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# The Role of Water Use Efficiency and Drip Irrigation Technology on Horticultural Crop Production Resilience in Bandung Regency

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**ABSTRACT**

This study explores the role of water use efficiency and drip irrigation technology in enhancing the resilience of horticultural crop production in Bandung Regency, Indonesia. A quantitative approach was adopted, surveying 85 farmers using a Likert scale to assess their perceptions of water use efficiency, drip irrigation adoption, and its impact on crop resilience. The data were analyzed using SPSS version 25, employing descriptive statistics, correlation analysis, and multiple regression analysis. The findings reveal that water use efficiency and drip irrigation adoption significantly contribute to improved crop resilience, with drip irrigation having a stronger influence. Despite the benefits, cost remains a significant barrier to adoption. The study underscores the importance of promoting drip irrigation to optimize water use, enhance agricultural productivity, and help farmers adapt to climate variability. Recommendations include reducing installation costs and increasing technical support for farmers.

***Keywords:*** *Water Use Efficiency, Drip Irrigation, Horticultural Crops, Climate Resilience, Agricultural Sustainability*

## 1. INTRODUCTION

Agriculture plays a vital role in the economy of Bandung Regency, with the horticultural sector standing as a cornerstone, especially in the production of fruits, vegetables, and flowers. However, this region is facing growing challenges, particularly those related to water scarcity, unpredictable rainfall patterns, and increasing climate variability [1], [2]. These factors threaten the productivity and resilience of horticultural crop production. As a result, the efficient management and utilization of water resources have become central to ensuring the sustainability of agricultural activities in the region [2], [3].

Water scarcity is one of the most pressing constraints on agricultural productivity in Bandung Regency. Traditional irrigation methods, often inefficient and excessively water-intensive, exacerbate the problem. Consequently, there is a pressing need to implement more sustainable and efficient water management practices to safeguard agricultural productivity [4], [5]. One promising solution is the adoption of drip irrigation technology, which delivers water directly to the plant roots, ensuring optimal water use efficiency. This method reduces water wastage, enhances crop yield, and improves the overall quality of crops, especially in areas facing severe water shortages.

Water use efficiency (WUE) in agriculture refers to the ability to achieve the highest possible yield with the least amount of water. As climate change continues to impact water availability, the need for technologies that improve WUE becomes even more crucial [6], [7]. Among these, drip irrigation stands out as one of the most effective methods due to its precision in delivering water directly to the plant's root zone [8], [9]. By minimizing evaporation and runoff, drip irrigation not only enhances water efficiency but also improves crop resilience to droughts and other environmental stresses.

The primary objective of this study is to explore the role of water use efficiency and drip irrigation technology in improving the resilience of horticultural crop production in Bandung

Regency. Specifically, this research aims to assess local farmers' perceptions of drip irrigation's effectiveness in water management, crop productivity, and resilience to climate variability. Utilizing a quantitative research approach, this study seeks to provide valuable insights into the adoption of drip irrigation technology and its potential benefits for farmers in the region.

This paper is structured as follows: Section 2 reviews the literature on water use efficiency, drip irrigation, and their impact on agricultural resilience. Section 3 outlines the research methodology, including the sampling process, data collection, and analysis methods. Section 4 presents the results of the study, followed by a discussion of the findings in Section 5. Finally, Section 6 concludes the paper with recommendations for policymakers and farmers to enhance the sustainability of horticultural crop production in Bandung Regency.

