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Traditional knowledge of karst land management in Gunung Sewu, Java, Indonesia

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Abstract. *Farikha KN, Arlysia V, Raharjo YAA, Santika YE, Deristani A, Setyawan AD. 2025. Traditional knowledge of karst land management in Gunung Sewu, Java, Indonesia. Intl J Trop Drylands 9: 1-9.* Karst is a landscape formed from the dissolution of rocks, particularly limestone, that are easily soluble in water. With the development of appropriate land management strategies, the karst area can be utilized as a productive and sustainable agricultural region. This research aims to understand how the community manages karst land by utilizing traditional knowledge in the villages of Songbledeg, Ketos, and Paranggupito of Wonogiri District, Central Java, Indonesia. The research employed qualitative method with data collection used interviews and field observations. Interviews was conducted using accidental sampling techniques, with questionnaires distributed to 100 respondents from the three research areas. The data was then analyzed using descriptively. The results show that most of the land is used to meet food and economic needs in the form of dry field (*tegalan*), rain-fed rice field (*sawah tadah hujan*), forest garden (*kebon*), homegarden (*pekarangan*), and vacant land. On rain-fed rice field that relies on rainwater, organic fertilizer is applied approximately two months before planting, continued with direct planting using rice seeds and the application of limestone to suppress insect pests. Since land productivity is highly dependent on rainfall, planting is typically done once a year or when the rainy season begins. To sustain their need, the farmers also plant drought-resistant crops such as peanuts (*Arachis hypogaea*), chili (*Capsicum frutescens*), and turmeric (*Curcuma longa*), as well as woody plants such as petai (*Parkia speciosa),* teak (*Tectona grandis*), etc. The local wisdom of *Gesik Deso* was conducted for clearing agricultural land at the end of dry season before rice planting. Additionally, any unused land is also utilized by the community for livestock, including cattle, goats, chickens, and ducks.

Keywords: Agriculture, community, karst, land management

INTRODUCTION

Karst is one of the most unique ecosystems in the world, characterized by its distinct topography, primarily shaped by the process of water dissolution on carbonate bedrock (Avrilan et al. 2022). The unique surface and subsurface relief characteristics of karst morphology allow it to store a large amount of water, making it strategically important (Nugroho et al. 2020). Karst serves as a water reserve because it contains aquifers that store and regulate groundwater, which is accessed through springs, caves, and wells. Karst morphology can be identified by the presence of springs in rock crevices, cone-shaped limestone hills, and underground rivers flowing through cave passages are key identifiers of karst morphology, adding to its unique charm (Nugroho and Paripurno 2019). As an ecologically important area, karst provides natural resources for various sectors, such as mining activities and utilization of karst aquifers (Pratiwi 2021). Additionally, the karst ecosystem plays an important role as a carbon sink, with its ability to capture carbon being twice as effective as that of forests (Chen et al. 2023). The larger carbon reserves in karst ecosystems are in the form of inorganic carbon stored in carbonate rocks, rather than in biomass or soil. Although the aboveground biomass of lowland rainforests such as those in Kalimantan, Sulawesi, and Sumatra is higher, however, if the carbon stored in carbonate rocks is also considered, karst ecosystems have far greater carbon reserves than any type of forest, including rainforests, peatlands, or mangroves.

Karst is a fragile terrestrial ecosystem with low resilience to environmental changes or disturbances. Its unique topography and distinctive ecology grant it high conservation value, but it remains highly vulnerable to both natural and human pressures (He et al. 2021). Natural threats to karst ecosystems include natural disasters and climate change (He et al. 2021). On the other hand, human activities such as population growth, mass tourism, water pollution, and declining water quality pose significant risks to the sustainability of its ecological functions (Duli and Mulyadi 2019; Siegel et al. 2023). These challenges highlight the critical need for immediate conservation efforts.

