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Irrigation needs of farmers based on local wisdom in the Rote Ndao District, Indonesia

Paul G. Tamelan[1,2]*, Maximilian M. J. Kapa[2], Priyono[1]

1. Department of Building Engineering Education, Faculty of Teacher Training and Education, Nusa Cendana University, Kupang, Indonesia
2. Study Program of Agribusiness, Faculty of Agriculture, Nusa Cendana University, Kupang, Indonesia

** Corresponding author's Email: pgtamelan@staf.undana.ac.id*

ABSTRACT

Efforts to address agricultural water scarcity in dryland areas, such as Rote Ndao, involve the implementation of micro-irrigation methods. The application of suitable irrigation technology is deemed essential for enhancing agricultural productivity and increasing farmers' income. Micro-irrigation aims to mitigate soil moisture depletion and water loss during prolonged dry seasons, ensuring the availability of water for plant growth. The integration of micro-irrigation technology with local cultural wisdom is anticipated to effectively meet the water requirements of dryland agriculture. This study presents key findings derived from the agricultural practices in Rote Ndao. It underscores the critical role of micro-irrigation in optimizing water efficiency, emphasizing the influence of soil texture on plant growth. Moreover, the study highlights the cultural guidance provided by local wisdom, shaping irrigation practices among local farmers. The findings reveal that a high level of trust within and between communities correlates with a low level of farmers' participation in rule-making processes. Conversely, increased interaction frequency between farmers and governmental officials positively influences their involvement in both rule-making and decision-making within irrigation management. The study recommends strategic interventions, including activities to enhance community experiences, knowledge, and understanding, improved communication and public relations regarding irrigation management, and a strengthened collaboration between agriculture-related government agencies and irrigation projects. These measures are proposed to foster sustainable irrigation management and mitigate conflicts of interest.

Keywords: Irrigation, local wisdom, dry land, Agriculture.
Article type: Research Article.

INTRODUCTION

The need for water in drylands with local wisdom is an important factor for the survival of farmers in Rote Ndao Regency, East Nusa Tenggara Province, Indonesia. Irrigation development is an effort to overcome irrigation obstacles related to the low level of water use efficiency on agricultural land in dryland areas. Water use efficiency can be optimized by collaborating irrigation technology with the local wisdom approach as a culture to support the application of micro irrigation, drip, or other appropriate technology such as the use of Sprinkler Irrigation, Drip Irrigation which is needed for rural farmers in rural areas of Rote Ndao Regency with their local wisdom to support the efficiency of irrigation water utilization in dryland farming systems. Irrigation according to Mulyani (2014) is an effort made by farming communities to irrigate agricultural land. In the modern world, there are currently many models of irrigation models carried out by farmers. The importance of irrigation systems in agriculture has led to many innovations developed in various types of irrigation applied, ranging from conventional methods to modern irrigation systems. In the context of the NTT region, which often experiences drought and water shortages, the implementation of micro-scale irrigation systems has provided dryland farmers with an effective and efficient alternative use of water, as well as ease in watering plants (Rosa 2022). The government's efforts to build irrigation areas on dry and wetland aim to develop agricultural land to fulfil food supplies for the community, emphasizing the importance of managing water wisely to meet the needs of the community (Kettani *et al.* 2022). Additionally, the contribution of irrigation infrastructure and facilities to food security has been significant, with 84% of rice production coming from irrigated areas (Velasco-Sánchez *et al.* 2021). Efforts to enhance irrigation engineering curricula and related programs have been justified by the rapid technological advancements in designing, implementing, and managing precision agriculture components, such as variable-rate irrigation and irrigation automation (Porter *et al.* 2020). Furthermore, the historical significance of irrigation in achieving large agricultural yields, especially in arid areas, has been emphasized, highlighting the fundamental role of irrigation in agriculture (Evett & Steiner 2020). It is evident that irrigation engineering plays a crucial role in providing water with the right quality, space, and time in an effective and economical way, which is essential for supporting national food supply and food security (Velasco-Sánchez *et al.* 2021). The socioeconomic and environmental feasibility of water storage infrastructure, often overlooked, is a critical aspect in the context of sustainable irrigation. Expansion of irrigation is often paired with changes in agricultural practices, industrialization of agriculture, and increased fertilizer application, which has energy implications and creates additional greenhouse gas emissions that are still unquantified (Rosa 2022). Moreover, the economic value of irrigation water has been a subject of estimation, indicating the complexity of assessing the economic aspects of irrigation (Rosa 2022). The synthesis of the references highlights the critical role of irrigation systems in addressing water scarcity, enhancing agricultural productivity, and ensuring food security. The integration of traditional and modern irrigation methods, along with advancements in irrigation engineering, is essential for sustainable water management and agricultural development. Water is known as a solvent, and a source of plant nutrients. According to Kurnia in Witmau (2021) water plays a role in determining soil fertility as microbiology in the soil acts as an activator agent of soil fertility. In the dry season, especially in the vegetative period of root growth, watering must be done every 3-4 days to maintain water availability. Lack of water in dryland farmland will cause plants to wilt. In line with irrigation which is related to the distribution of water from the source to the plants, the irrigation system that is widely used is bulk irrigation on the ground. This irrigation requires large amounts of water while the level of water use efficiency is low. By the treatment of local wisdom, the traditional way to overcome the problem of limited water with micro irrigation systems is the right solution in increasing the efficiency of water use. The main benefits of using micro irrigation technology according to Napa (2019) are affordable and beneficial, because it eliminates the need for frequent maintenance and watering by plant owners. However, due to its unattractive appearance, it tends to reduce the beauty of the surrounding plants and gardens.

