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Literature Review: Water Spinach Variety KK-09 for Irrigation Optimization in Dry Land

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Abstract: The increasing need for food due to population growth demands the optimization of dry land through efficient irrigation strategies. One approach is the selection of alternative crops with low water requirements but high economic value. This study aims to assess the potential of the KK-09 water spinach variety as an alternative cropping pattern in optimizing dry land irrigation. The method used is a literature review based on the Scopus database with relevant keyword searches and topic mapping using the Vos viewer tool. A total of 70 articles related to irrigation optimization in dryland were identified. In addition, an analysis of water requirements was conducted based on plant growth phases (germination, vegetative, flowering, and ripening). The results show that KK-09 water spinach only requires ± 720 mm of water in one planting cycle (110 days), with an average discharge requirement of ± 0.069 liters/second/hectare. The economic water efficiency reaches IDR 68/mm and a profit of IDR 100,400/m³, making it superior to other secondary crops such as corn, sorghum, and mung beans. These findings indicate that the KK-09 variety has the potential to be a sustainable irrigation solution for areas with limited water availability.

Keyword: Crop water requirements; Dry land irrigation; Irrigation optimization; Water efficiency; Water spenach KK-09

Introduction

Rapid population grow (Chen et al., 2022) has significantly increased food demand (Abbas et al., 2025). To address this challenge, it is essential to enhance agricultural productivity (Febrianti et al., 2024; Tegar et al., 2025), narrow the gap between food supply and demand, and improve farmers' livelihoods. Agriculture remains a vital economic sector (Mandasari & Prabawati, 2019; Bangkole et al., 2024), particularly in rural areas, where close ties between communities and local governments offer opportunities to strengthen agricultural development from the village level. With its strategic role, agriculture is key to ensuring food security (Wijayanti et al., 2024), boosting welfare, and supporting sustainable economic growth. Thus, increased investment and focus on the sector are crucial.

Agriculture supports sustainable development by providing food (Wijayanti et al., 2024), employment, and economic stability while conserving natural resources. Sustainable practices aim to meet current food and economic needs without compromising future generations. Key elements include resource management (Sodikin et al., 2025), social equity (Buri et al., 2025), biodiversity, climate resilience, food security (Lestari et al., 2023), waste reduction, and efficiency. When integrated, these elements position agriculture as a driver of Sustainable Development Goals, including poverty reduction, food availability, and climate action. Consequently, agricultural development not only

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enhances productivity but also strengthens the national economy.

However, the realization of sustainable agriculture faces significant challenges the availability and efficient use of water resources. As climate patterns shift and competition for water increases, irrigation becomes a critical constraint in many agricultural regions, especially in dryland areas.

Water availability, varying by region, is a critical factor in agricultural success. Water shortages, especially during dry seasons, can severely damage crops. Droughts are among the most serious agricultural disasters, threatening both environmental sustainability and food security.

Selecting the right cropping strategy can increase yields and farmer income. Techniques such as crop rotation (Andriani et al., 2025), intercropping, seasonal planting, use of high-value or superior varieties, and data-driven scheduling—when tailored to local conditions—can improve productivity and resilience. Efforts to optimize irrigation systems and align crops with available water are essential for sustainable agriculture in drylands.

Cropping patterns play a central role in sustainable agricultural production. Their optimization must account for local water availability, socio-economic conditions, and ecological impacts. Well-structured cropping systems not only improve yields but also enhance water use efficiency and reduce agricultural pollution (Chen et al., 2022).

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Given the increasing pressure on water resources—particularly in dryland regions—the selection of crops that require minimal irrigation yet offer high economic returns becomes essential. In this context, this article explores the potential of KK-09 water spinach (Ipomoea Aquatica) as an alternative crop suited for such environments. Known for its low water requirement, adaptability to dry conditions, and high market value (Jaya et al., 2024), KK-09 presents a promising opportunity to enhance irrigation efficiency and improve farmer livelihoods in water-scarce areas.

Method

The method used in this article is a literature review to synthesize the KK-09 variety of water spinach as an alternative cropping pattern in dry land agriculture (Ansyar & Herdiana, 2023). The search was conducted through the SCOPUS database. The search query has been determined, so that the resulting research has the following characteristics: the keywords searched are "irrigation AND optimization AND in AND dry AND land" dan "Water AND Spinach AND Variety AND KK-09 AND for AND irrigation AND optimization AND in AND dry AND land".