One of the ecological functions of karst is to regulate the hydrological system, as most springs in karst areas have significant rainfall variation (Lv et al. 2020). Karst area management must open up opportunities to utilize all existing potentials and regulate development efforts to

align with the capabilities and challenges of a region. Karst areas are complex, and therefore, management must consider the specific values related to geology, geomorphology, and hydrology, as well as flora and fauna (Soedwiwahjono and Utomo 2020). Sustainable utilization of natural resources in karst area management requires careful consideration of what is used to measure maximum capacity, as exceeding this capacity can lead to damage that is difficult to recover. This potential damage underscores the urgency of responsible resource use in karst areas (Peng et al. 2021).

The villages of Songbledeg, Ketos, and Paranggupito are part of a karst geomorphology of Gunung Sewu, Wonogiri District, Central Java Province, Indonesia. The agricultural land in these areas faces various challenges related to water availability and soil fertility. The karst environment is fragile, and the rapid water flow presents many challenges for environmental protection and management (Li et al. 2021). Karst areas often experience drought, especially during the dry season, due to the soil's inability to retain water. This affects agricultural production, as crops require sufficient soil moisture to grow well (Khotimah et al. 2019). Agricultural land management should be approached not only to increase productivity but also to conserve the environment to prevent further damage.

Traditional techniques are often more suitable for application in certain areas because they are adapted to local natural conditions and cultures. Traditional agriculture is part of cultural heritage and ancestral legacy, often encompassing unique practices and community values. Preserving traditional agriculture based on local knowledge is part of the effort to safeguard valuable identity and traditions. Local knowledge also often includes ways to adapt to climate and reduce pest risks naturally without excessive chemicals. Furthermore, developing traditional agriculture based on local knowledge is an essential strategy to achieve economic independence that aligns with the culture and way of life of local communities. The development of appropriate land management strategies is expected to make the area a productive and sustainable agricultural region, ensuring food security (Satria et al. 2018).

There are several studies focusing on traditional ecological knowledge of land management in karst area. Karst areas face challenges that require restoration to restore ecological balance (Zhang et al. 2024). The potential of applying a landscape approach to karst systems lies in developing models that provide relevant ecological information to understand karst systems and their implications for natural resource management (Canedoli et al. 2022). Communities and governments must work together to carefully consider land use change and management to minimize the risk of environmental damage to karst areas (Li et al. 2021). This research aims to understand how the community manages land by utilizing traditional knowledge in Gunung Sewu karst area, i.e., the villages of Songbledeg, Ketos, and Paranggupito of Wonogiri District, Indonesia. This study is important by integrating traditional ecological knowledge and community-based land management, it offers insights into balancing resource use with ecological conservation while safeguarding cultural heritage and ensuring food security.

MATERIALS AND METHODS

Study area and period

This research was conducted in the villages of Songbledeg, Ketos, and Paranggupito in the Gunung Sewu karst area. Administratively, these villages are located in Paranggupito Subdistrict, Wonogiri District, Central Java, Indonesia (Figure 1).

