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The Common Characteristics of Land and Water Resources to Develop Agricultural Cultivation: A Case of a Developing Nation

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Indonesia produces rice as a staple crop, but its water resources are limited, resulting in a severe battle for water between industry and agriculture. In many regions, the overexploitation of groundwater has resulted in a significant lack of water resources, creating a formidable obstacle to agricultural development. To maintain regional food security and sustainable rice agriculture, eight cities in the province of South Sulawesi were studied as study units in this work. The study's objective was to establish the optimal layout for rice cultivation regarding agricultural water and land resources. Secondly, the author evaluated the cultivated area based on existing agricultural water resources and irrigation development. Second, the study determined the layout for water-appropriate rice cultivation. Results indicated that the amount of agricultural and irrigated area that available water resources can support has about reached its maximum capacity. Ensure the sustainable development of the entire region, mitigate water scarcity, and ensure national food security. Yet, the spatial distribution of water demand for rice production has altered in the opposite direction of the quantity of water resources for agriculture per unit of irrigated area and precipitation. This indicates a mismatch between rice production and water availability, necessitating more water to sustain rice agriculture. The growing trend of the Gini coefficient shows that water restrictions constrain large-scale expansion of agricultural and irrigated regions. The study suggested focusing on regions with abundant water resources to promote irrigation and water-appropriate rice agriculture further.

Key words: Water Suited Cultivation; Development Layout; Cultivated Land Area; Rice Production; South Sulawesi Province.

1. INTRODUCTION

Agricultural cultivation development involves careful evaluation of the water and soil resources of a given place (Ippolito et al., 2021; Pramananda et al., 2022). The compatibility of these resources can substantially impact the success and yield of agricultural cultivation (Yue & Guo, 2021). Thus, it is crucial to construct an agricultural cultivation plan based on water and land resources to undertake a comprehensive assessment of the available resources (Sabzevar et al., 2021). This evaluation should evaluate the soil type, topography, precipitation patterns, and region's water availability (Zobeidi et al., 2022). Based on this data, it is possible to identify which crops are most suitable for the region and how they should be cultivated. For instance, regions with heavy precipitation and adequate water resources are good for water-intensive crops like rice (Rahman et al., 2022). In contrast, locations with low precipitation and limited water supplies may be more suited for drought-resistant crops like maize and sorghum. Based on the unequal global distribution of land and water resources, several regional agricultural developments and water shortage challenges arise (Salem et al., 2022). According to the FAO report "Food and Agricultural Situation in 2020," severe water scarcity exists in around sixty percent of irrigation regions. In addition, roughly 41% of the world's irrigation water originates from ecological systems as the primary water supply for grain production (Syed et al., 2022). To sustainably grow regions and agriculture, it is essential to make efficient and effective use of agricultural land and water resources. Furthermore, the type and quality of soil in a region can significantly impact crop yields (Kumar et al., 2022). Evaluating the soil quality and selecting crops suitable for certain soil conditions is essential. In regions with low soil quality, strategies such as adding organic matter and fertilizers should be considered for soil development (Barton & Ho, 2020). Similarly, regions with steep slopes may require terracing to avoid soil erosion and promote water retention.

Concurrently, prior scholars have evaluated the value of adequate water resources for crop production in many tropical settings (Liu et al., 2022). While designing a pattern for agricultural production, it is essential to account for the current land usage in the area carefully (Ippolito et al., 2021). Existing agricultural areas may require crop rotation to prevent soil depletion and increase yield. Other land uses, such as urban development or conservation, may necessitate adopting alternate cultivation methods, such as container gardening or hydroponics (Prabhakar, 2021). In addition, researchers have assessed the impact of soil quality, topography, climate, and existing land usage on the design of agricultural production layouts

(Saptutyningsih et al., 2020; Sulaiman et al., 2019). Yet, there is a dearth of studies matching the characteristics of water and land resources to design an agricultural cultivation pattern. With careful consideration of water supply, the present study enabled the development of a layout that maximizes environmental effects and decides on rice agriculture in emerging nations. In addition, this research was undertaken in Indonesia. Agriculture has a long history in Indonesia and plays a key part in the country's economy. Indonesia is an archipelago of approximately 17,000 islands, and its land area is rich in agriculturally-viable natural resources (Boedhihartono, 2022). The country's tropical temperature and copious precipitation make it excellent for cultivating various crops (Ma'Mun et al., 2021). Indonesia's interest in organic and sustainable agriculture has recently increased (Sinring & Buana, 2022). Several farmers are implementing these strategies to increase their yields and lessen the environmental effect of agriculture. To boost the value of agricultural products, there has also been an emphasis on generating value-added items, such as processed foods and cosmetics (Raihan et al., 2022).