Literature review (Qomaruddin et al., 2024) conducted by collecting and analyzing data included in Scopus, which includes research studies and theoretical studies related to irrigation optimization on dry land with alternative plants of kale variety KK-09. This approach obtains a comprehensive picture of the latest developments in this field. Searching for related articles to find novelty using the help of Vos Viewer by filtering various articles from Scopus. The methodology is explained according to the search flow diagram in Figure 1.

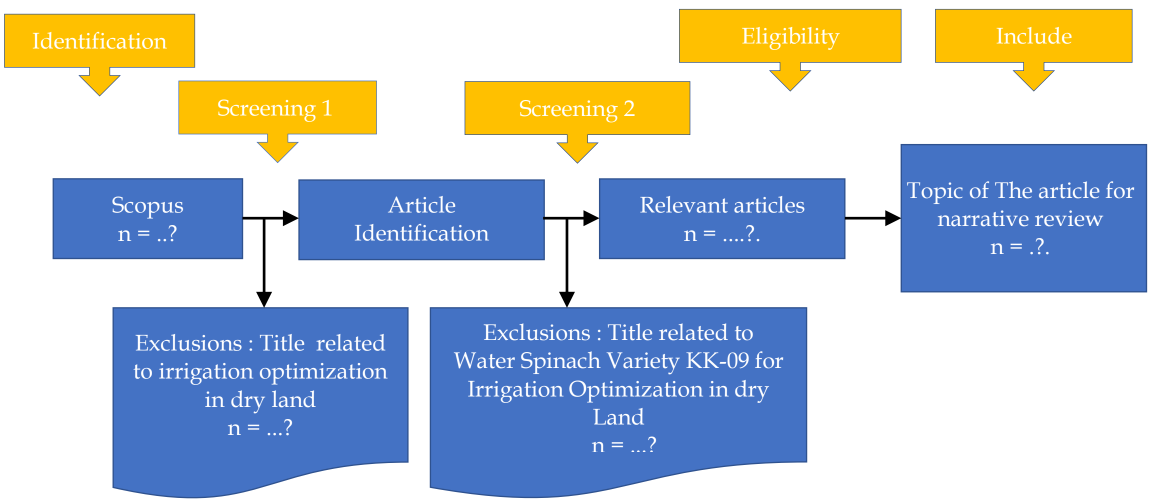

Figure 1. Search flow diagram

Result and Discussion

Scopus database (Abdelwahab et al., 2025; Shunmathy & Selvam, 2025; Tafese & Kopp, 2025) informs 70 relevant papers related to irrigation optimization in dry land (Figure 2). Subject areas covered by the keywords include: with the following limitations: no limitation on the range of years; subject areas include: Agriculture and Biological Science, Environmental Science; document type using: Article, Conference Paper, Review; Language English; keywords: Irrigation, Irrigation Optimization, Optimization, Water Management, Irrigation System, Water Supply, Crops, Agriculture, Irrigation Management, Agriculture Irrigation, Crop Production, Water Use, Crop Yield, Water Resources, Deficit Irrigation.