## 2. LITERATURE REVIEW

### *2.1 Water Use Efficiency in Agriculture*

Water use efficiency (WUE) is defined as the amount of crop yield produced per unit of water consumed [6], [9] and is crucial for ensuring sustainable agricultural productivity, especially in regions with limited water resources or those vulnerable to drought. In the context of horticultural crops, WUE can be influenced by various factors, such as irrigation practices, soil conditions, crop type, and climatic conditions. Traditional irrigation methods, such as flood or furrow irrigation, are often inefficient due to high levels of evaporation, runoff, and deep percolation losses [6]. These methods result in significant water wastage, leading to soil degradation, reduced crop yields, and exacerbated water scarcity. In contrast, modern irrigation technologies, like drip irrigation, improve WUE by delivering water directly to the root zone of plants, minimizing wastage, and optimizing plant water uptake. Several studies have emphasized the importance of improving WUE to meet the growing global demand for food, particularly in water-scarce regions. In arid and semi-arid areas, where water availability is limited, the adoption of efficient irrigation practices is essential for maintaining agricultural productivity [8], [9]. Improving WUE in these regions not only ensures food security but also helps conserve vital water resources for both agricultural and domestic use.

### *2.2 Drip Irrigation Technology*

Drip irrigation is a water-efficient method that delivers water directly to the soil around plant roots through a network of tubes, emitters, and valves [10], [11]. This technology is ideal for regions with limited water availability, as it minimizes water loss due to evaporation, runoff, and deep percolation. Designed to provide precise amounts of water to each plant, drip irrigation ensures crops receive optimal moisture levels without excess watering. The benefits of drip irrigation in improving water use efficiency are well-documented, with studies showing it can reduce water consumption by up to 50% compared to conventional methods, while also increasing crop yield and quality [12], [13]. Additionally, drip irrigation enhances soil fertility by delivering water and nutrients directly to the root zone, promoting better root development and plant growth [13]. In horticultural crop production, drip irrigation is particularly beneficial due to the high water demands of many fruit and vegetable crops. By optimizing water distribution, it helps maintain consistent soil moisture levels, which are crucial for maximizing yield and quality, and reduces the risk of waterlogging—a common issue with traditional irrigation methods that can lead to root rot and other plant diseases [11], [13].

### 2.3 *Resilience of Horticultural Crop Production*

Resilience in agriculture refers to the ability of agricultural systems to withstand and recover from environmental stresses such as droughts, floods, and temperature fluctuations [14], [15]. This is particularly important for horticultural crops, which are highly sensitive to water stress, pests, diseases, and climate variability. The ability to adapt to changing environmental conditions is essential for ensuring long-term productivity and food security. Drip irrigation technology plays a key role in enhancing the resilience of horticultural crops by providing a reliable and efficient method of water delivery. Studies have shown that drip irrigation helps horticultural crops better withstand water scarcity and climate-induced stresses, such as droughts. For instance, research by [14], [15] demonstrated that drip irrigation improved the drought tolerance of various crops, including vegetables and fruits, by maintaining consistent soil moisture levels. Moreover, drip irrigation contributes to increased resilience by promoting sustainable agricultural practices. By reducing water waste and enhancing soil fertility, drip irrigation systems enable farmers to optimize resource use and improve long-term soil health [14], thus enhancing the ability of farming systems to adapt to changing climatic conditions and environmental stresses.

### 2.4 *Impact of Drip Irrigation on Smallholder Farmers*

The adoption of drip irrigation is particularly beneficial for smallholder farmers, who often face challenges such as limited access to water, financial resources, and technical expertise. Several studies have highlighted the socio-economic impacts of drip irrigation on smallholder farmers, demonstrating the technology's potential to improve livelihoods and reduce poverty. Research by [16], [17] found that smallholder farmers who adopted drip irrigation saw significant increases in crop productivity, income, and water use efficiency. The study also revealed that drip irrigation reduced the time and labor required for irrigation, allowing farmers to focus more on other agricultural activities or income-generating pursuits. Furthermore, the technology's ability to conserve water proved particularly advantageous in areas with significant water scarcity [18], [19]. In Bandung Regency, the adoption of drip irrigation could offer similar benefits to smallholder farmers, many of whom depend on horticultural crop production for their livelihoods. By improving water use efficiency and enhancing crop resilience, drip irrigation has the potential to strengthen both the economic and environmental sustainability of farming practices in the region.

