Cropping pattern as the key for sustainable agriculture in the dry land of the Gunungsewu Gunungkidul karst area

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Abstract. Dry land of karst area depends on rainfall for water supply, so cropping pattern as an important factor in agricultural sustainability. This research aimed to formulate cropping pattern as the key to sustainable agriculture in the dry land of karst area. Research was conducted in dry land of karst area, Gunungsewu, D.I. Yogyakarta, Indonesia, from January to July 2024. Observation, interview and literature study were conducted to formulate sustainable cropping pattern. Results showed that crop water requirement and rainfall determine cropping pattern. Effective rainfall in first growing season allows for cultivation of rice, corn, groundnut, soybean, and cassava. In second growing season, effective rainfall supports cultivation of corn, groundnut, soybean, and cassava. Without irrigation, third growing season is fallow. Resources in the form of water, sunlight, plant commodities, manure, chemical fertilizers, pesticides, litter, household waste, fuel and electricity are managed to support the success of cropping pattern. Successful cropping pattern are characterized by resource optimization, increased crop diversity and yield, improved soil fertility and nutrient, reduced soil degradation and crop failure, and greenhouse gas mitigation. As key to sustainable agriculture, cropping pattern are built on the basis of resource optimization, taking into account physical, economical, social and environmental aspects.

1 Introduction

Dry lands offer both challenges and opportunities for agriculture. Despite limited water availability and harsh environments, they still hold the potential for developing innovative agricultural practices and even becoming a major food source [1]. Dry land farming is limited by water availability and soil condition, optimizing resources can be a driving force in

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overcoming these problems [2]. Dry land agriculture is cultivation with little or no irrigation, relying on natural rainfall. Dry land farming plays a key role in ensuring food security and has resulted in unique agricultural systems and cropping patterns (CP). Dry land agriculture becomes important in times of global warming and climate change [3]. CP develops based on the balance between crop water requirement (CWR) and water availability, provided the CWR are met. Dry land CP is highly dependent on rainfall [4]. The choice of commodities, planting time and agricultural technology support will determine the success rate of the CP.

Dry land management depends on its water storage capacity, which is determined by rainfall. Limited water availability and low soil fertility create physical, social, and economic barriers to dry land development. A complex relationship exists between crop yield and water availability. Water scarcity leads to low yields and makes it difficult for farmers to adopt technology. Resources are vulnerable to degradation in dry land, requiring careful utilization to maintain sustainability. Utilization must consider ecosystem sustainability [5]. Dry land CP is an ancient technology, dependent on rainfall and supported by local resources. CP is linked to physical, economical, social, and environmental aspects. A balanced relationship between economic, social, and environmental aspects in agriculture is necessary to maintain sustainability, considering the increasingly depleting resources in some places. While agricultural systems purpose to generate profits, maintaining ecosystems is crucial to ensure sustainability, conserve resources, and reduce environmental pollution. This can be achieved through the implementation of CP that accommodate economical, social, and environmental aspects. This research aimed to formulate CP as the key to sustainable agriculture in dry land of karst area, physically, economically, socially and environmentally.

2 Materials and Methods

Research was conducted in dry land karst area of Gunungsewu D.I. Yogyakarta, Indonesia, from January to July 2024. Research began with location determination in dry land of karst area, specifically in the subdistricts of Girisubo, Rongkop, Tepus, Tanjungsari, and Saptosari. Data collecting and processing were then carried out to form the basis for formulating sustainable CP. Data includes physical, economical, social and environmental aspects. Data is used to formulate sustainable CP in the form of diagram. The sequence of research implementation is show in Fig. 1.

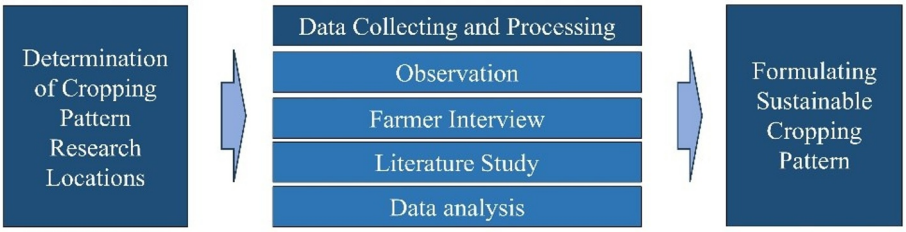

Fig. 1. Research stages as the visual representation of the entire research process

Observations referring to Creswell [6] were conducted to assess the CP actual conditions, Interviews referring to Levis [7] were conducted to gather information at the farmer level, with three key farmers in each sub-district. Data from farmer interviews were validated with findings in the field, especially related to farmer activities, crop conditions and rainfall. Literature review was conducted systematically, using Scopus, Google Scholar, and other indexing, with keywords such as dry land, CP, CWR, karst and commodities.

