Identification of Technical Practices for Climate-Smart Agriculture (CSA) in Indonesia: A Case Study in the Sukabumi Regency, West Java

Output 2 – Identify Technologies to Support the Identification of Water Content and Soil Chemistry on Agricultural Land

Technology Feasibility Analysis Report

D2.2.1

United Nations Environment
Programme (UNEP)

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1 Introduction

Effective implementation of climate-smart agriculture (CSA) technology depends on timely and precise information about soil conditions, including moisture and chemical composition. Accurate soil moisture data is crucial for efficient irrigation management, reducing water waste, and mitigating drought impacts. Additionally, soil chemical information can guide the precise application of fertilisers, promoting nutrient efficiency and reducing environmental impacts.

CSA in agroforestry system have been found to be beneficial. For example, farmers in the Lower Nyando valleys of Kenya benefit from improved cultivated cash crops in between rows of multi-purpose trees, thereby improving soil stability and enrichment when adopting knowledge of Information and Communication Technology (ICT) (Adesipo et al., 2020). Since there was an increase demand for trees, several nurseries were developed, adding farmers' incomes and women as the main beneficiaries.

Nowadays, the varieties of smart technologies adopted in agriculture are biosensors, agricultural drones, IoT, and Blockchain-based sensors (Adesipo et al., 2020). Biosensors with extremely small structures were found to be able to help in crop maturity evaluation, management of the amount of pesticides and fertilisers used, and detection of humidity levels in soils for effective irrigation (Adesipo et al., 2020). However, the most recent survey conducted by the U.S. Department of Agriculture shows that soil moisture sensors are utilized in only 12% of farms (Taghvaeian et al., 2021).

Several soil moisture sensing technologies have been proposed to help farmers achieve these objectives. These include on-site implanted sensors, remote sensing, Unmanned Aerial Vehicle (UAV) based sensors, and a combination of these technologies. These soil moisture sensors vary significantly in their working principles, costs, advantages, disadvantages, and suitability for different farm sizes and conditions. However, the adoption of these technologies in Indonesian agriculture has been limited, potentially due to various technical, economic, and social barriers.

1.1 Scope of Analysis

This document presents the feasibility analysis of soil moisture sensing technologies for their potential application in climate-smart agriculture (CSA) practices in Indonesia. The study identified the challenges and bottlenecks in adopting these technologies, and prioritized them based on several consideration cost, ease of use, and potential impact on CSA practices.

The adoption of soil moisture sensing technologies may possibly help farmers to improve their yields, reduce their water usage, and increase their resilience to climate change. However, there are several challenges and bottlenecks to the adoption of these technologies, including high costs, lack of awareness, and inadequate infrastructure.

1.2 Selected Geographical Location – the Sukabumi Regency in West Java, Indonesia

West Java is one of the provinces in Indonesia that holds great potential in the development of its natural resources. With a large population, ample quality infrastructure, and a variety of sectors to develop, West Java offers compelling development opportunities for many parties. It boasts a rapidly growing industrial sector, encompassing areas such as manufacturing, textiles, food, and other agricultural products.

West Java has a diverse topography, ranging from lowlands to mountains. Hilly areas sprawl across the central region, while the southern part of West Java is dominated by mountain ranges, including the Pangrango, Gede, and Ciremai mountains. Lowlands are located along the northern coast, such as the Indramayu, Subang, and Karawang regencies. This diversity allows for a variety of natural resource development opportunities, for instance, in agricultural businesses. The topographical variety also facilitates the diversity of commodities, ranging from rice, vegetables, fruits, as well as plantation commodities such as tea, coffee, and coconuts.

Farming activities in West Java encounter several challenges, such as water availability, labour force from the younger generation, gender inequality in access and control to farming resources, and financial access. The prolonged dry season and the varying rainfall patterns in West Java make the irrigation program very important. Some irrigation areas in West Java require infrastructure improvements such as damaged irrigation channels, less effective water control buildings, and suboptimal flood control systems. Proper maintenance and operation of the irrigation areas are key to ensuring optimal water distribution and adequate water availability for agricultural activities.

2 Description of Technologies

Feasibility analysis will be conducted for 4 identified technology categories. The technologies in question are explained in general below.

2.1 On-Site Implanted Sensors

On-site implanted sensors are placed directly in the soil to measure soil properties. These sensors can provide high-resolution data but can be challenging to install. Site-implanted sensors are inserted directly into the soil and provide real-time, accurate readings of soil moisture levels.

- Advantages:
  - On-site implanted sensors offer precise, localised data and are often easy to install and use.
  - This technology is typically durable and can function effectively for several years without requiring extensive maintenance.
- Disadvantages:
  - On-site implanted sensors may only provide data for a limited area, requiring multiple sensors for larger fields.
  - May also need manual reading or data extraction, which can be labour intensive.
  - Some sensors may need additional infrastructure for data transmission to a centralised system.