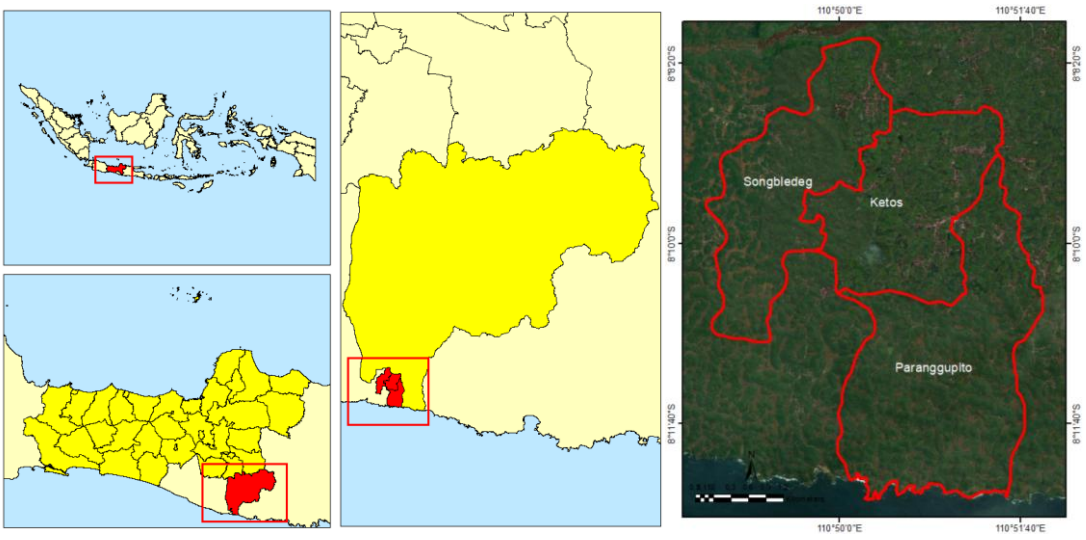

Figure 1. Map of the research location in Gunung Sewu karst area, including Villages of Songbledeg, Ketos, and Paranggupito, Paranggupito Subdistrict, Wonogiri District, Central Java, Indonesia

The reason for choosing these villages is that the agricultural activities are still considered to be traditional, which helps to reduce environmental degradation. The research was carried out in October 2024 through field observations and interviews with residents. The environmental conditions of the study area are karst, with unique topographical and hydrological characteristics, leading to limited utilization and availability of water (Jumadi et al. 2022). The southern part of Wonogiri District is known as a karst region that often faces issues of drought and a shortage of clean water due to the lack of usable clean water sources (Nurbaiti et al. 2023).

Procedures

Data were collected by field observation and semi-structured interviews using Indonesian and local language (Javanese). Data collection utilized an accidental sampling method (convenience sampling, grab sampling, or opportunity sampling) with interview questionnaires' instrument distributed to 100 respondents aged 17 years or more, representing resident of the three villages, i.e. Songbledeg, Ketos, and Paranggupito. The accidental sampling method involves selecting respondents met randomly by the researcher and are used as samples if they are suitable as data sources (Jainali et al. 2023). The selected respondents provide permission to be interviewed before the interviews proceed (Fahlevi and Fitrah 2022). Following this, interviews were conducted to determine the respondents' characteristics and gather socio-economic data such as education, occupation, gender, and age. Interviews can reveal issues more openly, allowing respondents to express their opinions in a more personal manner, which enables deeper information exploration (in-depth interview) (Ambarwati et al. 2021). This research also investigates information regarding the agricultural system, resource utilization, and policies implemented in the region. Additionally, documentation was used to capture data through images or audio recordings directly related to the research objects (Ardianti et al. 2022). A direct field survey gathered plant and animal inventory that were identified using an online sources (https://www.identify.plantnet.org/id and https://www.inaturalist.org/)

Data analysis

Interviews were conducted by filling in data or information obtained from informants into a pre-prepared questionnaire. The data was then analyzed using descriptive analysis, presenting the percentage (%) of social conditions with the total number of informants as follows.

$$Pi = \frac{ni}{N} \times 100\%$$

Where: Pi represents the proportion of socio-demographic characteristics (gender, education, occupation, and age group) in percentage (%), ni indicates the number of socio-demographic characteristics, and N denotes the total number of informants (Sagrim 2022). By using this formula, researchers can calculate and present data in the form of percentages for each socio-demographic characteristic, thus providing an overview of the overall social condition of the informants.

RESULTS AND DISCUSSION

Respondents' characteristics

This study conducted interviews to 100 respondents (Table 1), consisting of 50 males (50%) and 50 females (50%). Based on education level, the respondents can be described as follows: five respondents had no formal education (5%), 37 respondents completed elementary school (37%), 10 respondents completed junior high school (10%), and 45 respondents completed high school (45%). The majority of respondents (61%) work as farmers, eight respondents (8%) are civil servants, 13 respondents (13%) work in the private sector, and 18 respondents are entrepreneurs. Based on age, respondents were distributed as follows: over 51 years old 47 respondents (47%), 41-50 years old 16 respondents (16%), 31-40 years old 20 respondents (20%), 21-30 years old 10 respondents (10%), and under 21 years old 7 respondents (7%).