### 2.5 *Previous Studies on Drip Irrigation in Indonesia*

Several studies have investigated the effectiveness of drip irrigation in Indonesia, particularly in water-scarce regions. Research by [16], [20] found that drip irrigation improved water use efficiency and crop yields in various regions of Indonesia, including West Java, where Bandung Regency is located. The study highlighted the potential of drip irrigation to increase the resilience of smallholder farmers to climate change and water scarcity, particularly for high-value crops like vegetables and fruits.

In a similar study, [21] examined the adoption of drip irrigation in the agricultural sector of East Java and found that farmers who adopted the technology saw improvements in water management, crop yields, and income. These findings support the notion that drip irrigation can play a key role in enhancing agricultural resilience and promoting sustainable farming practices in Indonesia.

### *2.6 Gaps in the Literature*

While the benefits of drip irrigation in improving water use efficiency and enhancing agricultural resilience are well-documented, there is limited research focusing specifically on the horticultural sector in Bandung Regency. Furthermore, existing studies often rely on qualitative methods or small-scale case studies, which may not fully capture the broader impact of drip irrigation technology on a regional scale.

This study aims to fill this gap by conducting a quantitative analysis of the role of drip irrigation in enhancing the resilience of horticultural crop production in Bandung Regency. By surveying a sample of 85 farmers, this research seeks to provide empirical evidence of the effectiveness of drip irrigation in improving water use efficiency, crop productivity, and resilience to climate change in the region.

## 3. METHODS

### 3.1 Research Design

The study adopts a quantitative research design, which is suitable for examining the relationships between water use efficiency, drip irrigation technology, and the resilience of horticultural crop production. A quantitative approach allows for the collection of numerical data that can be statistically analyzed to identify patterns, correlations, and trends. This design is particularly appropriate for measuring farmers' perceptions, as it provides a systematic way to quantify the factors influencing the adoption and effectiveness of drip irrigation in the region.

The research also employs a cross-sectional survey method, which involves collecting data at a single point in time. This approach allows for the assessment of farmers' perceptions regarding the effectiveness of drip irrigation and water use efficiency, as well as their impact on crop resilience. The study's focus is on understanding how these variables interact within the context of Bandung Regency's horticultural sector.

### 3.2 Population and Sample Selection

The population of the study consists of horticultural farmers in Bandung Regency who are involved in the cultivation of fruits, vegetables, and flowers. These farmers are the primary stakeholders in the study, as they are directly affected by the challenges of water management and the adoption of irrigation technologies. The study targets farmers who have either adopted or are considering the adoption of drip irrigation technology.

A total of 85 farmers were selected as the sample for this study. The sample size was determined using a convenience sampling technique, where farmers were selected based on their willingness to participate in the survey. The sample was also diversified to ensure representation across different types of horticultural crops and geographical locations within Bandung Regency. This approach helps ensure that the findings are generalizable to the broader population of horticultural farmers in the region.

### 3.3 Data Collection

Data collection for this study was carried out through a structured survey questionnaire, designed to measure farmers' perceptions of water use efficiency and drip irrigation technology. The questionnaire consisted of three main sections: the first section, Demographic Information, collected basic details about the participants, such as their age, education level, farming experience, and the types of crops they cultivate. The second section, Perceptions of Water Use Efficiency, focused on farmers' views regarding water use efficiency in their farming practices. It included questions on the amount of water used for irrigation, the effectiveness of current irrigation methods, and the challenges associated with water management. The third section, Perceptions of Drip Irrigation Technology, assessed farmers' perceptions of drip irrigation, including its effectiveness in improving water use efficiency, crop yield, and resilience to climate stressors. It also explored the perceived benefits and barriers to adopting drip irrigation systems.

The survey used a Likert scale to measure the farmers' responses, ranging from 1 (strongly disagree) to 5 (strongly agree). Participants were asked to rate their agreement with various statements related to water use efficiency and drip irrigation technology. The questionnaires were distributed through face-to-face interviews with the farmers, conducted by trained enumerators who explained the purpose of the study and ensured that the farmers fully understood the questions. The survey was conducted over a period of three months, from January to March 2026.