In organizing irrigation on the surface, the irrigation network consists of main- and tertiary- networks. Irrigation is the business of providing, and controlling water to support agriculture. The main network, also known as the main or primary channel, secondary channels, and buildings, as well as other additional buildings, are all part of one irrigation system. The main channel is the pathway through which water passes from the main structure to the irrigation system for secondary channels and tertiary plots. The channels that transport water from primary to tertiary channels and irrigated tertiary plots are known as secondary channels, while the tertiary network consisting of sewers and drains is called a quaternary channel and serves as a water service infrastructure for tertiary plots (Wilhelmus 2011). Water is provided by irrigation, which involves dropping water through pipes near the crop or along its path. Here, only part of the root zone is wet, however in dry places, all excess water can be absorbed quickly. Thus, using irrigation water which is a very effective way is an advantage (Ludiana 2015). Based on several studies, irrigation methods with micro-irrigation can be an option that can be applied on land that has very limited water availability and physical conditions of dry land by collaborating with local wisdom. Therefore, in-depth basic research was carried out with the title "Micro Irrigation based on Local Wisdom as a solution to support irrigation in dryland areas in the rural area of Rote Ndao NTT.

MATERIALS AND METHODS

The method used in this research is descriptive in nature by describing ongoing events related to the irrigation water needs of farmers with local wisdom in Rote Ndao Regency. There are two approaches used, namely quantitative and qualitative ones. According to Sugiyono (2019), the quantitative approach records and formulas for irrigation needs that are still coloured numerically or numerically, while the qualitative approach uses a comparison of the local wisdom of the farmers. The research data analysis is an analysis of irrigation water requirements used in rice planting- patterns and rice-soy-corn planting patterns, using data in the form of potential evapotranspiration based on the empirical formula of the planting method, effective rainfall data obtained from the discharge calculation table. Water requirements for land preparation and crops are based on a constant water rate in litres/second during the land preparation period, irrigation water requirements (NFR) during the land preparation period, as well as water requirements for water changes in rice fields. Water requirement for percolation crop coefficient, discharge, and rainfall. This research has been conducted in Rote Ndao Regency by taking a case in Bebalian village, Lobalain sub-district.