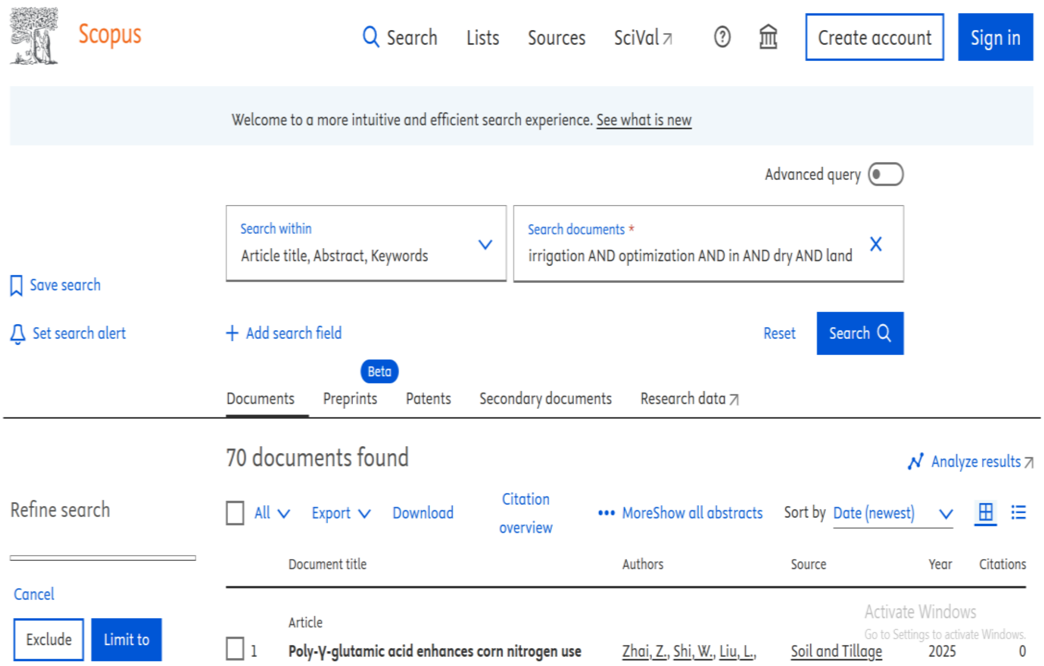

Figure 2. Scopus database with search keywords irrigation AND optimization AND in AND dry AND land

Figure 2 shows the search results with the keywords irrigation AND optimization AND in AND dry AND land in the SCOPUS database found 70 related article documents. Furthermore, the data from the article was traced using the help of Vos Viewer as in Figure 5, Figure 6 and Figure 7.

Research trends in Figure 3 show that the article database from 1990 to 2025 has increased. The number of papers in 2019 and 2020 reached 7 papers, while in 2021 it decreased to 4 articles, while in 2022 to 2025 there were 3 articles each. This trend shows the significance and is very urgent for optimizing irrigation in dry land.

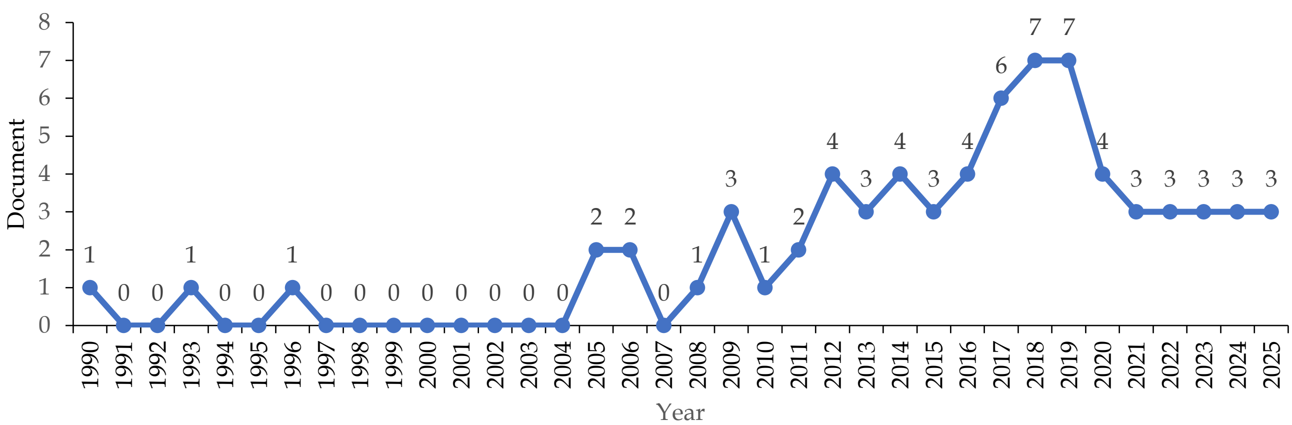

Figure 3. Research trends on the topic of irrigation optimization in dry land from 1990 to 2025