2.2 Remote Sensing

Remote sensing satellites collect soil data from space. These sensors can provide large-scale data but may not be as accurate as data collected from on-site implanted sensors or UAVs. Remote sensing technology capture and analyse reflections or emissions of electromagnetic radiation from the soil surface to determine soil moisture levels.

- Advantages:
  - Remote sensing technology provides comprehensive coverage, making it suitable for monitoring large fields or regions.
  - It can give a broad view of soil conditions without the need for physical contact with the soil.
- Disadvantages:
  - Remote sensing data may lack the precision of on-site implanted sensors.
  - It can be influenced by factors like plant cover, topography, or soil surface roughness.

  - Additionally, acquiring and interpreting remote sensing data can require sophisticated technology and expert knowledge.

2.3 UAV-Based Sensors

Unmanned aerial vehicle (UAV)-based sensors are mounted on drones or other small aircraft to collect soil data from above. These sensors can collect data over a limited area. UAV-based sensors involve the use of drones equipped with sensors to monitor soil conditions.

- Advantages:
  - UAV-based sensors can cover large areas more quickly than on-site implanted sensors, while providing more detailed data than remote sensing technologies.
  - They can be programmed to fly over fields at set intervals, providing regular, timely data.
- Disadvantages:
  - Regulatory constraints on drone usage could pose challenges.
  - Furthermore, the initial cost of purchasing and operating a drone can be high.
  - Analysis of data gathered from UAVs can also be complex, requiring specialist knowledge.

2.4 Combination of Technologies

Combination systems combine data from multiple sensors to provide a more comprehensive view of soil conditions. These systems can be the most expensive, but they can also provide the most accurate data. A combination of the above technologies attempts to leverage the strengths of each while mitigating their individual limitations.

- Advantages:
  - This approach can provide comprehensive, high-resolution data over large areas.
  - It can combine the precision of site-implanted sensors with broad coverage of remote sensing and UAV-based sensors.
- Disadvantages:
  - The main challenge of using combination technologies is the need for complex data integration and analysis.
  - It can also be the most expensive approach due to the investment in multiple types of technology.
  - Furthermore, managing and maintaining multiple systems can require significant resources and technical expertise.

3 Methodology

The feasibility study follows a systematic methodology to evaluate and prioritise soil moisture sensor technologies, specifically on-site implanted sensor, remote sensing, UAV technology, and a combination of these methods. The approach leverages a thorough gap and barrier analysis for each technology, which then influences the scoring and prioritisation process.

1. **Identification of Gap and Barrier:**
   - The first step involves the identification of potential gaps and barriers that might affect the implementation of each technology in the context of Indonesian climate-smart agriculture.
   - These gaps and barriers, drawn from literatures, expert opinion, and past experiences, cover a wide spectrum, including issues related to technical, economical, accessibility, adaptability, and social acceptance.
2. **Construction of Scoring Instrument:**
   - After the gaps and barriers are identified, scoring instrument is constructed. This instrument is based on a Likert Scale, an effective psychometric tool for measuring attitudes and perceptions. Likert scales provide a range of response options, typically from strongly disagree to strongly agree, allowing participants to express their opinions or perceptions on a given technology or technology-related question. In the context of CSA, implementing a Likert scale assessment can aid in determining the priority of different technologies
   - Each identified gap and barrier are translated into a corresponding question or statement, to which responses, the opinions or perceptions, on a given technology are to be provided on a scale ranging from "Strongly Agree" (Score = 5 or 10) to "Strongly Disagree" (Score = 1).
3. **Scoring of Products:**
   - With the scoring instrument, a scoring process on each technology listed in the catalogue is performed.
   - The scoring process is then carried out by a team of experts and the resultant scores provide a quantitative reflection of the extent to which each technology could potentially overcome or be impeded by the gaps and barriers.
   - The technologies are then preliminarily prioritised based on their aggregate scores, with higher scores indicating a more favourable standing in terms of feasibility and lower anticipated resistance in implementation. First, the four categories are evaluated and then followed by the products on the catalogue. Statistical and descriptive analyses were used to analyse the data.

The methodology is comprehensive and robust but has its limitations and assumptions. For instance, the expert opinions are assumed to accurately represent the potential users of the technologies and that the scoring process is free from bias. Also, due to the nature of this study, some technological nuances might have been overlooked.

3.1 Likert Scale Scoring Instrument

In determining the scoring, this study uses a Likert Scale analysis. According to Sugiyono (1997), the Likert Scale is a measurement scale given a gradation of weighting from positive to negative values. The Likert Scale is used to measure attitudes, opinions, and perceptions of a group or an individual about social phenomena, which are subsequently referred to as research variables.