RESULTS AND DISCUSSION

Role of local wisdom

Qualitatively, the role of local wisdom in the utilization of agricultural land by farmers in Bebalain Village, Rote Ndao Regency, is to direct the community to work properly and correctly or in other words to direct the community to use wise and wise farming methods, especially in terms of managing and utilizing dry land so that its balance and sustainability are maintained. The local wisdom approach in the use of dry land in Bebalain Village, Rote Ndao Regency is a legacy from ancestors who were able to preserve the environment in the form of a role model or a sacred habit and in the form of a marker that must be obeyed by the community which is hereditary. According to Ardi (2017) wisdom has a positive impact on the community, in increasing dry land productivity which has an impact on increasing farmers' income. Local wisdom is a cultural product of the past that should be continuously used as a guide for life. Although local in value, the values contained therein are considered very universal. According to Mas'ad (2015), local wisdom is an interesting thing to study and has an important role in the dynamics of the environment, even realizing that local wisdom has a positive impact on the community. Local wisdom is able to preserve nature in the form of a role model, sacred habits, and in the form of markers that must be obeyed by the community which is hereditary in the use of dry land. In relation to natural resource management, indigenous peoples, with their traditional wisdom, have managed natural resources wisely for a long time. The regulation of indigenous peoples' rights in terms of water resources management can be found in the laws and regulations governing water resources. The government guarantees the protection and empowerment of communities including indigenous peoples in efforts to conserve water and water sources. The government continues to recognize the ulayat rights of local customary law communities and similar rights, as long as they do not conflict with national interests, laws and regulations and as long as they still exist and have been confirmed by local regulations. MPR Decree No. IX/MPR/2001 on Agrarian Reform and Natural Resource Management mandates that natural resource management policies must provide living space for local cultures including environmental wisdom and legal pluralism that actually live and develop in the community. According to Adnyana (2018) local wisdom is defined as a view of life and knowledge as a strategy for community life in the form of activities carried out by local communities in meeting their needs. In addition, it can be interpreted that local wisdom is a habit that is traditionally carried out by community groups and is still maintained by the community, and can also be local ideas (local wisdom) which are wise, full of good value wisdom followed by community members, in agricultural cropping on dry land. Related to this research, local wisdom can take the form of real objects, one example is how to cultivate crops on dry land where the community uses local wisdom, namely the micro-irrigation method as a solution to support irrigation or dry land irrigation in helping farmers to grow crops. The same thing was also expressed by Hidayani (2016) "local wisdom is defined as a view of life and knowledge and life strategies in the form of activities carried out by local communities in meeting their needs". Based on Adnyana's opinion, it can be interpreted that local wisdom is customs and habits that have been traditionally carried out by a group of people for generations and are still maintained by certain customary law communities in certain areas. Based on the above understanding, it can be interpreted that local wisdom can be understood as local ideas that are wise, full of wisdom, and good value, which are embedded and followed by members of the community. Based on the opinions of the experts above, researchers take the common thread that local wisdom is an idea that arises and develops continuously in a society in the form of customs, rules/norms, culture, language, and daily habits. Local wisdom supports irrigation in this case in dryland agriculture, of course, this cannot be separated from irrigation. Related to irrigation water needs, Dwiwana (2007) explains that the need for irrigation water is the amount of volume needed to meet the needs of evapotranspiration, water loss, water needs for plants by taking into account the amount provided by nature and rain through the contribution of groundwater. To meet the water needs of plants, the determination of cropping patterns is something that needs to be considered. Table 1 is an example of cropping patterns that can be implemented.

Table 1. Planting pattern in one year for Rice-Paddy-Corn Crops.

No	Water availability for irrigation	Cropping pattern in one year
1	Ample water availability	Rice - Paddy - Maize
2	Availability of sufficient water	Rice - Paddy - Maize
3	Areas that tend to lack water Rice - Paddy - Maize	Rice - Paddy - Maize

Source: Priyonugroho (2014).

Water requirements for plants in the calculation of irrigation water requirements, according to Siarai (2021), is divided into several forms, namely: Water needs for land preparation, and planting, water needs for water changes in rice fields, and water needs for percolation, and washing.

Water needs for land preparation and crops

Land processing is carried out at the beginning of the planting season. The length of land cultivation is highly dependent on the tools used. The calculation of water requirements is done by a method based on a constant water rate in litres/second during the land preparation period with the following formula:

IR = M . ek / (ek - 1)
M = Eo + P
Eo = 1.1 Eto

Based on the irrigation water requirement (NFR) during the land preparation period is:

NFR = IR - Re

Water requirement for water turnover in rice fields

Drying of paddy fields planted with rice is done three times, namely:
(1) The first drying is done after the plant is one month old from the date of removal of seedlings from the nursery (transplantation).
(2) The second drying is done when the plant is approximately two months old, and
(3) The third drying is done about three weeks after the plants start flowering.