The population age in the three villages is divided into two categories: productive and non-productive age. The productive age includes individuals aged 15 to 64 who are considered capable of contributing to the production of goods and services (Prananta et al. 2023). Meanwhile, the non-productive age includes those over 64 years old, who are generally no longer active in productive activities. Figure 2 shows that 82% of respondents are in the productive age category, while the remaining 18% are in the non-productive category. The majority of the residents in the villages of Songbledeg, Ketos, and Paranggupito work as farmers (61%). People of productive age in these areas choose to work as farmers due to the limited availability of jobs outside the agricultural sector. Another influencing factor is the location of these villages, which are far from the city center; and the land uses are predominantly agricultural lands that have been managed for generations. Additionally, many respondents in the non-productive age category still work as farmers. This is due to the low rate of farmer profession regeneration among the younger generation (Oktafiani et al. 2021). The children of farmers who have completed formal education tend to migrate to other regions rather than continue working in the agricultural sector. Based on education, respondents with lower educational levels tend to choose farming because it does not require special skills or higher education (Sophan et al. 2022). On the other hand, respondents with higher education are less likely to choose farming as a profession, as most of them prefer to migrate to seek job opportunities with better income (Ibrahim 2023). This is in line with research conducted by Aprilia et al. (2019) stated that higher education leads to a preference for non-agricultural work.

Social conditions

The villages of Songbledeg, Ketos, and Paranggupito share the same natural conditions, being predominantly characterized by karst formations. Due to specific geological and hydrological backgrounds, karst areas are generally marked by high infiltration rates of water (Wu et al. 2017), thin soil layers (Ouyang et al. 2011), high soil erosion (Zeng et al. 2017), and low fertilization efficiency (Xiong and Chi 2015). These conditions shape the characteristics of karst regions, which have low environmental capacity, high sensitivity, poor stability, weak anti-interference ability, and ecological vulnerability (Hu et al. 2020). These factors contribute to the dryness or aridity of the karst surface areas, as water is stored deep underground. As a result, the local community relies on rainwater to meet their daily water needs. According to BBWS (Begawan Solo River Basin Authority 2024) data, the average monthly rainfall is 229.8 mm/month, classified as moderate based on the Meteorology, Climatology, and Geophysics Agency (BMKG).

The social conditions in the villages of Songbledeg, Ketos, and Paranggupito are influenced by the natural environment, as the difficulty in accessing groundwater forces the community to rely on rainwater for their needs. The majority of the residents in these villages work as farmers, and their work is affected by the availability of water. Some houses have rainwater storage tanks to meet the needs of several households (Figures 3.A and 3.B). The local government provided these storage tanks. Almost every house has a rainwater storage tank, with some reaching a capacity of approximately 25,000 liters. Figure 3.C shows the technique of channeling rainwater from the rooftops into the storage tanks. Harvesting rainwater in these tanks can supplement the water supply, replacing the need for springs, and is used for daily needs, including cooking (Kurniawan et al. 2023). The community perceives that the quality of rainwater is better. The three villages are also served by the regional water utility (PDAM), so water needs are fairly well met. However, residents believe that rainwater has higher quality than PDAM water. This perception may be influenced by the rural nature of the area, which means there are fewer pollutants mixed into the rainwater (Fahrudin et al. 2023). However, during the dry season, many residents seek alternative employment in the city, tend to their livestock, or rely on other crops that can still grow. Farmers often have to work outside the agricultural sector to make ends meet (Khotimah et al. 2019).