2. AIMS AND OBJECTIVES

Moreover, rice is the most significant crop in Indonesia, and the country is one of the world's major producers and consumers of rice (Pramananda et al., 2022). Among important crops are maize, cassava, sweet potatoes, soybeans, peanuts, and vegetables. Moreover, Indonesia is a leading palm oil, rubber, cocoa, and coffee producer. In Indonesia, small-scale farmers dominate agricultural production, and most practice subsistence agriculture (Susanto et al., 2021). Commercial agriculture is also prevalent, particularly in regions with extensive plantations (Ekananda, 2022). Despite its substantial contribution to the nation's economy, agriculture in Indonesia confronts several obstacles. In the coming years, land scarcity, soil degradation, climate change, and low productivity are anticipated to substantially impact crop yields and production (Ekananda, 2022; Pramananda et al., 2022). Considering these obstacles and the significance of rice as a staple meal for meeting the basic food requirements of the Indonesian populace, the current study seeks to examine the cultivated area based on water resources and irrigation development by available agricultural water. In addition, authors typically define the direction for a water-appropriate rice planting arrangement.

3. RESEARCH SIGNIFICANCE

Indonesia is a Southeast Asian nation comprised of tens of thousands of islands. Due to its geographical location and frequent precipitation, Indonesia has an abundance of water resources (Nasir et al., 2021). Yet, the distribution and quality of water vary across the nation, and there are concerns about water scarcity and pollution (Basuki et al., 2022). Moreover, surface water is Indonesia's principal source of freshwater, accounting for around 97% of the country's total water resources. The remaining 3% is provided by groundwater (Haryani, 2021). Many rivers and lakes constitute the vast majority of its surface water resources. The entire length of the nation's rivers is around 95,000 km (Morales-Simfors & Bundschuh, 2022). The Kapuas, Barito, and Musi rivers are among the most significant. Lake Toba in Sumatra is the largest lake in Southeast Asia, whereas Lake Poso in Sulawesi is the largest lake in Indonesia. Nevertheless, many rivers are highly polluted due to industrial and agricultural activity and household garbage (Maruf, 2021). Moreover, numerous of these lakes are threatened by pollution.

In some localities, particularly urban and industrialized zones, groundwater is a significant water supply. The country has multiple aquifers, including the world's largest, the Java Aquifer System (Shoedarto et al., 2022). However, excessive groundwater extraction has caused land subsidence and seawater intrusion in coastal areas. The Indonesian government has developed numerous programs and initiatives to enhance water management and conservation, such as the National Water Resources Management Strategy and the National Clean Water Movement (Surachman et al., 2022). Even though Indonesia has enormous water resources, there are worries regarding water quality and availability, especially in densely populated places such as Jakarta, where demand exceeds supply. It is also caused by pollution and excessive groundwater exploitation. It would be essential to address these concerns to ensure sustainable water management in the country (Basuki et al., 2022; Haryani, 2021). Additionally, water quality in Indonesia is highly variable, with certain regions suffering from low water quality due to industrial and agricultural contamination. Many people in rural areas still rely on unimproved water sources, such as rivers and ponds, which may be contaminated with bacteria and other pathogens (Basuki et al., 2022). Climate change is anticipated to have considerable effects on Indonesia's water supplies (Nasir et al., 2021). Increasing temperatures and shifting precipitation patterns may result in more frequent droughts and floods, altering the quantity and quality of water. For all Indonesians to have access to safe, dependable water, it is crucial that the country sustainably manages its water resources and invests in infrastructure and technology.