In this Likert Scale analysis, the variable to be measured is described into dimensions, the dimensions are then broken down into sub-variables, and the sub-variables are further broken down into measurable indicators. Finally, these measurable indicators can be used as a starting point to create instrument items in the form of questions or statements that need to be answered by respondents. Each answer is associated with a form of statement or attitude support expressed in words as follows:

- Strongly Agree (SA) = 5
- Agree (A) = 4
- Neutral = 3
- Disagree (D) = 2
- Strongly Disagree (SD) = 1

The descriptive analysis used is a percentage descriptive analysis. In this analysis, all scores from each aspect are summed and compared to their ideal score, thus obtaining a percentage score. From this percentage description, it is then compared with the criteria used and the level is determined.

Because the highest score for each score is 5 and the lowest score is 1, it can be calculated:

- Maximum percentage = 100% = 100%
- Minimum percentage = 100% = 20%
- Range = 100% - 20% = 80%
- Interval length = 80%: 3 = 16%

With an interval length of 16% and a minimum percentage of 20%, levels are obtained as shown in Table 3.1.

Table 3.1 Percentage descriptive table

No.	Percentage Interval	Description
1	84% - 100%	Very High
2	68% - 84%	High
3	52% - 68%	Medium
4	36% - 52%	Low
5	20% - 36%	Very Low

This criterion is used for each aspect and indicator in the study, due to the large number of items used and the differences between each aspect and indicator. The percentage score is obtained by comparing the total score with its ideal score. The ideal score is determined from the number of items multiplied by the ideal score of 5 and then multiplied by the percentage.

3.2 Hierarchical Cluster Analysis (HCA)

Hierarchical cluster analysis (HCA) is a method of cluster analysis that seeks to build a hierarchy of clusters from a data set. It can be done in two ways: agglomerative or divisive. Agglomerative clustering starts with each observation in its own cluster and then merges the most similar clusters until all observations are in one cluster. Divisive clustering starts with all observations in one cluster and then splits the most dissimilar clusters until each observation is in its own cluster. The result of HCA is usually presented in a dendrogram which is a tree diagram that shows the nested grouping of clusters and their distances (Tullis & Albert, 2013). HCA can use any valid measure of distance between observations, such as the Euclidean distance, and a linkage criterion, which specifies how to measure the dissimilarity between clusters based on the pairwise distances of observations. HCA is an exploratory tool that can reveal natural groupings within a data set that would otherwise not be apparent (*Hierarchical Cluster Analysis - IBM Documentation*, n.d.).

The use of this method can be found in various studies, for example in the identification of subgroups in bilingual samples by examining various language variables (Yim & Ramdeen, 2015). This analysis method is also compared with various other algorithms such as K-Medoids, K-Means, Farthest First and DBSCAN in analysing a data set (Gulagiz & Suhap, 2017). In another study, this method gave better clustering results when combined with K-Means, compared to using only K-Means (Alfina & Santosa, 2012).

Incorporating gap and barriers into sensor prioritisation using hierarchical cluster analysis would involve considering these barriers as part of the characteristics or variables defining each sensor. The general approach consists of:

- Variables Definition including Gaps and Barriers
- Data Collection
- Data Pre-processing
- Conduct Hierarchical Clustering
- Evaluate the Dendrogram
- Interpret the Clusters
- Prioritise

4 Results and Discussion

4.1 Identification of Gaps and Barriers

There are several gaps and barriers to the implementation of soil moisture and chemical sensing technology in Indonesia. These gaps and barriers are described below:

1. Financial Constraints:
   - The cost of acquiring and maintaining these technologies could be prohibitive, particularly for small-scale farmers.
   - There may also be limited access to financing or credit facilities.
   - High cost of getting score 1, low cost of getting score 5
2. Infrastructure Challenges:
   - The requisite infrastructure may not be adequately available.
   - This includes everything from the availability of reliable power sources to the need for secure data storage and processing facilities, especially in remote areas.
   - Complex infrastructure requirements get score 1, while hardly requiring dedicated infrastructure get score 5
3. Human Resource and Skill Gaps:
   - There may be a lack of trained professionals who can operate these technologies, analyse the data they produce, and translate it into actionable farming strategies.
   - This gap extends from the farmers themselves to agricultural extension workers and related professionals.
   - The need for trained human resources gets score 1, while technology that does not require specialized human resources gets score 5
4. Regulatory barriers:
   - There may be regulatory restrictions or lack of clear guidelines related to the use of certain technologies, particularly in the case of UAVs.
   - If it is related and there are regulations that limit the product, or require the support of legal aspects, then the score is 1, while if it does not require the legality aspect, then the score is 5
5. Market Gaps:
   - There may be a lack of effective supply chains and markets for the technologies in question, especially in more remote or less developed regions of Indonesia.
   - If the availability of the product in the market is difficult, then the score is 0. If it is easy to get anywhere, then the score is 5
6. Technological capacity:
   - There may be a gap in local technological capacity required for the use, maintenance, and interpretation of these technologies.
   - This includes both hardware (like drones or remote sensors) and software (for data analysis). It is related also to number of literature and information available.
   - If there is little literature and operating instructions, as well as success stories, then the score is 1.
7. Knowledge and Awareness barriers:
   - Some regions might be dominated by low educatiion level, and then it is difficult to accept new technology.