Table 1. Respondents' characteristics based on gender, education, occupation and age

Characteristics	Number of respondents	Percentage (%)
Gender		
Male	50	50
Female	50	50
Education		
No education	5	5
Elementary school	37	37
Junior high school	10	10
High school	45	45
College/University	3	3
Occupation		
Farmer	61	61
Government employees	8	8
Private - employee	13	13
Businessman	18	18
Age		
>51	47	47
41-50	16	16
31-40	20	20
21-30	10	10
< 21	7	7

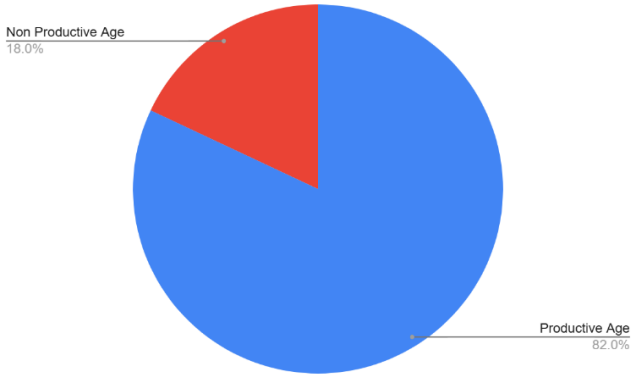

Figure 2. Respondents' characteristics based on productive and non-productive age

Figure 3. Water management at household level in Paranggupito Sub-district: A. Large-scale water storage tank; B. Small-scale water storage tank; C. Pipes for channeling rainwater into the storage tank

Biophysical conditions

Karst is utilized to support the livelihoods of the community, such as farming and cultivation, housing, plantations, clean water sources, and even tourist destinations (Bakri et al. 2023). This is exemplified by the residents of the karst area in Paranggupito Sub-district, who use karst for building houses. In addition to be used for residential, the karst in Paranggupito Sub-district is also used for agriculture by terracing fields with edges covered by karst stones. The landscape is predominantly characterized by solutional landforms resulting from the dissolution of easily soluble rocks, which typically develop on carbonate rocks (White 2020). Ecologically, karst areas function as habitats for various endemic flora and fauna (Villanueva et al. 2021). The villages of Songbledeg, Ketos, and Paranggupito host fauna such as monkeys (*Macaca fascicularis*) and porcupines (*Hystrix javanica*).

The soil in karst areas is usually formed from Mediterranean soil or soil developed from limestone (Noywuli 2023). This soil is located in hilly terrain and is characterized by a reddish to yellowish-red color, clayey texture, granular to clumpy structure, very sticky consistency when wet, slow permeability, and is classified as having low to moderate fertility (Prihatanto et al. 2022). The utilization of land resources by the communities in the villages of Songbledeg, Ketos, and Paranggupito still needs to be improved despite the large extent. The land in this area is dominated by dry fields, agroforestry land, and settlements (Wijayanti et al. 2020). These lands consist of fields located adjacent to residential areas (Figure 4.A). The land is planted with annual crops such as corn (*Zea mays*), soybean (*Glycine max*), and casava (*Manihot esculenta*). This is due to the fact that the soil in the karst tends to be very dry during the dry season (Pratama et al. 2021). The conditions of the land in karst areas lead farmers to adopt different farming practices compared to farmers in other areas, as the region is characterized by barren land and water scarcity due to the presence of limestone hills (Pranata et al. 2023).

The vacant land is also utilized by the community for livestock farming, such as cattle, goats, chickens, and ducks, as shown in Figure 4.B. The karst area also has mining activities that can alter the land's shape, which affects the hydrogeological system because the karst has a low-storage aquifer type. Fractures control water flow within the karst. Therefore, if fractures occur due to mining activities, water may not flow, altering the karst's function as an aquifer (Pratiwi 2021). In the villages of Songbledeg, Ketos, and Paranggupito, there are few new developments, whether in housing or industry. This is because the raw water sources that flow on the surface are difficult to find due to the dry soil type (Nugroho et al. 2020). Groundwater sources, such as deep wells, can reach depths of 20 meters from the surface.