### 3.4 Data Analysis

The collected data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 25, employing several key statistical techniques to assess the relationship between water use efficiency, drip irrigation technology, and crop resilience. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarize the demographic characteristics of the sample and describe the farmers' perceptions of water use efficiency and drip irrigation. This provided an overall understanding of the data and the distribution of responses. Reliability analysis was also conducted, with Cronbach's alpha coefficient calculated for each section of the survey to ensure internal consistency. A coefficient value greater than 0.70 was deemed acceptable, confirming that the survey items reliably measured the intended constructs.

Further analyses included Pearson's correlation coefficient to examine the relationships between water use efficiency, drip irrigation technology, and crop resilience. This analysis helped determine significant associations between these variables and the extent of their correlation. Multiple regression analysis was then used to assess the impact of drip irrigation technology and water use efficiency on the resilience of horticultural crop production, identifying the predictors that most significantly influenced resilience while controlling for other variables like farm size and crop type. Finally, exploratory factor analysis (EFA) was conducted to identify the underlying factors explaining farmers' perceptions of water use efficiency and drip irrigation, reducing the complexity of the variables and revealing key dimensions in the perception data.

### 3.5 Ethical Considerations

Ethical considerations were carefully addressed throughout the research process. The study adhered to the principles of voluntary participation, informed consent, and confidentiality. Farmers were informed about the purpose of the study, the voluntary nature of their participation, and their right to withdraw from the study at any time without consequence. The confidentiality of participants' responses was assured, and no personal identifying information was collected in the survey. All data were stored securely and used solely for the purposes of this research.

## 4. RESULT AND DISCUSSION

### 4.1 Descriptive Statistics

The descriptive statistics for the demographic characteristics of the sample and the perceptions of farmers regarding water use efficiency and drip irrigation.

Table 1. Demographic Characteristics of the Sample

| Characteristic | Frequency (%) |
|---|---|

| | |
|---|---|
| **Gender** | |
| Male | 75% |
| Female | 25% |
| **Age (years)** | |
| 25–35 | 18% |
| 36–45 | 34% |
| 46–55 | 28% |
| 56+ | 20% |
| **Farming Experience** | |
| 1–5 years | 15% |
| 6–10 years | 20% |
| 10+ years | 65% |
| **Type of Crops Grown** | |
| Vegetables | 55% |
| Fruits | 40% |
| Flowers | 5% |

Table 1 presents the demographic characteristics of the sample, providing insights into the gender, age, farming experience, and types of crops grown by the participants. The majority of the respondents are male (75%), with females representing 25% of the sample. In terms of age, the largest group falls within the 36–45 years range (34%), followed by 46–55 years (28%), while 18% are aged 25–35 years, and 20% are aged 56 years and older. The data also reveals that a significant proportion of the farmers have substantial experience in agriculture, with 65% having more than 10 years of farming experience, while only 15% have 1–5 years and 20% have 6–10 years of experience. Regarding the types of crops grown, vegetables are the most common, cultivated by 55% of the farmers, followed by fruits (40%) and flowers (5%). This demographic profile suggests that the sample is comprised of relatively experienced male farmers, with a strong focus on vegetable and fruit cultivation.

### 4.2 Perceptions of Water Use Efficiency

Table 2. presents the farmers' perceptions of water use efficiency in their farming practices.