- Some regions might be dominated by careless society due to low income and education level
- If the society is dominated by low education that does not care about technology, then the score is 1. Meanwhile, if the community is accustomed to the application of technology, then the score is 5.

8 Socio-Cultural Barriers:
   - Farmers may be resistant to adopting new technologies due to traditional farming practices, a lack of trust in new technology, or perceived complexity of use.
   - The diverse geography and climate of Indonesia related to socio cultural can pose unique challenges.
   - If people tend to avoid applying technology due to customary influences or low income, then the score is low (1).

Addressing these gaps and barriers requires a comprehensive approach involving governmental policy support, investment in infrastructure, capacity building, public education, and collaboration with technology providers and relevant stakeholders.

4.1.1 On-Site Implanted Sensors

The use of on-site implanted sensors in Indonesia faces several regulatory challenges. There is currently a lack of clear guidelines regarding the usage and installation of these sensors. Regulation may also lag in terms of data privacy and security. This could make it difficult for farmers and other users to adopt this technology.

Another challenge to the use of field-implanted sensors in Indonesia is the lack of reliable infrastructure. In some areas, there may be limited availability of power or internet access, which could make it difficult to operate and maintain these sensors. Additionally, the diverse topography of Indonesia could pose challenges for the uniform installation and operation of these sensors.

The cost of acquiring, installing, and maintaining field-implanted sensors can be high, particularly for small-scale farmers. Additionally, there may be a lack of trained professionals who can interpret the data from these sensors into actionable farming insights. This could make it difficult for farmers to benefit from this technology.

In addition to the challenges mentioned above, there are also cultural and market barriers to the adoption of field-implanted sensors in Indonesia. Farmers may be hesitant to adopt this new technology due to a lack of trust or perceived complexity of use. Additionally, there might be a lack of robust supply chains for these sensors, especially in less developed or remote regions.

4.1.2 Remote Sensing

Remote sensing is a powerful tool that can be used to collect data about the Earth's surface. However, there are several regulatory challenges associated with this technology. Like UAVs, there might be regulatory concerns regarding data privacy and usage rights. These concerns could make it difficult to obtain licenses to operate remote sensing equipment and to collect and use data.

Another challenge to the use of remote sensing is the need for robust data storage and processing infrastructure. The massive amounts of data generated by remote sensing can be difficult and expensive to store and process. This could limit the number of organizations that are able to use.

The cost of acquiring, operating, and maintaining remote sensing equipment can be high. Additionally, there may be a lack of trained professionals who can interpret the data from these sensors. This could make it difficult for organizations to benefit from this technology.

In addition to the challenges mentioned above, there are also cultural and market barriers to the adoption of remote sensing. There may be resistance to the adoption of this technology due to a lack of understanding of its benefits. Additionally, the market for remote sensing data and services may be underdeveloped, particularly in remote or less developed regions.

4.1.3 UAV-based Sensors

The use of UAVs (unmanned aerial vehicles), or drones, is typically more heavily regulated than other technologies. There may be restrictions related to flying zones, altitude, and privacy considerations. These restrictions can make it difficult to obtain the necessary permits and approvals to operate drones in Indonesia.

Another challenge to the use of drones in Indonesia is the need for secure and robust data storage and processing facilities. Drones generate substantial amounts of data, which can be difficult and expensive to store and process. This could limit the number of organizations that are able to use this technology.

The cost of acquiring, operating, and maintaining drones can be high. Additionally, there may be a lack of trained professionals who can operate and maintain drones, and who can analyse the data they generate. This could make it difficult for organizations to benefit from this technology.

In addition to the challenges mentioned above, there are also cultural and market barriers to the adoption of drones in Indonesia. There may be resistance from farmers and communities due to privacy concerns or a lack of understanding about the benefits of this technology. Additionally, the market for drones and related services might be limited, particularly in more remote or less developed regions of Indonesia.

4.1.4 Combination of Technologies

This approach combines the advantages and the challenges of all three technologies listed above. A more integrated and comprehensive approach is needed to implement this.

4.1.5 Summary

The criteria for scoring were also constructed for the scoring of each product listed in the catalogue. There are 17 criteria that related to the 8 gaps and barriers above. Here is the description of each evaluation criterion that can be used to prioritize soil moisture sensing technology products as listed on catalogue:

1 **Availability**: Evaluates how readily available the sensor is. Is the sensor always in stock (Score = 5) or does it need to be pre-ordered (Score = 0)?

2 **Price**: Determines the affordability of the sensor. Price ranges can be from IDR 100,000 (Score = 5) to IDR 30,000,000 (Score = 0) per sensor.

3 **Installation**: Evaluates the level of difficulty in installing the sensor. Is the sensor ready to use (Score = 5) or does it need to be assembled / installed in the field (Score = 0)?

4 **Operation**: Assesses the level of difficulty in using the sensor. Is it sufficient to read the instructions (Score = 5) or is analysis/telemetry required (Score = 0)?