Figure 4. Land management practices in Paranggupito Subdistrict: A. Field adjacent to residential areas; B. Utilization of vacant land for livestock farming; C. Land awaiting cultivation; D. Land that has been fertilized

Table 2. Plant diversity in agricultural land of Paranggupito karst area, Wonogiri, Indonesia

Local name	Scientific name
Crash crops	
Groundnut	*Arachis hypogaea* L.
Chili	*Capsicum frutescens* L.
Turmeric	*Curcuma longa* L.
Red Rice	*Oryza rufipogon* Grif.
Rice	*Oryza sativa* L.
Corn	*Zea mays* L.
Cassava	*Manihot esculenta* Crantz
Sweet Potato	*Ipomoea batatas* (L.) Lam.
Woody plants	
Petai	*Parkia speciosa* Hassk
Coconut	*Cocos nucifera* L.
Teak	*Tectona grandis* L.f
Acacia Trees	*Acacia auriculiformis* A.Cunn. ex Benth

Agricultural practices

The farmers in the karst area in Songbledeg, Ketos, and Paranggupito apply several agricultural practices to meet their economic needs, mainly based on dry land agriculture, including dry field (*tegalan*), upland rice field (*sawan tadah hujan*), forest gardens (*kebon*), home gardens (*pekarangan*), vacant lots and others. The land in the studied area has dry soil characteristics. They are dominated by easily soluble limestone, resulting from dissolution, which produces soil that is less fertile for agriculture. In their agricultural system, the farmers in Songbledeg, Ketos, and Paranggupito rely solely on rainwater without irrigation due to limited water sources, leading to a high risk of crop failure. This planting system is usually done once a year or according to the arrival of the rainy season. During the dry season, the farmers utilize drought-resistant crops such as ground nut (*Arachis hypogaea*), chili (*Capsicum frutescens*), petai (*Parkia speciosa*), and turmeric (*Curcuma longa*) to support their daily needs. Farmers also planting timber tree species such as coconut (*Cocos nucifera*), teak (*Tectona grandis*), and acacia (*Acacia auriculiformis*) to enhance economic diversification. Sometimes woody plants such as lamtoro (*Leucaena leucocephala* (Lam.) de Wit) and gamal (*Gliricidia sepium* (Jacq.) Kunth ex Walp.) are planted on agricultural land for fences and source of animal feed (Table 2). Figure 4.C shows the condition of the land that is still left vacant and waiting for processing as the rainy season begins.

Local communities rely on dryland agriculture as their main source of livelihood. The agricultural system implemented is intercropping. Intercropping is a traditional agricultural technique that involves planting two or more types of crops simultaneously on one piece of land (Mulu et al. 2020). Intercropping allows farmers to harvest various products in a single growing season. For example, farmers can plant corn and legumes together, generating income from multiple commodities. This practice helps farmers avoid dependence on a single crop and reduces the risk of crop failure due to pests, water scarcity, etc. Intercropping also allows for more efficient land use, as plants can grow side by side without competing for resources (Habibah and Astika 2020). As a result, land productivity increases, leading to greater profits from the same area. Crops cultivated during the rainy season include rice (*Oryza sativa*) (albeit in limited areas), red rice (*Oryza rufipogon*), Corn (*Z. mays*), cassava (*M. esculenta*), and sweet potato (*Ipomoea batatas*).

Unlike the common planting system, where rice paddies are directly sown with seeds, dryland planting begins with the use of seeds and planting holes that have been fertilized before the rainy season arrives (Figure 4.D). Farmers use organic fertilizers such as chicken, cow, and goat manure. Organic fertilizers are considered more environmentally friendly, enhance productivity, and are cost-effective (Kugbe 2019). They contain nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), microorganisms, and high fiber that enrich the soil (Maula 2023). Farmers prepare the land about two months before the rainy season starts. The longer the fertilization process, the better it is for maintaining the availability of microorganisms in the soil (Verma et al. 2023). Holes are made in the soil to a depth of approximately 25-30 centimeters, and then the organic fertilizer is inserted into them. The depth of 25-30 cm is where the root growth process occurs. As in the study conducted by Anshori et al. (2022), rice cultivation is carried out on the topsoil at a depth of 20-30 centimeters.