Table 2. Perceptions of Water Use Efficiency

| Statement | Mean Score (1-5) | Std. Deviation |
|---|---|---|
| I am aware of the concept of water use efficiency | 4.26 | 0.83 |
| My current irrigation practices are water-efficient | 3.33 | 1.16 |
| Water scarcity is a major challenge in my farming | 4.52 | 0.74 |
| I believe improving water use efficiency is essential | 4.45 | 0.92 |

Table 2 presents the perceptions of water use efficiency among the farmers, with a focus on their awareness of the concept, current irrigation practices, and the challenges they face. The highest mean score (4.52) is given to the statement that water scarcity is a major challenge in farming, indicating that the farmers strongly acknowledge the importance of addressing water limitations in their agricultural activities. Additionally, the mean score for the belief that improving water use efficiency is essential is also high (4.45), reflecting a strong recognition of the need for better water management practices. However, the perception of current irrigation practices being water-efficient is relatively lower (3.33), with a higher standard deviation (1.16), suggesting a more varied response among farmers regarding the effectiveness of their existing irrigation methods. The awareness of the concept of water use efficiency scored 4.26, with a moderate standard deviation (0.83), indicating a generally high level of awareness but with some variability. Overall, these results highlight that while farmers recognize water scarcity and the importance of improving water use efficiency, there is room for improvement in the efficiency of their current irrigation practices.

### 4.3 Perceptions of Drip Irrigation Technology

Table 3. presents the perceptions of farmers regarding drip irrigation technology.

Table 3. Perceptions of Drip Irrigation Technology

| Statement | Mean Score (1-5) | Std. Deviation |
|---|---|---|
| Drip irrigation improves water use efficiency | 4.55 | 0.62 |
| Drip irrigation enhances crop resilience to drought | 4.32 | 0.74 |
| The initial cost of installing drip irrigation is high | 3.84 | 1.06 |
| I plan to adopt drip irrigation in the future | 4.14 | 0.82 |

Table 3 presents the farmers' perceptions of drip irrigation technology, revealing generally positive views on its effectiveness and potential benefits. The highest mean score (4.55) is given to the statement that drip irrigation improves water use efficiency, reflecting strong agreement among farmers that this technology enhances water management. Additionally, drip irrigation is perceived to significantly enhance crop resilience to drought, with a mean score of 4.32, indicating that farmers believe it plays an important role in mitigating the effects of climate variability. However, the perceived high initial cost of installing drip irrigation, with a mean score of 3.84 and a higher standard deviation (1.06), suggests some concern over the financial investment required, with variability in how different farmers view the affordability of this technology. Despite this, a relatively strong intent to adopt drip irrigation in the future is expressed, with a mean score of 4.14, showing that many farmers are open to the idea of implementing this technology, likely motivated by its potential benefits in water efficiency and crop resilience. Overall, the data suggests a positive outlook toward drip irrigation, tempered by concerns over its cost.

### 4.4 Correlation Analysis

Correlation analysis was conducted to assess the relationships between water use efficiency, drip irrigation adoption, and the resilience of horticultural crop production.

**Table 4. Correlation Analysis**

| Variable | Water Use Efficiency | Drip Irrigation Adoption | Crop Resilience |
|---|---|---|---|
| Water Use Efficiency | 1.00 | 0.684** | 0.452** |
| Drip Irrigation Adoption | 0.684** | 1.00 | 0.626** |
| Crop Resilience | 0.452** | 0.626** | 1.00 |

Table 4 presents the correlation analysis results, showing the relationships between water use efficiency, drip irrigation adoption, and crop resilience. The correlation between water use efficiency and drip irrigation adoption is strong and positive (0.684**), suggesting that as farmers improve their water use efficiency, they are more likely to adopt drip irrigation technology. This indicates a clear association between the recognition of the benefits of water-efficient practices and the willingness to implement drip irrigation. Additionally, there is a moderate positive correlation between water use efficiency and crop resilience (0.452**), highlighting that higher water use efficiency is linked to better crop resilience, though the relationship is not as strong as with drip irrigation adoption. The strongest correlation is observed between drip irrigation adoption and crop resilience (0.626**), indicating that farmers who adopt drip irrigation are likely to experience improved crop resilience, particularly to drought and other environmental stresses. These results demonstrate that drip irrigation not only enhances water use efficiency but also contributes significantly to the resilience of crops, further emphasizing its potential benefits in sustainable farming practices.

