure 4, it can be explained that the criteria for sustainable land management have three sub-criteria, including Crop Rotation, No-till land management and Use of land cover. Of the three sub-criteria, the sub-criteria that is most prioritized in the criteria for sustainable land management is crop rotation with a weight of 43.8%. The analysis results for efficient water management criteria are as follows:

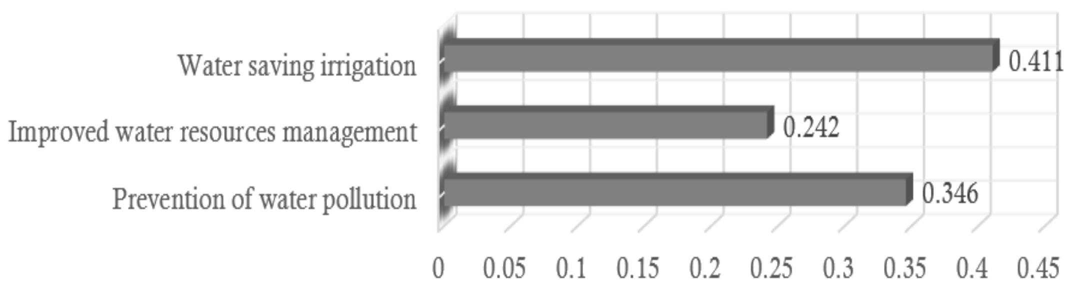


**Figure 5.**
Criteria for efficient water management.

Figure 5 explains that the criteria for efficient water management have three sub-criteria, including water-saving irrigation, improving water resource management, and preventing water pollution. The most prioritized sub-criteria is water-saving irrigation with a value of 41.1%. The analysis results for biodiversity conservation criteria are as follows:

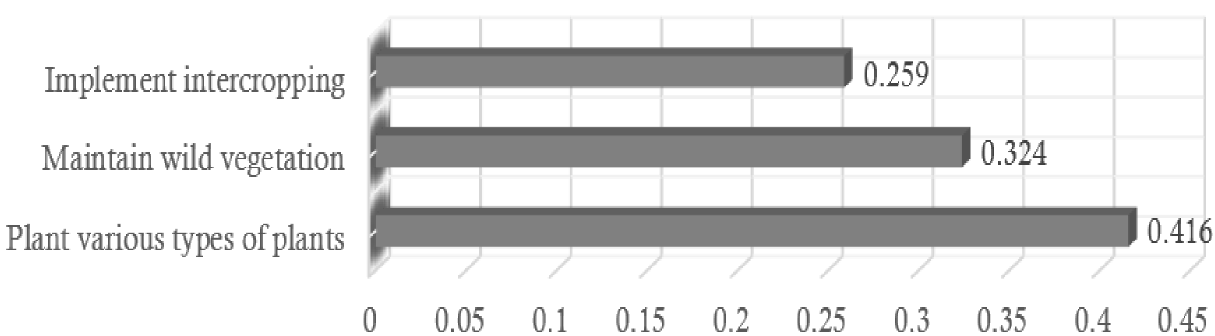


**Figure 6.**
Biodiversity conservation.


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Based on Figure 6, it can be explained that the criteria for biodiversity conservation have three sub-criteria, including planting various types of plants, maintaining wild vegetation, and implementing intercropping. The sub-criteria that is the main priority is planting various types of plants with a value of 41.6%. The analysis results for chemical reduction criteria are as follows:

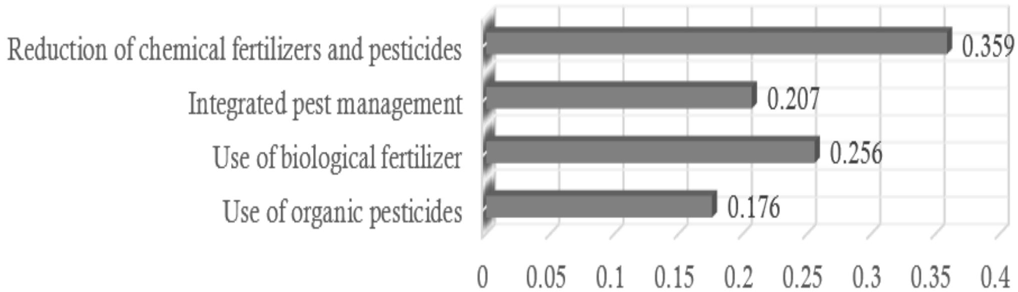


**Figure 7.**
Chemical reduction.

Based on Figure 7, it can be explained that in the criteria for reducing chemicals there are four sub-criteria, namely reducing chemical fertilizers and pesticides, integrated pest management, using biological fertilizers, and using organic pesticides. The most prioritized sub-criteria is reducing the use of chemical fertilizers and pesticides with a value of 35.9%. The results of the analysis of the criteria for Increasing Farmers' Social and Economic Welfare are as follows:

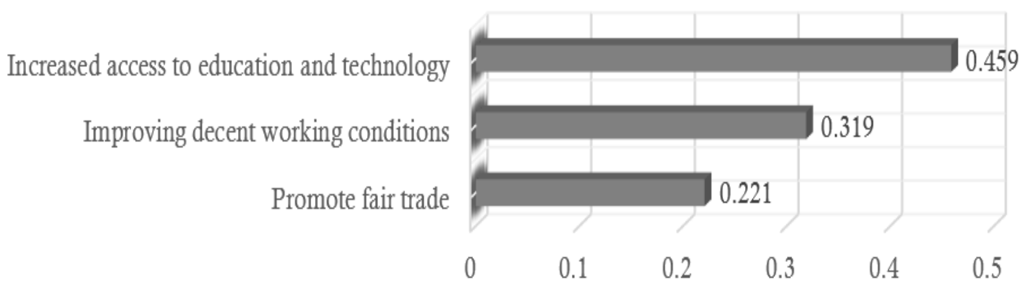


**Figure 8.**
Increasing the social and economic welfare of farmers.

Figure 8 shows that in the criteria for Increasing Farmers' Social and Economic Welfare there are three sub-criteria, including Improving decent working conditions, Increasing access to Education and technology, Promoting fair trade. The most prioritized sub-criteria is expanding marketing partner collaboration with a value of 45.9%. The analysis results for climate change adaptation and mitigation criteria are as follows:

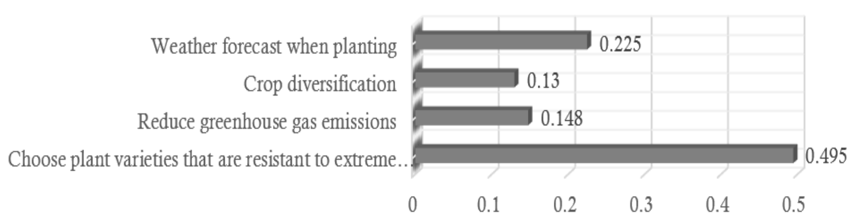


**Figure 9.**
Climate change adaptation and mitigation.

Figure 9 explains that the criteria for adapting and mitigating climate change have four sub-criteria, namely choosing plant varieties that are resistant to extreme weather, reducing greenhouse gas emissions, crop diversification, forecasting the weather when planting. The most prioritized sub-criteria is selecting plant varieties that are resistant to extreme weather with a value of 49.5%.

### *4.2. Creating a Pairwise Comparison Matrix between Criteria*

A pairwise comparison matrix between criteria/groups was created based on the questionnaire that had been filled in by*keyperson.*This pairwise comparison matrix uses values with numbers 1-9. Next, after the assessment has been carried out, it will continue with calculating the average value of the questionnaires that have been filled in, so that you will obtain a relative value. This relative value will then be used as the input value in ANP, namely the super decision application created by M Saaty. The following are the results of group comparisons/between criteria:

**Table 2.**
Results of comparative analysis between criteria.

| Criteria | Weight |
|---|---|
| Chemical reduction | 0.2155 |
| Efficient water management | 0.0852 |
| Biodiversity conservation | 0.1375 |
| Increasing the social and economic welfare of farmers | 0.1154 |
| Increasing the social and economic welfare of farmers | 0.1332 |
| Sustainable land management | 0.3134 |

Table 2 shows that the priority strategy for implementing sustainable agriculture is based on good agricultural practice when viewed from the priority value (eigen vector), where the criterion of sustainable land management ranks first with a value of 31.34%. Then the second place is the reduction of chemicals with a value of 21.55%. Meanwhile, the third place is biodiversity conservation with a value of 13.75%.

### *4.3. Priority Order Based on Criteria*

The final priority referred to in the ANP model is absolute weighting using an interval scale (1.0) and also as a measure of relative dominance. The priority value is obtained by normalizing the matrix vector. In the final priority there are limiting weights, normalized by cluster and ranking. The final priority value can be seen in the following table. The final priority is the weight of all elements which include limiting and normalizing by cluster. Limiting weight is the weight obtained from the limit supermatrix, while normalized by cluster is the division between the limiting element weights and the sum of the limiting element weights in a component. Final priority determines the best alternative with the greatest final value.

The final priority is obtained from the relationship between the criteria and the alternatives that have been described by the ANP model in the Figure 3. The following are the final priorities for choosing a strategy for implementing sustainable agriculture based on good agricultural practices:

**Table 3.**
Results of comparative analysis of all criteria and sub-criteria.

| No | Criteria | Sub Criteria | Normalized by cluster | Limiting |
|---|---|---|---|---|
| 1 | Sustainable land management | Use of land cover | 0.3360 | 0.0663 |
| | | No-till land management | 0.2253 | 0.0445 |
| | | Crop Rotation | 0.4385 | 0.0865 |
| 2 | Efficient water management | Prevention of water pollution | 0.2422 | 0.0388 |
| | | Improved water resources management | 0.3463 | 0.0555 |
| | | Water saving irrigation | 0.4113 | 0.0660 |
| 3 | Biodiversity conservation | Plant various types of plants | 0.2592 | 0.0230 |
| | | Maintain wild vegetation | 0.3246 | 0.0288 |
| | | Implement intercropping | 0.4161 | 0.0370 |
| 4 | Chemical reduction | Use of organic pesticides | 0.1763 | 0.0286 |
| | | Use of biological fertilizer | 0.2562 | 0.0416 |
| | | Integrated pest management | 0.2076 | 0.0337 |
| | | Reduction of chemical fertilizers and pesticides | 0.3597 | 0.0584 |
| 5 | Increasing the Social and Economic Welfare of Farmers | Promote fair trade | 0.2216 | 0.0199 |
| | | Improving decent working conditions | 0.3192 | 0.0287 |
| | | Increased access to education and technology | 0.4591 | 0.0412 |
| 6 | Climate change adaptation and mitigation | Weather forecast when planting | 0.1300 | 0.0391 |
| | | Crop diversification | 0.1487 | 0.0447 |
| | | Reduce greenhouse gas emissions | 0.2256 | 0.0678 |
| | | Choose plant varieties that are resistant to extreme weather | 0.4956 | 0.1490 |

From Table 2, it can be seen the strategic priorities for implementing sustainable agriculture based on good agricultural practices. Where the priorities chosen above are strategies that have been determined by the key person, in this case a person who understands their field, which is processed through the super decision application to obtain a strategy for implementing sustainable agriculture based on good agricultural practices. The results of this priority are from all sub-criteria elements, so the most prioritized isChoose extreme weather resistant plant varieties with a limiting value of 14.9%. The second priority isCrop Rotationwith a limiting value of 8.6%. Meanwhile, the final priority isPromote fair trade with a limiting value of 1.9%.

## 5. Discussion

Sustainable agricultural management by implementing Good Agricultural Practice (GAP) is an important strategy to overcome the impacts of climate change, especially in agricultural areas such as Kopeng Village. One of the key elements of GAP is sustainable land management. By using techniques such as crop rotation, use of organic fertilizers, and soil conservation practices, soil fertility can be maintained and erosion can be reduced. Effective land management ensures agricultural productivity remains high without damaging local ecosystems, so that land can continue to be used productively in the long term. Apart from that, efficiency in water management is also an important component in GAP. By utilizing drip irrigation systems and rainwater collection techniques, water needs for agriculture can be met without excessively depleting water resources. This efficient use of water not only saves water resources but also helps plants grow better amidst increasingly uncertain weather conditions due to climate change [9].

Biodiversity conservation is also very important. By maintaining and increasing biodiversity on agricultural land, the risk of pest and disease attacks can be minimized naturally. This supports a more balanced and resilient ecosystem, as well as providing habitat for various species that play a role in pollination and natural pest control. Reducing the use of chemicals such as pesticides and synthetic fertilizers is also part of the GAP [7, 8]. By switching to biological pesticides and organic fertilizers, negative impacts on the environment can be reduced. This practice not only maintains healthy soil and water but also reduces health risks for farmers and consumers, and helps maintain ecosystem balance.

The implementation of GAP also contributes to improving the social and economic welfare of farmers. With more consistent and sustainable harvest results, farmers' income can increase. The education and training provided as part of GAP implementation also increases farmers' capacity and knowledge, making them more adaptive and able to face the challenges of climate change. Climate change adaptation and mitigation through GAP in Kopeng Village also includes specific actions such as selecting plant varieties that are resistant to extreme conditions, planting protective trees, and integrated land management [4-6]. This strategy not only helps farmers adapt to climate change, but also reduces greenhouse gas emissions from the agricultural sector, which ultimately helps mitigate climate change.

Overall, the implementation of GAP-based sustainable agriculture in Kopeng Village shows how the integration of various aspects such as managing land, water, biodiversity, reducing chemicals, and increasing the socio-economic welfare of farmers can be an effective strategy in dealing with the impacts of climate change. By implementing these practices, agriculture in Kopeng Village will not only become more productive and sustainable, but also more resilient to climate change, maintain ecosystem balance, and improve the quality of life of local farmers.

## 6. Conclusion

Based on the results and discussion, it can be concluded that the Sustainable Agriculture Implementation Model Based on Good Agricultural Practice as a Strategy for Adapting to the Impact of Climate Change in Kopeng Village requires attention to six criteria, including sustainable land management, efficient use of water, conservation of biodiversity, reduction in the use of chemicals, increasing the socio-economic welfare of farmers, adapting and mitigating climate change. The most prioritized criterion is sustainable land management. In the criteria for sustainable land management, there are three sub-criteria, including Crop Rotation, No-till land management and Use of land cover. Of the three sub-criteria, the sub-criteria that is most prioritized in the criteria for sustainable land management is crop rotation. When carrying out crop rotation, farmers need to choose plants according to the prevailing weather so as to reduce the risk of crop failure. Crop rotation needs to be done to maintain land quality and fertility. This research has limitations in the form of a research location that focuses on only one area so that further research is expected to expand the research location for comparison.

## Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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