5 **Maintenance**: Evaluates the degree of maintenance required by the sensor, from no maintenance required at all (Score = 5) to needing to maintain the surrounding environment (Score = 0).

6 **Mobilization**: Assesses how easily the sensor can be moved, from being small in size and easy to carry (Score = 5) to being heavy and large (Score = 0).

7 **References**: Evaluates how much reference or information is available about the sensor, ift it is al lot of refference the Score = 5, and if it is difficult to find reference, the score should be 0

8 **Security**: Evaluates the sensor's security system, whether it's integrated (Score = 5) or requires additional infrastructure (Score = 0).

9 **Precision**: Evaluates how precisely the sensor can measure, from a small (Score = 5) to a large scale (Score = 0).

10 **Accuracy**: Evaluates how accurate the sensor's measurements are, from small (Score = 5) to large errors (Score = 0).

11 **Durability**: Evaluates the effective life of the sensor, which can range from 1 (Score = 0) to 5 (Score = 5) years.

12 **Integration Flexibility**: Evaluates how easily the sensor can be integrated with other systems, whether it's easy to integrate (Score = 5) or can only be used with the same brand (Score = 0).

13 **Geographical Suitability**: Evaluates how well the sensor fits with geographical conditions, from broad (Score = 5) to specific (Score = 0).

14 **Familiarity**: Evaluates how familiar the technology is, from field technology (Score = 5) to wireless technology (Score = 0).

15 **Infrastructure Requirements**: Evaluates the additional infrastructure requirements such as electricity, buildings, and ICT. If it need additional infrastructure, Score = 0. While if it is no need of additipnal infrastructure, the score will be 5.

16 **Human Resources Requirement**: Evaluates the level of expertise required to use the sensor, from regular workers (Score = 5) to specialist graduates (Score = 0). It should provide gender equality for women and men farmers as human resources in agriculture to have calculation skills of water needs. While using the sensor application, the farmer will utilize his skills to decide on the final amount of irrigation water to be applied and should search within the range provided in the app (Development Asia, 2020). The ADB pilot and demonstration activity have shown that current irrigation applications could be reduced by 33% (Development Asia, 2020). Instead of irrigating every day, the pivots at the KyzylSha farm are now irrigated 2 out of 3 days. Pivot is a crop irrigation method in which the equipment rotates around a pivot, and crops are watered with sprinklersWomen farmers can optimise their time allocation to improve their capacity in other social and economic activities when sensor technologies allow women to have extended hours than managing the irrigation water. By

strengthening women capacity to use the sensor through many trainings can significantly decreasing the gender inequality in human resources between men and women to access and control the farming facilities.

17 **Income increment probability**: it is related to financial analysis. If there are no income increment the score = 0, and if it increase the income then the score should be 5.

4.2 Scoring

A two-step scoring was conducted, first for the four technologies, with gap and barriers mentioned in the previous section. A peer group was asked to rate 4 technology categories based on the 8 gaps and barriers described earlier. The score obtained is recapitulated for each technology vs. gaps and barriers. The second is by using parameters related to each product in the catalogue that probably affect its implementation. The peer group was asked to assess the list of products from the catalog presented in the previous report. The score of the assessment results is recapitulated for each product vs criterion. The scoring is shown in Table 4.1 for 4 category of technology and Table 4.2 for the products in the catalogue.

The scoring against gaps and barriers mentioned above are shown in Table 4.2. The average scores for each technology shown that field implanted sensor technology is most preferable to be implemented with the highest average score, and UAV is the most challenging to be implemented. Less awareness about and regulatory restriction may be the cause of the low score for drones because drones are sophisticated technology, requiring compliance with the applicable regulations and skills to control them.

The second scoring of the product showed that field-implanted sensors with the name of 5TE by Meter Group and the sensors made by Campbell had the highest scores. The two brands are well-known and target different user segments or price points. However, they are not easily integrated with other systems without using their own production devices. Combination products have the lowest scores because combining three other technological approaches requires additional investment, operating, and maintenance costs. Nevertheless, combining technologies can solve problems that arise when only one type of technology is used.

Table 4.1 Scores for the four categories of technology against gaps and barriers

No	Technology	Financial Constraints Score (1-5)	Infrastructure Constraints Score (1-5)	Human Resource Limitations Score (1-5)	Legal and Regulatory Hurdles Score (1-5)	Limited Market Access Score (1-5)	Technological Constraints Score (1-5)	Lack of Knowledge and Awareness Score (1-5)	Socio-cultural Factors Score (1-5)	Average
1	Site Implanted Sensor	4.7	4.5	4.3	5.0	5.0	4.7	4.3	3.7	4.5
2	Remote Sensing	4.0	3.7	3.7	3.3	4.0	4.0	3.0	3.7	3.7
3	UAV Based Sensor	3.0	3.2	3.3	3.3	3.7	4.0	3.0	4.0	3.4
4	Combination	3.3	3.3	3.3	4.0	3.3	4.0	3.0	3.7	3.5