Water requirement for percolation

The amounts of percolation according to Rice Irrigation in Japan OTCA in Dwiwana (2007) include Sandy Loam: 3 - 6 mm/day, Loam: 2 - 3 mm/day, and Clay Loam: 1 - 2 mm/day. Meanwhile, according to the Directorate General of Irrigation of the Ministry of Public Works, the percolation rate in heavy clay soils with good puddling characteristics reaches 1 to 3 mm/day. In lighter soils, the percolation rate can be higher.

Crop coefficient (Kc)

Kc is the ratio between evapotranspiration of a plant (Etc) to the reference evapotranspiration (ETo) on a large area of land and optimum environmental conditions to produce maximum production.
These optimum conditions are free from disease attack, optimum water availability, optimum fertilization (FAO in Dwiwana 2007).
In another way the crop coefficient is expressed by the following formula:

Kc = Etc / Rto

Flow velocity is calculated using the empirical formula of direct measurement in the field.

Real Discharge

Discharge in the field to flow an irrigation is calculated based on the following formula.
Q = V × A
where:
Q = Real discharge (m^3/det)
V = Flow velocity (m/s)
A = Wet cross-sectional area (m^2).

Consumptive use of plants

Consumptive use of plants can be calculated using the following equation.

ETc = Kc × Eto
where:
ETc = Plant evapotranspiration (mm/day)
Kc = Plant coefficient
ETo = Potential evapotranspiration obtained by the modified Penman method (mm/day)

Effective Rainfall

Effective rainfall is determined by the amount of R80 which is the amount of rainfall that can be exceeded 8 times out of 10 times, in other words, the amount of rainfall smaller than R80 has a possibility of only 20%. Calculating effective rainfall for rice and similar crops is 70% of R_{80} of the time in a period.

Table 2. Recapitulation of effective rainfall for rice crops.

Month	Period	R_{80}	Re Rice	
			70% R_{80}	mm/hari
Jan	1	129.30	90.51	6.03
	2	111.83	78.28	4.89
Feb	1	105.07	73.55	4.90
	2	41.67	29.17	3.24
Mar	1	75.67	52.97	3.53
	2	66.17	46.32	2.89
Apr	1	93.67	65.57	4.37
	2	89.67	62.77	4.18
May	1	53.63	37.54	2.50
	2	60.17	42.12	2.63
Jun	1	39.00	27.30	1.82
	2	15.53	19.37	2.72
Jul	1	51.67	36.17	2.41
	2	29.70	20.79	1.30
Agt	1	23.00	16.10	1.07
	2	28.67	20.07	1.34
Sep	1	51.33	35.93	2.40
	2	27.33	19.13	1.28
Oct	1	90.67	76.53	4.23
	2	109.35	63.47	4.78
Nov	1	91.67	64.17	4.28
	2	143.33	100.33	6.69
Dec	1	83.67	58.57	3.90
	2	103.00	72.10	4.51

Source: Modified results of researcher calculations.

The coefficient of plant growth depends on the type of plant being grown. The modified coefficient table according to Nedeco/Prosida and FAO can be seen in Table 3.

Table 3. Rice plant growth coefficient by age.

Age (month)	Rice (*Nedeco/Prosida*)		Rice (FAO)	
	local	superior	local	superior
0.5	1.20	1.20	1.10	1.10
1.0	1.20	1.27	1.10	1.10
1.5	1.32	1.33	1.10	1.05
2.0	1.40	1.30	1.10	1.05
2.5	1.35	1.15	1.05	0.95
3.0	1.24	0.00	1.05	0.00
3.5	1.12		1.05	
4.0	0.00		0.95	

Source: The results of the researcher's calculations are modified.

In calculating the evapotranspiration rate, the Penman method is used. The data used are climatological data obtained from the Kupang Meteorology, Climatology and Geophysics Agency (BMKG), namely. The analysis of irrigation water requirements in the rice-paddy cropping pattern is prepared based on the ETo value where the value is obtained from evapotranspiration because it is based on monthly rainfall data (Table 5).

Table 4. Recapitulation of average monthly evapotranspiration in 2022.