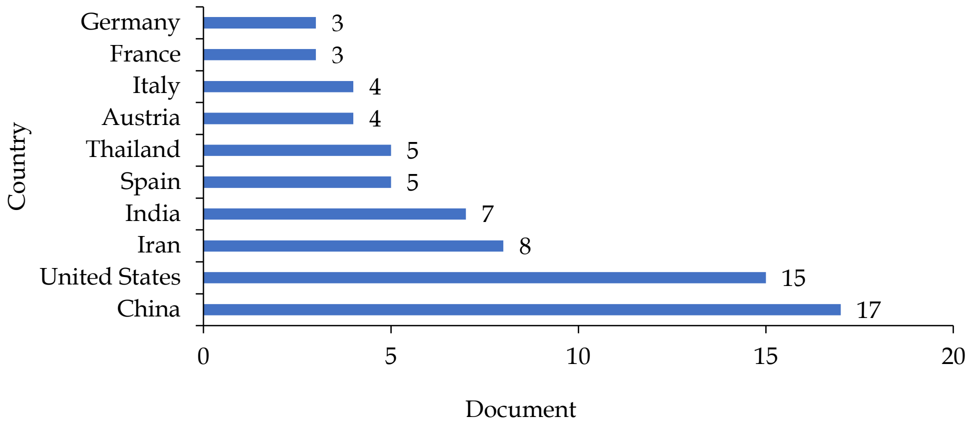

Figure 4. Trends in contributions from authors from various countries

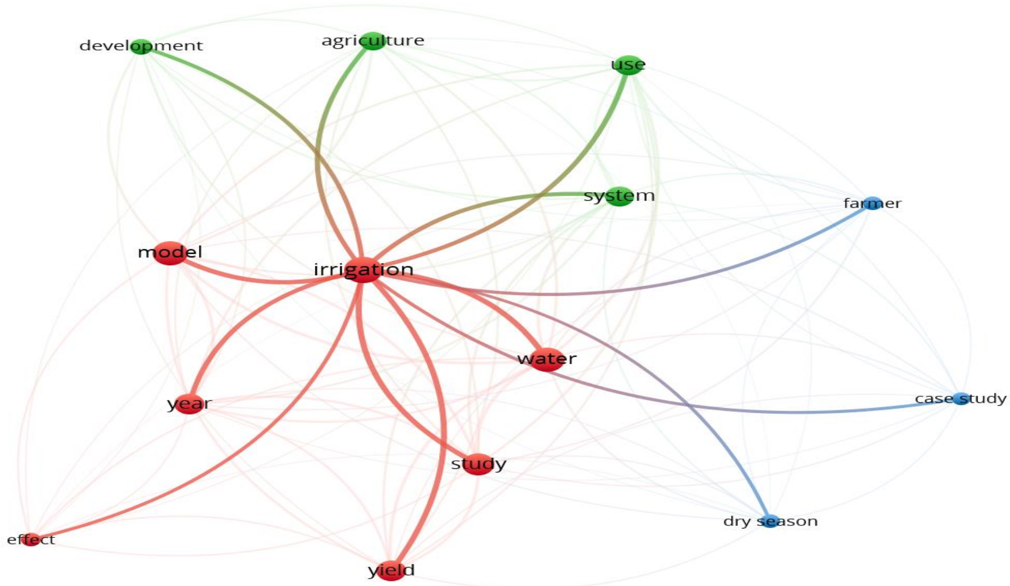

Figure 5. Irrigation research keywords with Vos Viewer

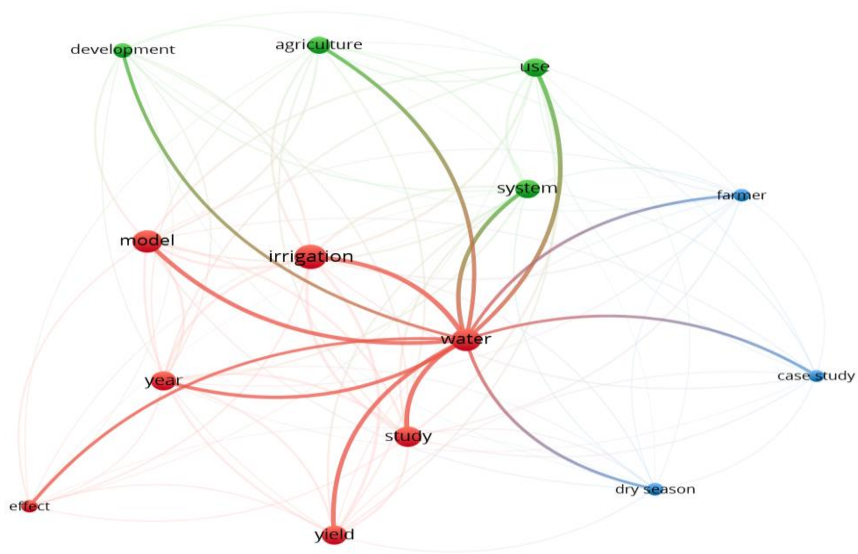

Figure 6. Water research keywords with Vos Viewer

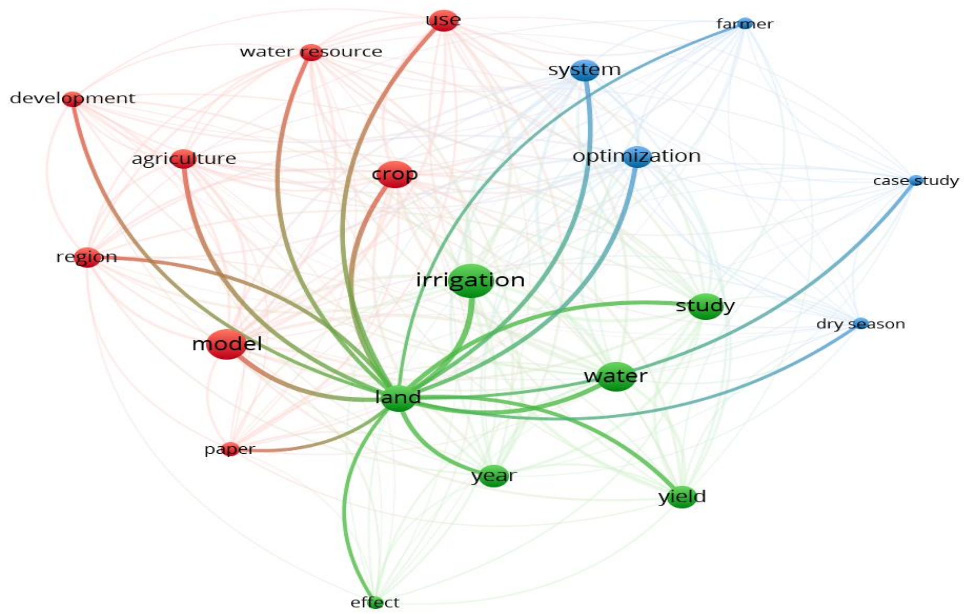

Figure 7. Land research keywords with Vos Viewer

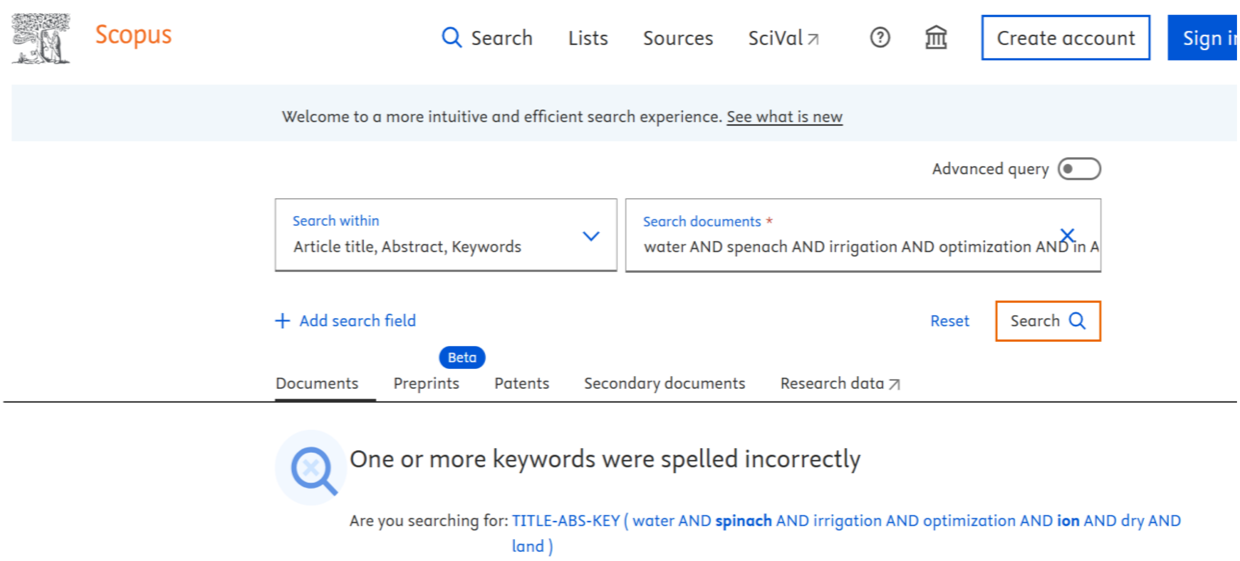

Figure 8. Scopus database with search keywords water AND spenach AND irrigation AND optimization AND in AND dry AND land

Various countries are also competing to conduct research on irrigation optimization. Figure 4 shows that China, the United States, Iran and India are quite active in conducting research on irrigation optimization in water and land constraints.

To find novelty from each study that discusses irrigation optimization by selecting types of plants that have high selling prices and small plant water requirements. Figure 8 shows the SCOPUS database by entering the keyword Scopus Database with the search keyword water AND spenach AND irrigation AND optimization AND in AND dry AND land no data was found. This can be interpreted that irrigation optimization with kale as an alternative plant has never been studied.

From the results of the search for article documents discussing the KK-09 water spinach plant as an alternative for irrigation optimization, the researcher conducted observations and interviews with farmers and technicians of the KK-09 variety of water spinach plant with the result as in Table 1.