Table 4.2 Scores for the products on the catalogue

No	Product	Availability	Price	Installation	Operation	Maintenance	Mobilisation	References	Security	Precision	Accuracy	Durability	Integration Flexibility	Geographical Suitability	Familiarity	Infrastructure Requirements	Human Resources Requirement	Income increment probability	Average
1	METER 5TE	10.0	9.3	10.0	10.0	8.7	9.3	9.7	9.0	9.5	9.3	8.0	7.0	8.0	8.5	10.0	9.5	9.0	9.1
2	SENTEK SDI-12 SERIES II Probe	9.7	6.3	8.7	9.7	8.0	9.0	9.3	8.7	9.3	9.7	8.0	6.5	8.0	7.5	9.3	9.0	9.0	8.6
3	AquaCheck Sub-Surface	8.3	7.0	8.0	9.5	8.5	9.5	10.0	9.5	10.0	9.5	8.0	6.0	8.0	8.0	10.0	10.0	9.0	8.8
4	Delta-T PR	9.0	6.5	8.5	9.0	8.5	10.0	10.0	9.0	10.0	9.5	8.0	6.0	8.0	9.0	10.0	10.0	9.0	8.8
5	Jingxunchangtong (JX IoT) Soil analyzer-5 in	9.3	9.0	9.5	9.5	9.5	10.0	9.0	9.5	8.0	8.5	7.0	9.0	8.0	8.0	10.0	10.0	9.0	9.0
6	Campbell CS655	9.3	7.5	9.0	9.0	9.0	10.0	10.0	9.0	10.0	9.5	9.0	9.0	8.0	8.0	10.0	10.0	9.0	9.1
7	The RiTx Jinawi sensor	9.0	8.0	9.5	10.0	9.5	10.0	9.0	10.0	8.0	9.0	7.0	8.0	8.0	8.0	10.0	10.0	9.0	8.9
8	Soil Moisture and Ocean Salinity (SMOS)	9.5	6.5	7.5	8.0	10.0	9.5	9.0	10.0	7.5	8.5	10.0	8.5	8.0	6.5	9.0	6.5	8.0	8.4
9	Sentinel-2	9.5	6.5	7.0	8.0	10.0	9.5	9.0	10.0	8.0	8.5	10.0	8.5	8.0	6.5	8.0	6.5	8.0	8.3
10	Landsat - 8	9.5	7.5	7.5	8.0	10.0	9.5	9.0	10.0	7.5	8.5	10.0	8.5	7.5	7.0	8.5	7.0	8.0	8.4
11	Landsat - 9	9.5	7.5	7.5	8.0	10.0	9.5	9.0	10.0	8.0	8.5	10.0	8.5	7.5	7.0	8.5	7.0	8.0	8.5
12	Sentinel - 1	8.5	6.5	7.0	8.0	10.0	9.5	9.0	10.0	8.5	8.5	10.0	8.5	9.0	6.5	8.0	6.5	8.0	8.4
13	Sentinel - 3	8.5	6.5	7.0	8.0	10.0	9.5	9.0	10.0	8.5	8.5	10.0	8.5	8.5	6.5	8.0	6.5	8.0	8.3
14	ASCAT	6.5	6.5	7.0	8.0	10.0	9.5	9.0	10.0	8.0	8.5	10.0	8.5	8.0	6.0	8.0	6.5	8.0	8.1
15	MODIS	7.5	6.0	7.0	8.0	10.0	9.5	9.0	10.0	7.5	8.5	10.0	8.5	8.0	6.0	8.0	6.5	8.0	8.1
16	SMAP	7.5	6.0	7.0	8.0	10.0	9.5	9.0	10.0	8.0	8.5	10.0	8.5	8.0	6.0	8.0	6.5	8.0	8.1
17	Dove CubeSats	7.0	5.0	7.0	8.5	8.5	10.0	8.0	8.0	9.0	8.5	10.0	8.5	8.5	5.5	8.0	6.5	8.0	7.9
18	DJI Phantom 4 RTK with Sentera 6X Multispectral Senso	9.5	7.0	6.5		7.5	9.5	8.0	8.0	9.0	9.0	7.5	6.5	9.0	7.0	9.0	6.5	9.0	8.0
19	Parrot Bluegrass Fields with Parrot Sequoia Multispectral Sensor	8.5	7.0	6.0	8.5	7.0	9.5	8.0	8.0	9.0	9.0	7.5	6.5	9.0	6.5	9.0	6.5	9.0	7.9
20	senseFly eBee X with MicaSense RedEdge-M	8.5	6.5	6.0	8.5	7.0		8.0	8.0	9.0	9.0	7.5	6.5	9.0	6.5	9.0	6.5	9.0	7.8