Month	ETo (mm/day)	Total (day)	ETo (mm/month)
January	5.26	31	163.08
February	5.36	28	150.1
March	5.26	31	163.06
April	4.89	30	146.78
May	5.21	31	161.61
June	5.2	30	155.87
July	5.7	31	176.56
August	7.14	31	221.49
September	8	30	240.06
October	8.33	31	258.37
November	7.59	30	227.8
December	5.79	31	179.63

Source: The results of the researcher's calculations are modified.

Table 5. Maximum NFR of rice-paddy cropping patterns.

No	Plant start	NFR maximum	
		Mm/day	Lt/secon
1	January	12.61	1.46
2	February	12.61	1.46
3	March	12.81	1.48
4	April	12.58	1.46
5	May	12.59	1.46
6	June	12.59	1.46
7	July	12.81	1.48
8	August	12.81	1.48
9	September	12.61	1.46
10	October	12.40	1.44
11	November	12.45	1.44
12	December	12.45	1.44

Source: The results of the researcher's calculations are modified.

The analysis of irrigation water requirements based on the rice-paddy-corn cropping pattern is prepared based on the ETo value where the value obtained from evapotranspiration based on monthly rainfall data can be followed in Table 6.

Table 6. Maximum NFR for rice-rice-corn cropping patterns.

No	Plant beginnings	NFR max	
		Mm/hr	Lt/dt
1	January	12.47	1.44
2	February	12.47	1.44
3	March	12.45	1.44
4	April	12.58	1.46
5	May	12.58	1.46
6	June	12.47	1.44
7	July	12.45	1.44
8	August	12.45	1.44
9	September	12.58	1.46
10	October	12.29	1.42
11	November	11.37	1.32
12	December	11.42	1.32

Source: The results of the researcher's calculations are modified.

DISCUSSION

The results of this study explain that the overall irrigation water requirement is one of the important and very necessary factors in the planning and management of irrigation systems. Water availability and needs are important in irrigation activities. According to Krisnayanti (2019), factors that influence the way water is supplied and water is given are agricultural soil conditions, crop types, local climate, rain conditions, and land topography. Geographically, Rote Ndao Regency is located at 10°25'52"-11°00'27" South latitude and 122°38'33"-123°26'29" East longitude. It consists of 107 islands, including Rote Island as the main- and surrounding small- islands. The district has an area of 1,280.10 km² and is located at an altitude between 0-444 meters above sea level (masl) with the highest point at Musaklain Hill (444 masl) in the south of Rote Island. The entire area is bordered by waters including the Rote Strait, Sawu Sea, Timor Sea and Indian Ocean. Major rivers in Rote Ndao Regency include the Kuli and Batulilok rivers. Large population growth and little average rainfall around 113.93 mm cause problems with food needs. Irrigation water needs are the amount of water needed to meet the needs of growing crops in rice fields plus water loss in irrigation networks. The challenges posed by large population growth and low average rainfall, around 113.93 mm, have significant implications for food needs and irrigation water requirements. Dadang (2019) highlights several factors influencing irrigation water requirements, including evapotranspiration, effective rain, percolation, plant type, growth, tillage period, and inundation replacement. This underscores the complex interplay of environmental and agricultural factors in determining irrigation needs. Istiawati (2016) emphasizes the role of local wisdom in guiding people's responses to environmental changes, shaping societal consciousness, and influencing behaviours from the sacred to the profane aspects of life.

This underscores the importance of indigenous knowledge in addressing challenges related to water and food needs in arid regions. The study by Ewaid *et al.* (2019) provides insights into crop water requirements and irrigation schedules, demonstrating the variability of evapotranspiration and effective rainfall, which are crucial factors in determining irrigation needs. Similarly, Rajaona *et al.* (2012) offer valuable insights into the calculation of gross irrigation requirements, considering factors such as crop evapotranspiration, effective rainfall, and reduction factors for crop cover. These findings contribute to understanding the quantitative aspects of irrigation water requirements in arid environments. Furthermore, Achyadi *et al.* (2019) discuss the impacts of climate change on agriculture and local paddy water requirement irrigation, highlighting the need to consider future climatic scenarios in water management strategies. This aligns with the challenges posed by the limited average rainfall in addressing irrigation water needs. Additionally, Jha *et al.* (2016) present research on the impact of irrigation methods on water use efficiency and productivity of fodder crops, providing valuable insights into optimizing irrigation practices to meet agricultural water needs in dry periods. Moreover, the role of local wisdom in addressing water and food needs is evident in the works of Bakri *et al.* (2020) and Pramudia *et al.* (2022), who emphasize the use of indigenous knowledge for disaster mitigation and agroclimatology analysis, respectively.