To determine the irrigation water requirements for the KK-09 variety of water spinach, an approach based on the plant's growth phases was used: the initial planting phase, vegetative growth, and the pre-harvest phase. Each phase has different water requirements, depending on the irrigation intensity and cultivation techniques used. Details of irrigation water requirements based on these growth phases are presented in Table 2.

From Table 2, it can be seen that the total water requirement for 110 days is 720 mm. The average flow rate is ~0.069 liters/second/ha — this is very low and efficient, suitable for rainfed or low-flow areas. The most critical water phase is the flowering–seedling phase (Days 41–80), where the ideal irrigation flow rate is >0.09 l/second/ha.

Table 1. Cultivation technology for water spinach variety KK-09

Components	Description
Variety	Kangkung KK-09.
Planting Method	Seeds are sown in seedbeds until they are 24 days old.
	Planting distance: 60 cm x 40 cm.
Watering	Water the planting holes during initial planting.
	Light flooding is applied at 15 days.
	Re-flooding is applied at 25 days.
Fertilization	Ponska is applied at 1 quintal/ha on the first day after planting.
	SP-36 at 1.5 quintals/ha at 15 days.
	ZA at 2.5 quintals/ha at 25 days.
Fertilizer & Medication	Foliar spray is applied at 15 days.
	Pesticides are applied if necessary.
	Fruit spray is applied at 42 days.
Plant Age	Maximum age to harvest: 110 days.
Seed Harvest	Seed production: 1.8 tons/ha.
Selling Price	IDR. 17,000/kg or equivalent to IDR. 30,600,000 per hectare.

Table 2. Irrigation water requirements for kangkung KK-09 based on growth phase

Growth Phase	Duration (Days)	Kc	Etc (mm/day)	Gross NFR (mm/day)	Total Volume (mm)	Q (l/Sec/ha)
Germination	15	0.40	1.80	3.00	45.00	0.035
Vegetative	25	0.90	4.05	6.75	168.75	0.078
Flowering–Seedling	40	1.05	4.73	7.88	315.00	0.091
Maturation	30	0.85	3.83	6.38	191.25	0.074
Total/Average	110	—	—	—	720.0	0.069

Irrigation Optimization in Dry Land

Modern agriculture (Babcock-Jackson et al., 2023; Balamurali et al., 2025; Fu et al., 2024; Kleinman & Harmel, 2023; Riedo et al., 2025; Zanni et al., 2022) facing major challenges in the form of uncertainty of water resources (Li et al., 2024) and the increasingly narrow land (Chen et al., 2022; Buri et al., 2025) which are available. In the context of climate change (Abbas et al., 2025) and population growth, innovative approaches are needed that can maximize agricultural output without burdening natural resources. One approach that has received attention in the last decade is irrigation optimization (Bian et al., 2024) by selecting types of plants that not only have low water requirements, but also have high sales value.