No	Product	Availability	Price	Installation	Operation	Maintenance	Mobilisation	References	Security	Precision	Accuracy	Durability	Integration Flexibility	Geographical Suitability	Familiarity	Infrastructure Requirements	Human Resources Requirement	Income increment probability	Average
21	Integrated Soil Monitoring System	7.5		5.5		6.0	7.5	7.5	7.5	8.5	9.0	7.5	8.0	8.0	6.0	8.0	6.5	9.0	7.5
22	Precision Agriculture Solution	7.5	6.0	5.5	7.5	6.0	7.5	7.5	7.5	8.5	9.0	7.5	8.0	8.0	6.0	8.0	6.5	9.0	7.4
23	Comprehensive Soil and Crop Health Management System	7.5	6.0	5.5	7.5	6.0	7.5	7.5		8.5	9.0	7.5	8.0	8.0	6.0	8.0	6.5	9.0	7.4

4.3 Prioritisation of Technologies

The technology prioritised for use is determined based on HCA. The HCA results for the technologies in Table 4.2Tabel 4.1 are depicted in the dendrogram in Figure 4.1, the y-axis shows the four technology groups. On-site implanted sensor technology has the first hierarchy, which can be perceived as the first priority, since it is very far distance to consider it as the same cluster with other technology.The next priority is Remote sensing technology, UAV, and then combination technology, as showed at Tabel 1..

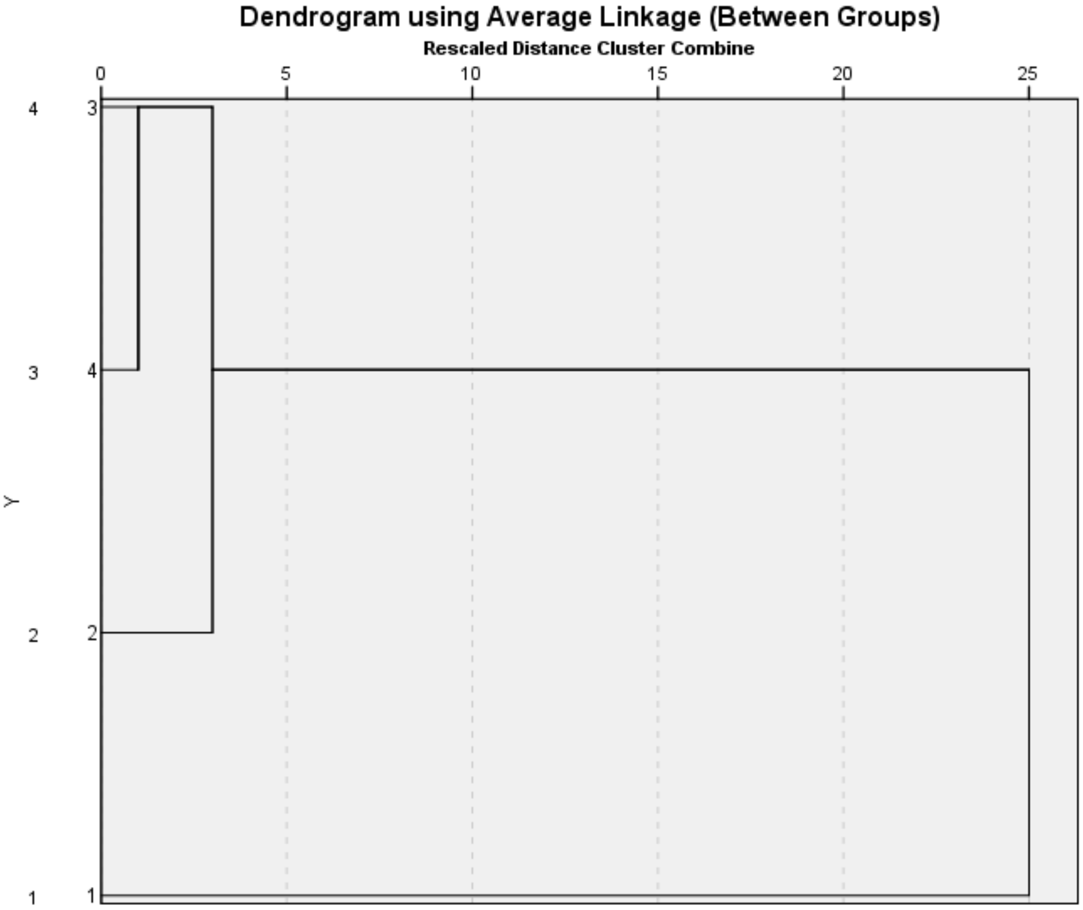

Figure 4.1 Dendrogram resulted from Hierarchical Analysis on Technologies on Table 4.1

The HCA results for the products in the catalogue in Table 4.2 are depicted in the dendrogram in Figure 4.2, the y-axis shows 20 technology products. At a distance of 25, there are two clusters where Cluster 1 members consist of site implemented sensor products, and other technologies are members of Cluster 2. Products no. 2 (SENTEK SENSOR PROBE) and 6 (CS655) get the highest hierarchy, which can be perceived as priority products. In Cluster 2, products no. 22 (combined technology Precision Agriculture Solution) and 17 (Dove CubeSats satellite service) are perceived as priority products.