4. STRUCTURE OF REVIEW

Indonesia made some progress in developing and exploiting its water resources between 2000 and 2021, but significant obstacles and issues continued. During this period, Indonesia made some strides in developing its water infrastructure by constructing many new dams and reservoirs. Yet, many old water infrastructure projects were inadequately maintained, resulting in leaks and water losses (Pasaribu, 2021). Despite significant progress in water infrastructure development during this period, many Indonesians lacked access to safe and reliable water. During this period, water quality remained a serious concern in Indonesia, with numerous rivers and lakes affected by industrial and agricultural pollutants. In 2019, according to the National Socioeconomic Survey, just 69.8 percent of Indonesian households had access to upgraded water sources, especially in rural areas (Nurhidayati & Riyadi, 2022). However, the Ministry of Environment and Forestry reported in 2019 that only 15.4% of Indonesian rivers have adequate water quality (Sempewo & Kayaga).

Throughout this period, the over-extraction of groundwater continued to be a concern in many regions of Indonesia, leading to land subsidence, saltwater intrusion, and other issues. The government initiated several programs to reduce and adapt to these effects, including developing early warning systems and promoting water conservation measures (Octavia et al., 2022). The government also enacted laws to minimize groundwater pumping, but enforcement was often lax. Yet, the country continued to endure the effects of climate change on its water resources during this time, with more frequent droughts and floods reducing the supply and quality of water (Nugroho et al., 2022). In 2018, the Indonesian government began the National Movement for Clean and Healthy Rivers program to enhance water quality in rivers nationwide (Budiman et al., 2023). This program seeks to minimize pollution and improve the sustainable management of water resources. In 2018, a groundwater regulation was enacted to regulate groundwater extraction and avoid saltwater intrusion (Basuki et al., 2022). As a response, the government has developed a National Action Plan on Climate Change Adaptation, which includes steps to improve water resource management and strengthen resilience to climate impacts. The government launched the Clean Water and Sanitation Movement in 2020 to expand access to these vital services (Nugroho et al., 2022). Access to adequate water and sanitation remains a problem in Indonesia, particularly in rural regions, and must be addressed philosophically and practically despite gains in infrastructural development.

In addition, the current investigation was conducted in the Indonesian region of South Sulawesi. The water conditions in the Indonesian region of South Sulawesi might vary depending on location and season (Ma'Mun et al., 2021). Several big rivers and lakes in South Sulawesi are significant irrigation and drinking water supplies. The condition of these bodies of water might change with the season and the amount of human activity in the region (Sinring & Buana, 2022). River and lake water levels are often high during the rainy season (November to April). However, water levels can drop dramatically during the dry season (May to October) (Mustafa et al., 2022). In some regions, water pollution is a hazard due to industrial and agricultural operations. Generally, the water conditions in South Sulawesi are complex and very variable depending on location and season. It is crucial to safeguard and conserve water resources in the region to encourage sustainable water use (Dobler et al., 2022). The average water resources in South Sulawesi Province, Indonesia, from 2015 to 2021 are depicted in Table 1.

Table 1. Average water resources in the South Sulawesi Province, Indonesia, from 2015-2021

River basin	Precipitation		Water Resources		Surface Water Resources		Surface Water Resources/Total Water Resources
	Amount (mm)	Proportion (%)	Amount (108 m3)	Proportion (%)	Amount (108 m3)	Proportion (%)	(%)
Jeneerang River	621	23.73	321.1	23.4	197.3	10.5	61.4
Walanae River	301	6.31	132.5	4.8	84.4	2.9	63.7
Saddang River	732	30.42	823.9	27.5	435.2	37.5	52.8
Bila River	857	39.54	1123.1	44.3	613	44.5	54.5
Cenrana River	302	/	197.1	/	90	4.6	45.6

5. RESEARCH METHOD

5.1 The Gini coefficient

The Gini coefficient is a statistical measure of the inequality of a distribution that is often employed to measure disparities associated with population phenomena (Blesch et al., 2022). It is a number between 0 and 1, with 0 indicating complete equality (where everyone has the same income) and 1 indicating perfect disparity (where one person has all the income and everyone else has none). To compute the Gini coefficient, divide the area between the Lorenz curve and the line of perfect equality by the entire area under the line of perfect equality (Zhang et al., 2022). The Lorenz curve is a graphical representation of the cumulative distribution function a distribution, with the x-axis representing the cumulative population share and the y-axis representing the cumulative income share (Kaplaner & Steinebach, 2022). The line of perfect equality is a diagonal line that portrays a situation where all individuals have the same income.