Crops are not free from threats posed by pests that interfere with growth and productivity. Farmers utilize the availability of limestone resources as a pest deterrent (*Organisme Pengganggu Tanaman*, OPT). There are several ways in which compounds related to limestone, such as quicklime (*calcium oxide*) or slaked lime (*calcium hydroxide*), can play a role in pest control or as additives in organic farming practices. Limestone is used to raise the pH of acidic soils, creating an environment that is less ideal for the development of certain soil pathogens and pests (Oktafiansyah et al. 2020). Soils with a more balanced pH tend to support healthier plant growth and are more resistant to pest attacks (Sucofindo 2023). Some farmers also use lime to reduce moisture in crops or soil, which can help decrease the populations of certain insects that prefer humid conditions. Crushed limestone or processed limestone into agricultural lime can also improve soil structure, thereby reducing soil-dwelling insects like nematodes. Some farmers always bring their pet dogs to the fields to guard against attacks from porcupines or groups of monkeys, especially during the harvest season.

During the pre-planning phase, there is a traditional community activity called *Gesik Deso* a land clearing in preparation for planting. The entire community participates in this activity, including farmers, stakeholders, and the general public. Clearing the land of weeds and wild plants helps prevent competition with the main crops that will be planted (Grecia et al. 2022). Weeds can absorb nutrients, water, and light that should be used by cultivated plants, thereby reducing harvest yields (Satriyo and Husni 2019). By cleaning the land, it can be rearranged so that farmers can maximize the space for planting. Clean, flat soil facilitates orderly row arrangements of plants, making it easier to manage. For the community, the *Gesik Deso*

activity also fosters a sense of cooperation. The community still uses traditional tools such as hoes to loosen the soil. Also, it uses machetes to clean grass, like research conducted by Sagrim (2022), which used traditional agricultural tools, machetes, sickles, and axes to clear bushes.

The designation of karst areas must refer to legislation in a holistic manner. Regulations are implemented with the aim of optimizing the sustainable utilization of karst for the continuity of human life (Osronita et al. 2023). Based on the Regional Regulation of Wonogiri District Number 2 of 2020 regarding the Regional Spatial Planning of Wonogiri District, the karst area in Paranggupito Sub-district is classified as a Geological Nature Reserve, where forestry, agriculture, fisheries, tourism, settlement, defense and security, research, and the construction of public facilities are permitted, provided that they do not change the function of the area and an environmental impact document is prepared for the Karst Landscape Area (*Kawasan Bentang Alam Karst,* KBAK). However, medium and large-scale industrial activities and mining are not permitted in this area. There are also policies regarding the raw water network for clean water optimization of groundwater resources in the form of Groundwater Basins (CAT) and groundwater within the karst. In addition, there is the development of Rainwater Harvesting (PAH) systems and Artificial Aquifer and Rainwater Storage Systems (ABSAH) in drought-prone areas. The community's high level of awareness and active participation in avoiding building structures in agricultural areas to preserve the environment is crucial. Although regulations regarding water networks are in place, the communities in Songbledeg, Ketos, and Paranggupito still need help accessing clean water during dry seasons. The residents of Songbledeg, Ketos, and Paranggupito continue to survive and manage their land using their traditional knowledge. Collaboration is key to addressing these challenges and ensuring the sustainable management of karst areas.