High Value Water Saving Plants

Irrigation optimization (Bian et al., 2024; Abd-Elaty et al., 2024) through the selection of plant types (Kumar & Singh, 2021) is a smart strategy, especially in areas with limited water availability (Setyandhinavia et al., 2025). The basic principle is to plant crops that are suited to the water conditions available (Anderson & French, 2019; Hao et al., 2018; Li et al., 2020; Shafa et al., 2022), not forcing water for wasteful plants.

a. Spinach Variety KK-09 (200-300 mm/season, selling value: IDR 17,000/kg)
b. Sorghum (water requirement: 250-400 mm/season, selling value: IDR 4,000-6,000/kg)
c. Green beans (300-400 mm/season, IDR 10,000-12,000/kg)
d. Red chili (400-500 mm/season, IDR 30,000-40,000/kg)
e. Millet and quinoa (400-600 mm/season, high export value)

Compared to lowland rice (1000-1200 mm/season, IDR 5,000-7,000/kg), these plants can save up to 50-70% of water.

Simple Optimization Model

With the formula: Maximize Profit = Σ (Area_i × (Price_i - Cost_i)) Constraints: water and land limitations as follows:

$\Sigma (\text{Area}_i \times \text{WaterRequirement}_i) \leq \text{Total Water}$

$\Sigma \text{Area}_i \leq \text{Total Land}$

Area_i ≥ 0

Simulation

In the scenario of 1 ha of land with a total water of 5000 m^3. To calculate the optimal combination of plants on 1 ha (10,000 m^2) of land with a total water of 5,000 m^3, we can use a manual approach based on profit efficiency to water (IDR profit / m^3 of water) as a priority guide. Table 1 is the Estimation Data (average).

Table 3. Estimation data (average)

Plant	Water Requirements (mm)	Water Requirements (m^3/m^2)	Value (IDR/kg)	Cost (IDR/m^2)	Result (kg/m^2)	Margin (IDR/m^2)	Profit Efficiency (IDR/m^3 air)
Water Spenach KK-09	250	0.25	17.000	5.500	1.8	25.100	100.400
Sorgum	325	0.325	5.000	2.500	0.9	2.000	6.154
Green beans	350	0.35	11.000	4.000	0.8	4.800	13.714
Red Chili	450	0.45	35.000	15.000	0.6	6.000	13.333
Millet/Quinoa	500	0.50	20.000*	8.000	0.7	6.000	12.000

Water spenach KK-09 yielded the highest irrigation profit efficiency, at Rp 100,400/m^3 of water, indicating its suitability for areas with limited water. Other crops, such as red chilies and mung beans, still yielded moderate efficiencies. Sorghum had the lowest efficiency, and although suitable for marginal land, its economic margin was smaller. To optimize irrigation based on water needs and sales value (or economic value), we need to find a balance between water use efficiency and potential revenue per unit of water. The goal is to maximize revenue per mm of irrigation water. The method used is the sales value per liter of water. (rupiah/mm). Using average selling value and average water requirements per season.

Table 4. Plant data summary

Plant	Water Requirements (mm)	Water Average (mm)	Value/kg (IDR)	Value Average (IDR)	Selling Value per mm Water (IDR/mm)
Water Spenach KK-09	200 – 300	250	16.000 – 18.000	17.000	17.000 ÷ 250 = 68
Sorgum	250 – 400	325	4.000 – 6.000	5.000	5.000 ÷ 325 = 15.4
Green beans	300 – 400	350	10.000 – 12.000	11.000	11.000 ÷ 350 = 31.4
Red Chili	400 – 500	450	30.000 – 40.000	35.000	35.000 ÷ 450 = 77.8
Millet/Quinoa	400 – 600	500	(high export value)	Example IDR 25.000	25.000 ÷ 500 = 50