$GN = A/(A+B)$ is the formula for the Gini coefficient (1)

Where G represents the Gini coefficient, A represents the region between the Lorenz curve and the line of perfect equality, and B represents the region beneath the line of perfect equality. Economists, sociologists, and policymakers often use the Gini coefficient to analyze and compare the degree of inequality across various nations, regions, or people (Kaplaner & Steinebach, 2022). It can also be used to examine changes in inequality over time and assess the efficacy of programs designed to reduce inequality. The smaller values with the Gini coefficient closer to the 45-degree line indicate that water and land resources are well-matched. In contrast, the greater values indicate the least compatible degree of land and water resources (Kaplan & Haenlein, 2010). According to the UNDP Google coefficient criterion, as shown in Table 2, there are five classes ranging from Excellently matching to Very poorly matching, with corresponding Gini coefficient value ranges of "[0–0.2), [0.2–0.3), [0.3–0.4), [0.4–0.5), and [0.5,1".

Table 2: The Gini Coefficient Measuring the Level of Compatibility Between Water and Cultivated Land Resources

The rages of the Gini Coefficient	The grade of the matching degrees
0 ≤Gini Coefficient < 0.2	(a) Excellently matching
0.2 ≤ Gini Coefficient < 0.3	(b) Well matching
0.3 ≤ Gini Coefficient < 0.4	(c) Relatively reasonable matching
0.4 ≤ Gini Coefficient < 0.5	(d) Poorly matching
0.5 ≤ Gini Coefficient < 1.0	(e) Extremely poorly matching

5.2 The Available Agricultural Water Resources and Their Calculation

Due to the insignificance of precipitation in meeting the water requirements for agricultural output, irrigation is essential for developing agriculture worldwide, especially in Indonesia. Thus, water availability in irrigation areas is regarded as a precondition for agrarian development, contributing to the prosperity of the entire region (Odhiambo et al., 2021). In addition, using irrigation water in agriculture contributes to resource scarcity because it exceeds the top limits of the total water control value minimally required for crop production in Indonesia (Ma'Mun et al., 2021). Due to the limited or scarce nature of irrigation, the Indonesian government has established Water Resource Management Units that allocate water considerably based on the needs of the region, as shown in the following equations:Re_i= R_i/(1/n ∑_(i=1)^n R_i)×100 (i=1,2,3,…..n) (2)

R_i=(W_i a_i)/IA_i (3)

a_i=U_ai/U_i (4)

Where;

"Rei = index of the irrigation water resources' availability

i = abundance degree per unit area

Ri = amount of available water resources for agricultural irrigation per unit area in unit i, mm, Wi = amount of water resources in unit i104 m3

IAi = is the area of effective irrigation in unit i104 ha

αi = is the proportion of the amount of agricultural water used in total water use in units i, 104 m3/104

Uai and Ui = water amount used by agriculture and the total water use amount in unit i, respectively; i is the ith calculated unit, i = 1,2, n; n is the total number of units in the study (n=52)." Moreover, REI's value determines the abundance of irrigation water resources. It comprises three grades following the available irrigation water ratio with the region's total water availability, as shown in Table 3. If the corresponding grade is less than 0.50, it reflects the extreme shortage. However, grades ranging from 0.5 to 0.9 presents a relatively insufficient value. At the same time, the above 0.90 indexes reflect rich values of the corresponding quality.

Table 3: The grades of the abundance degree index of the agricultural water resources per unit area

The ranges of the index of abundance	The grades of the abundance degree
The index ≤ 0.5	Extreme shortage
0.5 < The index ≤ 0.9	Relatively insufficient
The index ≤ 0.9	Relatively rich

5.3 The Water Requirements of the Rice, along with Requirements of Water Regulations

The use of agricultural water resources is intimately related to irrigation areas, meteorological conditions, and crop types. In addition, irrigation water is in high demand for some drops. For example, there is a mismatch between the rice growth and the timing of precipitation. Concurrently, rice requires a quantity of irrigation water. To avoid water scarcity for irrigation purposes, rice output must be proportional to the cultivated land and available water. Concurrently, the water requirements for rice are determined by reference evapotranspiration (ET0) and crop coefficient (Kc). In this regard, the fundamental equations include the following:

$$TWD = K_C \times ET_0 \quad (5)$$

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma\frac{900}{T+273}U_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad (6)$$

where:

TWD	=	water requirement for rice, mm
Kc	=	crop coefficient of rice in the growth period
ET0	=	reference evapotranspiration, mm
Rn	=	net radiation on the surface of the crop, MJ/(m2 d)
G	=	soil heat flux, MJ/(m2 d)
T	=	daily average temperature at 2 m high, °C
u2	=	the wind speed at 2 m high, m/s
es	=	saturated water vapor pressure
kPa, ea	=	is the actual water vapor pressure, kPa
Δ	=	the inclination of the pressure curve
Γ	=	hygrometer or constant, kPa /°C

Effective precipitation during rice cultivation indicates how much rainfall may be immediately utilized as irrigation water for growing rice. In contrast, when the minimal water requirements for rice growth cannot be met through effective precipitation, irrigation water becomes the primary demand, for which the calculation is as follows:

$$P = \begin{Bmatrix} TWD & \text{if } P > TWD \\ P & \text{if } P \leq TWD \end{Bmatrix} \quad (7)$$

$$IR = \begin{Bmatrix} 0 & \text{if } EP > TWD \\ TWD - EP & \text{if } EP \leq TWD \end{Bmatrix} \quad (8)$$

where:

EP = is the effective precipitation in the rice growth period, mm

TWD = is the water requirement of rice, mm

P = the precipitation, mm

IR = the amount of irrigation water, mm

TWD = the water requirement for rice, mm

5.4 Data Sources and Unit of Analysis

Using data-sharing networks, the current study's data collection was based on convenience sampling. The authors investigated eight cities of South Sulawesi, Indonesia, and screened the sites and sounding areas. Choose fifty-six regular weather stations in certain cities with data from 2000 to 2020. In addition, data on the amount of sunlight, average wind speed, relative air humidity, average lowest and maximum temperatures, and daily precipitation were gathered and examined. The average special values of each methodological element were calculated using spatial interpretation. The quantity of water resources and agricultural water usage from 2000 to 2020 was estimated based on regional, municipal, and provincial Indonesian water resources bulletins. From the national or provincial statistical yearbook for 2000-2020, the population effective irrigated area, the cultivated area, and the planting area for rice were extracted simultaneously. In addition, the crop coefficient (Kc) was included for calculating rice's agricultural water needs.

6. RESULTS

6.1 The Condition of the Water Resources Development and Utilization in South Sulawesi Province

The availability of water resources can vary based on several factors, including rainfall patterns, geography, and land use practices. Nonetheless, the coastal regions of South Sulawesi tend to have superior water supplies compared to the inland regions. This is because coastal regions receive higher precipitation and have access to the sea, which might provide different water sources (Ma'Mun et al., 2021). Selayar Islands Regency and Pangkajene Islands Regency are located on islands and have access to seawater that can be desalinated for use. In addition, the Selayar Islands Regency contains several rivers and streams that supply potable water. Gowa Regency and Maros Regency are situated in the southern portion of the province and have access to the sea and several rivers and streams. The other regions under investigation are located further inland and may have limited access to water resources, although rivers and groundwater may still be accessible. It is important to note that climate change, population increase, and land use practices can alter the availability of water supplies. Therefore, the situation may evolve. In addition, Table 4 displays the average water resources in several South Sulawesi Province regions from 2015 to 2021.

Table 4: The average water resources from 2015 to 2021 in different regions of South Sulawesi Province

Partition of the administrative region	2015-2021	2021			
	Average water Resources amount (108 m3)	Population (104)	Cultivated Area (104 ha)	Rice output (104t)	Sown Area of Rice (104 ha)
Pangkajene Islands Regency	639.4	216	182.2	1432	101.2
Barru Regency	110.2	256	152.1	342	97.3
Bone Regency	89.2	764	159.6	223	34.7
Selayar Islands Regency	856.5	436	211.5	1765	123.2
Gowa Regency	523.3	700	178.7	762	103.4
Enrekang Regency	15.3	225	123.2	143	27.6
Pinrang Regency	57.6	496	191.7	211	80.2
Maros Regency	437.1	300	146.4	654	115.7