This approach can be repeated when there are new technologies or products that will be introduced and studied for application. To do so, peer scoring must be done again for new technology or products. Scoring can be redone for all of the technologies and products and not just for the new items, if needed. HCA can be done quickly by utilizing statistical software that is available and has been commonly used. To perform this supervision from expert is advised.

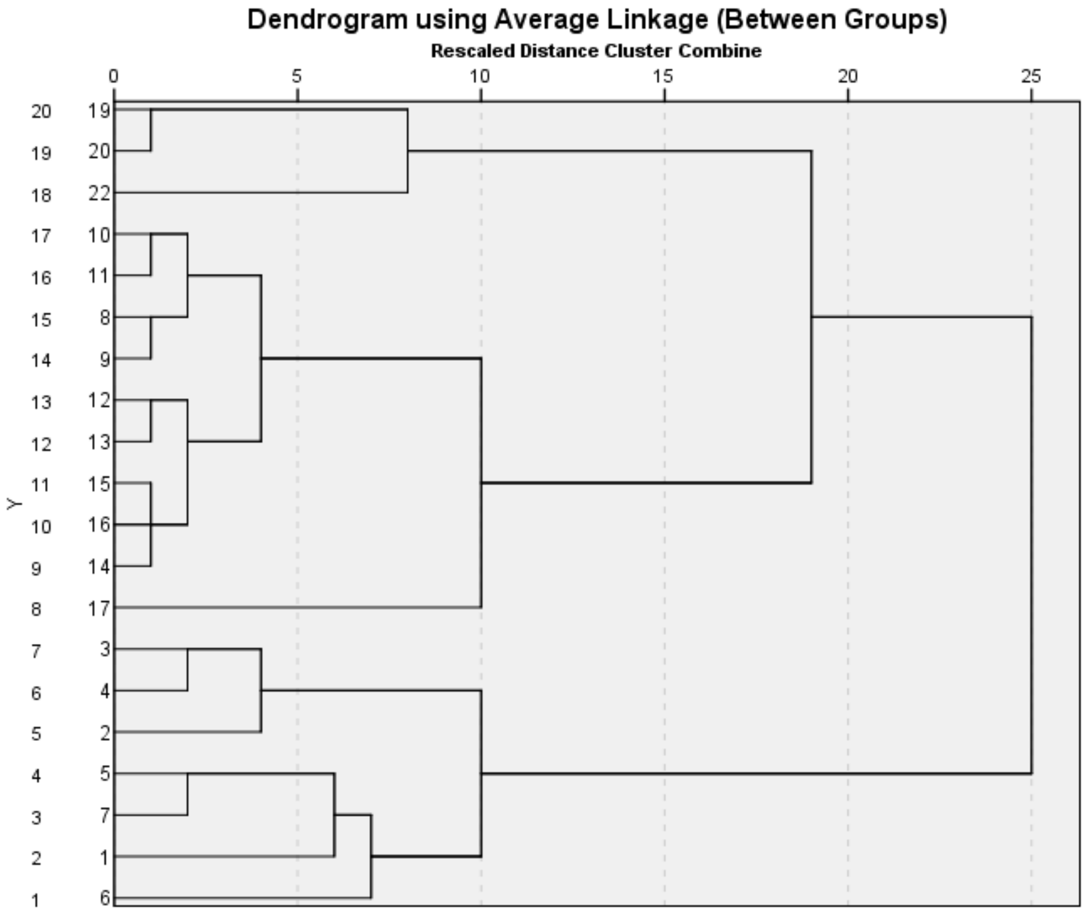

Figure 4.2 Dendrogram resulted from Hierarchical Analysis on Technologies on Table 4.2

5 Recommendations

Based on the analysis conducted, it was found that the priority technology is on-site implanted sensor. Likewise, the products that considered priority were products within this group. Consequently, the recommended technology to be designed are as follows:

1 Using on-site implanted sensor as the main part, with product priority from brands that have the highest average score or highest hierarchy, namely:

   - 5TE sensor from Meter Group;
   - CS655 sensor from Campbell; and
   - SENTEK Probe sensor.

2 Other technologies such as remote sensing and UAV can be designed as additional technologies.

3 The technology designed can use field implanted sensor as the main approach, then equipped with a UAV system and a remote sensing system in a decision support system.

4 The technology product that will be used can be from outside the brand that has been presented, by paying attention to the technical specifications and other factors that are used in this analysis.

5 Technology offer equals opportunity for women and men to access and control in the farming activities. It can be reached through a training and affirmative action in women selection as the worker

6 Conclusion

Based on the results of the feasibility analysis conducted, the priority technology is the on-site implanted sensor. UAV and remote sensing technologies can be used as complements in the decision support system. The design of the subsequent technology must involve a more specific selection to obtain the appropriate product that can be integrated well.

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