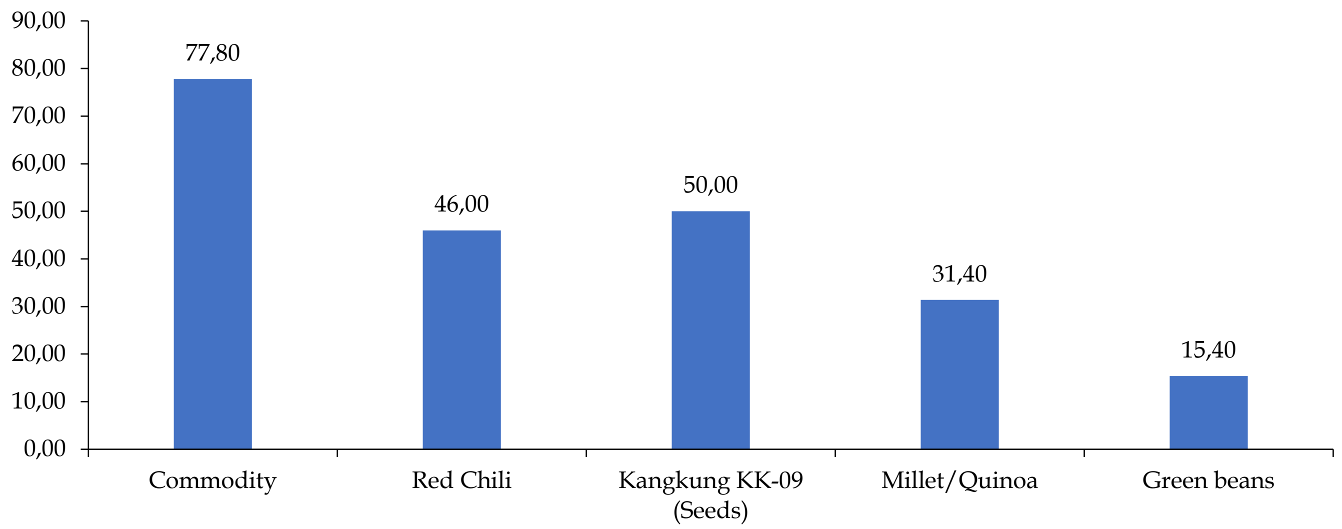

Figure 9. Graph of selling price value per mm of water for each type of selected plant (IDR/mm)

From Table 4, it is known that Red Chili has the highest economic value per mm of water (IDR 77.8/mm), although it requires a lot of water, it is very suitable for intensive irrigation. Kangkung KK-09 has good selling value and is water efficient (IDR 68/mm), suitable for efficient irrigation systems. Millet/Quinoa has high export potential, although its efficiency is moderate (IDR 50/mm), suitable for land with sufficient but not abundant water access. Green beans have a medium level of efficiency (IDR 31.4/mm), it can be an alternative crop rotation. Sorghum has a low selling value and the lowest water efficiency (IDR 15.4/mm), suitable only for dry or subsistence land. This combination provides maximum profit with minimal water consumption. Figure 9 shows a comparison of the selling price value per mm of water for each type of selected plant.

Conclusion

Selecting plants that adapt to dryland conditions is a crucial strategy for supporting sustainable irrigation and food security. Based on a literature review and water requirement analysis, the KK-09 water spinach variety has been shown to have significant advantages compared to other alternative crops. With a total water requirement of approximately 720 mm per planting cycle and an average irrigation flow rate of approximately 0.069 liters/second/hectare, KK-09 water spinach demonstrates high water utilization efficiency. Furthermore, the resulting profit margin reaches IDR 100,400 per cubic meter of water, far exceeding that of crops such as sorghum, mung beans, and red chilies. These findings indicate that KK-09 water spinach is a variety with significant potential for integration into adaptive cropping patterns in dry climates. In addition to its efficient water use, this plant also provides high economic value in a relatively short growing period. Therefore, developing the KK-09 variety could be a strategic solution for optimizing irrigation and sustainably increasing dryland productivity.

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Author Contributions
Conception and design of the study, data collection and analysis, interpretation of results and discussion, writing the article, revision and improvement, M.; provided scientific guidance, methodological validation, and feedback on the draft article during the writing process, S. and D.A.W.

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Conflict of Interest
The authors declare no conflict of interest.

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