6.2 Cultivated Land Resources and Agricultural Water Based on Change in Matching Degree

Hydrological series for the years 2000-2007, 2008-2014, and 2015-2021 were utilized to calculate the Gini coefficients. The current farmed areas were also considered to comprehend this shift in the degree of matching. The results of these three hydrological series indicated a good fit between water sources and farmed land. Concurrently, the Gini coefficients were 0.254, 0.321, and 0.338, indicating an excellent range match for the Gini coefficients. From 2000 to 2021, three hydrological ranges showed an increasing Gini coefficient trend. It also shows the continued degradation of irrigation water availability, which serious problems have plagued for the past 21 years. The Gini coefficient of 0.338 reflects the critical matching stage, even though the results demonstrated a growing trend in water resources due to climate change over the past decade. It also shows the impossibility of expanding the farmed land on a significant scale due to the scarcity of water supplies. Also, it indicates that the nations will face severe consequences if they increase their cultivated land on a vast scale.

In addition, a downward trend was seen for the relationship between cultivated area and irrigation water resources from 2007 to 2014, which rose by 0.017 between 2015 and 2021. It also highlights a critical situation of available water resources and the difficulties of developing large-scale agricultural areas due to inadequate water resource management and a lack of water savings. These data indicate that Indonesia is a densely populated nation that has exhausted its crop-irrigation water resources. Due to the lack of water resources, improving or expanding the irrigation area and producing more food on a greater scale than its capacity is very difficult. Specifically, the South Sulawesi region has been viewed as a state with an overabundance of agricultural land, with few opportunities to expand irrigation and produce additional crops or food.

6.3 Agricultural Available Water Resources Based on Spatial Distribution and Abundance Degree Index

Considering the various regions of South Sulawesi, the analysis of irrigation water resources and its index of abundance degree revealed a total availability of irrigation water resources in the region of around 3,726 m3/ha. In addition, it reflects approximately 16% of the national average level with a radically unequal geographical distribution that increases from the greatest to the smallest locations. Moreover, the results demonstrated that the province of South Sulawesi comprises eight regions with substantial irrigation water resource availability. Their matching abundance was greater than 0.90. In addition, the results demonstrated an unequal distribution of available irrigation water resources following the irrigation areas.

6.4 Agriculture Water Resources Quantity as Facilitators of Optimization of Rice Plantation

With a large-scale rice plantation and a considerable correlation between the timing of precipitation and the rice's growth rate, abundant irrigation water resources are necessary for balanced growth. In the Indonesian province of South Sulawesi, the significance of rice plantation layout raises challenges with the logical use of uneven and limited irrigation water distribution. In addition, Figure 8 depicts the average water demand for rice in the presence of effective precipitation from 2000 to 2021. According to the data, the litigation water resource availability for rice in the province of South Sulawesi fluctuated from 501.6mm with average climatic circumstances from 2000 to 2021.

7. FINDINGS

The province of South Sulawesi in Indonesia has a long history of rice production. Rice is South Sulawesi's primary staple food and an important crop for the local economy. The predominant rice farming method in South Sulawesi is wet or paddy cultivation, including water flooding the rice fields (Limpo et al., 2022). This kind of rice growing requires substantial water and sophisticated irrigation infrastructure (Fahmid et al., 2022). The high rainfall rate and abundance of rivers in South Sulawesi make it suited for wet rice farming. Rice is normally planted in South Sulawesi during the rainy season, which typically begins in November and lasts until April (Tualle et al., 2023). They utilize a range of rice seeds, including native and hybrid kinds. The rice fields are prepared by plowing and leveling the soil, followed by flooding. The rice plants are then transferred to the flooded areas and allowed to mature. Rice harvesting in South Sulawesi often begins in May and continues until June or July, depending on the planted type. Rice is threshed and dried before being sold or kept for future use. Rice production is essential to South Sulawesi's agricultural sector, providing food and income for numerous regional families.

Even though South Sulawesi has a high rainfall rate and several rivers, the availability of water for the irrigation of rice crops might be a problem in some regions. This is due to the province's limited and uneven distribution of water resources. In some regions of South Sulawesi, rainwater is used for growing rice. Yet, water might become scarce during droughts, resulting in decreased rice yields or crop failures (Hasyim et al., 2022). Farmers in South Sulawesi have used a variety of water management practices to optimize the use of water resources to address this issue. In addition, the data demonstrated a declining correlation between water resources and cultivated land, which ultimately affected agricultural water use in the educated area of the region. In this setting, the Gini coefficient declined from 0.254 to 0.338 over 20 years, indicating a well-matched population significantly superior to the c-grade matched population. It also represents a continuing drop in the availability of production water resources in the region to cultivate rice, one of Indonesia's staple foods.