Discussion

The limited water conditions experienced in the villages of Songbledeg, Ketos, and Paranggupito pose risks of crop failure and hinder the economic development of the community. Unpredictable rainfall has resulted in crop failures in these villages. Groundwater in the karst areas is generally deep, leading to high exploitation costs. The water scarcity in karst areas can be addressed by expanding artificial rainwater harvesting areas to increase surface runoff coefficients and rainwater collection. In a study on karst areas in South and Southwest China, the use of water tanks for rainwater harvesting was proposed with a new design, namely by making the karst slope as a rainwater collection source and better supply service objectives to serve the local community better, increase crop production, and improve the ecology in the karst area (Jiang et al. 2019). The community could also develop concave water storage or small reservoirs to capture rainwater using geomembrane techniques (Qin et al. 2015). Further research is needed to identify potential sources of groundwater or underground rivers that can be channeled as irrigation water sources. Additionally, given the limited water conditions, farmers could switch from high-water-demand crops, such as rice (*O. sativa*), to low-water-demand crops, such as corn (*Z. mays*) or Fabaceae. It is also necessary to study the quality of rainwater the community uses for daily needs.

Farmers can also shift to cultivating crops that are less vulnerable to unpredictable rainfall, such as *Zingiber officinale* and *C. longa*, which can generate income (Putri et al. 2024). Another effective way to improve agricultural productivity is by covering rock outcrops with mulch film. This method can effectively increase groundwater content in karst agricultural land and enhance corn productivity by using film layers that cover the rocks, subsequently improving groundwater availability in the root zone (Zhao et al. 2024). Further research is still needed to focus on developing drought-resistant agricultural varieties. Another adaptation strategy is to provide financial assistance to communities for agricultural adaptation. This support is crucial for farmers to implement necessary changes and feel secure in the face of climate change. Finding alternative income sources (non-agricultural) is also important. There is a need for diversification in both agricultural and non-agricultural businesses so that the community has flexibility and economic resilience in the event of drought.

The settlement patterns in Songbledeg, Ketos, and Paranggupito villages are clustered. The clustered settlement pattern in the Wonogiri karst area results from community adaptation to challenging environmental conditions, such as limited air, difficult topography, and the need for infrastructure access and security. This pattern is supported by social traditions that encourage cooperation in everyday life. Land use in Songbledeg, Ketos, and Paranggupito villages is dominated by agriculture. Table 2 shows the plants found in the research area. The combination characteristics of Wonogiri's rocky karst soil and low rainfall are very suitable for plants with high adaptability and minimal maintenance requirements. With good management, these plants are not only suitable for planting but can also provide good economic results for local communities. Karst areas are suitable for livestock because the topography, vegetation, and environmental conditions support grazing and raising livestock. Utilizing this area for livestock also helps people optimize land resources other than for agriculture. Many people in karst areas with dry land choose to raise livestock because of limited environmental conditions for agricultural activities. Karst areas generally have thin, rocky, and less fertile soil, making it difficult to support intensive agriculture. Apart from that, low rainfall and limited water availability are the main obstacles to managing crops. Therefore, livestock farming is the main alternative as a source of livelihood because livestock such as goats, cows, or sheep are more adaptive to dry environments. These animals can take advantage of natural food available in nearby grasslands or bushes, which grow even in less fertile soil. Breeding livestock also has high economic value for society, both for

daily needs and as an asset that is easy to buy and sell when needed.

In conclusion, the land utilization in the karst areas of Songbledeg, Ketos, and Paranggupito is divided into residential, agricultural, livestock, and plantation uses. The agricultural system implemented in these three villages is intercropping, where various types of crops are planted simultaneously to reduce the risk of crop failure and maximize land use. The crops cultivated during the rainy season include *O. sativa, O. rufipogon, Z. mays, M. esculenta,* and *I. batatas*. Planting begins with the use of seeds and planting holes that have been fertilized before the rainy season arrives. During the dry season, farmers utilize drought-resistant crops such as *A. hypogaea, C. frutescens, P. speciosa,* and *C. longa* to meet their daily needs. The community uses livestock manure for organic fertilizer and limestone to help suppress pests and participates in the *Gesik Deso* activity. Traditional agriculture practiced by communities can help preserve the environment and reduce land degradation.

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