The integration of traditional practices with modern approaches is crucial for addressing challenges related to water and food needs in arid regions. Factors such as evapotranspiration, effective rainfall, indigenous knowledge, and climate change considerations play a significant role in determining irrigation water requirements and agricultural practices (Confessor *et al.* 2009; Ferrand & Cecunjanin 2014; Schmidt & Pearson 2016; Jin & Wang 2016; Liyanage & Ekanayaka 2018; Goparaju & Ahmad 2019; Hailu *et al.* 2021). Goparaju & Ahmad (2019) emphasize the need for synergic approaches in arid and semi-arid regions to mitigate the impact of climate change on food security. This aligns with the importance of considering climate change considerations in determining irrigation water requirements and agricultural practices. Additionally, the study by Ferrand & Cecunjanin (2014) discusses the potential of ancient and traditional rainwater harvesting applications in response to the general climate of arid regions and past climate change events, which further supports the integration of traditional practices with modern approaches. Furthermore, the research by Hailu *et al.* (2021) highlights the significant role of traditional building techniques and materials, in combination with consideration of microclimate, in regulating the indoor environment. This underscores the importance of indigenous knowledge and traditional practices in addressing challenges related to water and food needs in arid regions.

Moreover, the study by Liyanage & Ekanayaka (2018) provides insights into the competency and challenges of traditional medical systems in contemporary Sri Lanka, emphasizing the relevance of indigenous knowledge in addressing modern challenges. Additionally, Schmidt & Pearson (2016) studied the impact of environmental, institutional, and cultural changes on natural resource management strategies, highlighting the importance of considering indigenous practices in addressing challenges related to water and food needs in arid regions. In addition, the study by Jin & Wang (2016) assessed ecological vulnerability in Western China, providing a reference for taking appropriate actions to protect ecosystems in arid regions, which is essential for addressing food needs. Furthermore, the research by Confessor *et al.* (2009) documented ethnoveterinary practices in a local semi-arid region in Northeast Brazil, demonstrating the relevance of traditional practices in addressing animal health needs in arid regions. Overall, the synthesis of these references supports the importance of integrating traditional practices with modern approaches to address challenges related to water and food needs in arid regions, emphasizing the significance of factors such as evapotranspiration, effective rainfall, indigenous knowledge, and climate change considerations in determining irrigation water requirements and agricultural practices.

CONCLUSION

1. Utilization of micro-irrigation for water efficiency is needed to maintain soil moisture and water loss caused by the dry season so that the availability of water for plants can be achieved and fulfilled for farmers on dry land in Rote Ndao Regency.
2. Soil texture is an important characteristic in micro irrigation in agricultural land because it can affect plant growth and can indirectly improve the circulation of water, air and heat, the activity of soil life, and the availability of nutrients for plants. A well-structured soil will help the optimal functioning of plant growth factors, while poorly structured soil will cause inhibition of plant growth and will be detrimental to farmers in Rote Ndao Regency.
3. Local wisdom is a binding cement in the form of an existing culture that is recognized for its existence. Local wisdom in the Rote Ndao community is a culture created through a repetitive process, through internalization and interpretation of religious and cultural teachings that are socialized in the form of norms and used as guidelines in daily life for the community in utilizing irrigation by farmers in Rote Ndao Regency.

SUGGESTIONS

1. The results of this study are expected to provide information to the people of Rote Ndao Regency in general and especially the people of Bebalain Village, Rote Ndao Regency about the importance of preserving local wisdom as a form of regional cultural preservation, especially in managing dryland resources.
2. This study is basically more aimed at technical design, not including economic analysis. Therefore, further study is needed, especially regarding field tests and economic feasibility analysis.
3. There needs to be attention from the local government to assist the community in implementing the drip irrigation system because it requires a fairly high investment.

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