8. CONCLUSION

Concurrently, the results highlighted problems with the planting structure, resulting in food scarcity in the region and raising various questions about food security. The geographical water requirements and fluctuations and their composition for rice cultivation in South Sulawesi were evaluated. Results also revealed that in some regions of South Sulawesi, it is becoming impossible to increase food production to meet the population's needs. These worrying circumstances demonstrate the reliance of rice cultivation on the availability of irrigation water resources and the quantity of precipitation throughout the irrigation process. Previously, the research described the adjustment of planting arrangements for various crops based on an examination of meteorological circumstances (Susanto et al., 2021). For example, researchers described rice as a staple crop and its annual production as necessary for maintaining food security in Indonesia to assist the populace in meeting its basic dietary needs (Limpo et al., 2022). In addition to highlighting the impact of climate on rice cultivation as a staple meal in south Asian locations, researchers have uncovered encouraging results (Ekananda, 2022). In addition to rainwater, the Indonesian government and local authorities must manage the availability and quality of water resources for irrigation to sustain rice production over a longer period.

9. CONTRIBUTIONS AND IMPLICATIONS

Rice is a water-intensive crop that requires a lot of water for maximum development and output. Hence, managing irrigation water resources is vital to its cultivation (Ekananda, 2022). Therefore, appropriate irrigation management can assist rice producers in conserving water. Farmers can reduce the water needed for rice production while maintaining good yields by employing techniques such as alternating wetting and drying (AWD) and controlled irrigation. Also, rice producers can increase crop yield when irrigation water is efficiently managed. Farmers can employ appropriate water management practices to guarantee that their crops receive the proper amount and timing of water. Since inadequate irrigation management methods can lead to water contamination, negatively affecting human health and the environment, these practices should be improved (Almeida et al., 2021). Effective water management measures can lessen the water pollution caused by rice cultivation.

Managing irrigation water resources can also aid in water conservation. Appropriate irrigation management strategies can reduce water waste and promote sustainable water use. Proper irrigation management can also provide rice growers with economic benefits. Farmers may decrease their water costs and raise their earnings by conserving water. Managing irrigation water resources is also essential for the sustainability of rice production. Appropriate water management strategies can increase crop yield, decrease water pollution, conserve water resources, and offer farmers economic benefits. Overall, designing an agricultural cultivation plan based on the compatibility of water and land resources is a crucial factor for sustainable agricultural output.

By carefully examining available resources and selecting suitable crops and cultivation methods, it is feasible to increase output while reducing environmental damage and supporting the region's long-term agricultural development. Similarly, small-scale irrigation facilities, such as canals and reservoirs, are developed to gather and store rainwater for use during the dry season. In addition, farmers have embraced water-efficient practices like alternate wetting and drying (AWD), which can reduce water consumption by as much as 30 percent compared to conventional flooded rice growing methods. AWD entails regularly allowing the soil to dry up between irrigations, which can also minimize rice field methane emissions. Although water resources can be low in certain regions of South Sulawesi, farmers are implementing innovative water management practices to maximize available water resources and maintain rice agriculture in the region.

The government and many groups should collaborate to address these concerns and encourage sustainable agricultural methods. Similarly, the Indonesian government should pursue numerous policies and initiatives to address these issues to raise agricultural productivity and farmer incomes. They include fertilizer and seed subsidies, extension and training services, and the building of irrigation infrastructure. In addition to land reform, lending programs, and infrastructure development, the government should pursue numerous policies and initiatives to encourage agricultural development.

10. FUTURE RESEARCH WORK

This study evaluates the arrangement of farmland irrigation regions and the evolution of rice cultivation, particularly on water and land resources. However, additional investigation of other factors influencing rice farming and topography is required.

11. LIMITATIONS

In addition to the natural characteristics of the land and water resources, evaluating the cultural and economic elements that can affect agricultural productivity is essential. This may involve a review of local markets and customer preferences, as well as an examination of the existing infrastructure and transportation networks. It is possible to design a cultivation pattern that considers the area's particular qualities if these aspects are considered. This may involve crop rotation, intercropping, and cover crops to preserve soil fertility and prevent erosion.

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