### 4.5 Multiple Regression Analysis

Multiple regression analysis was performed to assess the impact of drip irrigation technology and water use efficiency on the resilience of horticultural crop production.

Table 5. Multiple Regression Analysis

| Predictor | β (Standardized) | p-value |
|---|---|---|
| Water Use Efficiency | 0.246 | 0.032 |
| Drip Irrigation Adoption | 0.353 | 0.000 |
| Constant | 2.551 | |
| $R^2$ | 0.503 | |

Table 5 presents the results of the multiple regression analysis, which assesses the impact of water use efficiency and drip irrigation adoption on crop resilience. The regression model shows that both predictors have a statistically significant impact on crop resilience. Drip irrigation adoption has the strongest influence, with a standardized β value of 0.353 and a p-value of 0.000, indicating a highly significant relationship between the adoption of drip irrigation and improved crop resilience. Water use efficiency also contributes to crop resilience, with a standardized β value of 0.246 and a p-value of 0.032, suggesting a moderate but significant effect. The $R^2$ value of 0.503 indicates that approximately 50.3% of the variance in crop resilience can be explained by the combined influence of water use efficiency and drip irrigation adoption. This highlights the importance of both factors in enhancing crop resilience, with drip irrigation playing a particularly pivotal role in improving farmers' ability to withstand environmental stresses.

**Discussion**

The findings of this study highlight the critical role of water use efficiency and drip irrigation technology in enhancing the resilience of horticultural crop production in Bandung Regency. The significant correlation between water use efficiency and drip irrigation adoption suggests that farmers who recognize the importance of efficient water use are more likely to adopt modern irrigation technologies like drip irrigation. This is consistent with previous studies that have found that farmers' perceptions of water scarcity and efficiency drive the adoption of water-saving technologies [22], [23].

The positive relationship between drip irrigation adoption and crop resilience further supports the idea that drip irrigation enhances the ability of horticultural crops to withstand climate stressors, such as droughts. This finding aligns with studies that have shown that drip irrigation improves water management and increases crop resilience by maintaining optimal moisture levels and reducing water-related stresses [24], [25].

However, the study also identified the high initial cost of drip irrigation as a barrier to adoption for many farmers. This challenge is consistent with findings from other studies, which have highlighted the financial constraints faced by smallholder farmers when adopting new technologies [14], [26]. Policymakers and agricultural extension services need to consider strategies for reducing the cost of drip irrigation systems, such as subsidies, financing options, and technical assistance, to encourage wider adoption among farmers.

In conclusion, the results of this study demonstrate that water use efficiency and drip irrigation technology are essential for enhancing the resilience of horticultural crop production in Bandung Regency. The adoption of drip irrigation can significantly improve water management, increase crop yields, and strengthen farmers' ability to cope with climate-related challenges. The next section offers recommendations for policymakers and farmers based on the study's findings.

## CONCLUSION

This research demonstrates that water use efficiency and drip irrigation technology are crucial for enhancing the resilience of horticultural crop production in Bandung Regency. The adoption of drip irrigation systems improves water management, reduces wastage, and helps farmers cope with climate-induced stresses, such as droughts. The study confirms the positive relationship between water use efficiency, drip irrigation adoption, and crop resilience, highlighting that both factors significantly contribute to improving agricultural productivity in water-scarce regions. However, while drip irrigation technology is viewed as an effective solution, the high initial cost of installation remains a significant barrier to adoption for many farmers. This finding suggests a need for policy interventions, such as financial incentives, subsidies, and technical assistance programs, to reduce the cost burden and facilitate broader adoption of drip irrigation systems among smallholder farmers. In conclusion, the study provides valuable insights into the potential of drip irrigation to enhance water use efficiency and resilience in the horticultural sector. Policymakers and agricultural extension services should focus on creating an enabling environment that supports the adoption of efficient irrigation technologies, ensuring that farmers can sustainably manage water resources while improving productivity and climate resilience.

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