Data of CWR were based on the literature studies for dry land rice [8], corn [9], soybean [10], groundnut [11] and cassava [12]. According to the literature, CWR is determined based on the crop coefficient and potential evapotranspiration in the dry land conditions, thus supporting this research. Daily rainfall data was obtained from the Tepus Gunungkidul rainfall observation station and used to calculate effective rainfall (ER) using a simple method based on the USDA-SCS. ER can be calculated simply based on daily rainfall data. Rainfall <5 mm is categorized as ineffective and has a value of 0, rainfall 5 to 50 mm is calculated according to the rainfall value, and rainfall >50 mm is recorded as 50 mm considering that the remainder will be lost through surface runoff [13]. ER determination method was selected based on data availability and can be applied in the dry land of karst area.

3 Results and Discussion

CP are key to dry land agriculture, with rainfall and commodities as the primary resources. Commodity choice determines CWR. Rainfall distribution determines the amount of ER. CP require resource and technological support, which are related to physical, economical, social, and environmental aspects. Several parameters can be selected as criteria for determining CP sustainability.

3.1 Cropping pattern

Rainfall, in terms of distribution and quantity, determines the pattern of planting and timing. The choice of commodities determines the success of farming efforts. Drought stress becomes a serious problem. Inaccurate planting timing can reduce yield or crop failure. Several commodities are commonly relied upon by farmers, such as rice, corn, groundnut, soybean, and cassava. The general CP is rice-palawija-fallow. Palawija are crops other than rice, grown on dry land. Palawija include various types of crops such as legumes, tubers, and corn, which serve as sources of carbohydrates, protein, and vitamins. Without irrigation, in the third growing season is fallow. Detail the CP is rice/corn/groundnut/soybean/cassava-corn/groundnut/soybean/cassava-corn/groundnut/soybean/fallow (Fig. 2).

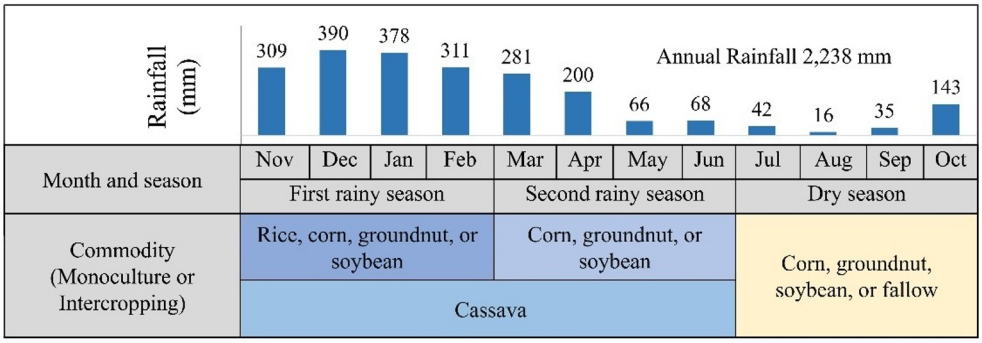

Fig. 2. Monthly rainfall and CP in dry land of Gunungsewu Gunungkidul D.I. Yogyakarta karst area

Determining CP is key to agricultural success. Accurate commodity selection and planting timing will impact growth, development, and yield. Two key considerations are CWR and ER. Another key factor is the availability of appropriate resource management technology to support CP.

3.2 Crop water requirement and effective rainfall

CWR varies throughout the growing season, influenced by variation in weather conditions and land cover. CWR is an important consideration in any cropping system, particularly in relation to water availability. CWR is based on crop type, crop phase, soil type, climatic condition, and evapotranspiration requirement. Crop coefficients at various growth stages, early, mid, and late, under specific climatic condition have been helpful in determining CWR [14]. Several types of plants have water requirement values, which have been determined by special measurements and calculations, such as water requirement for dry land rice of 563-623 mm [8], corn of 213-299 mm [9], soybean of 300-350 mm [10], groundnut of 321-425 mm [11] and cassava for 8 months growth of 624 mm [12] (Table 1).

Table 1. CWR of the agricultural comodities

Comodity	Growing periods	Plant age	Crop water requirement (mm)	
		Day	Per periods	Total
Rice of dry land [8]	Initial		69-79	563-623
	Vegetatif		139-153	
	Generative		168-189	
	Maturing		187-202	
Corn [9]	Initial	0-20	16-30	213-299
	Crop Development	21-45	78-102	
	Mid-season	46-70	116-141	
	Late-season	71-80	3-26	
Soybean [10]	Early growth	0-15	53-62	300-350
	Active vegetative	16-30	53-62	
	Flowering–pod filling	31-65	124-143	
	Seed ripening	66-85	70-83	
Groundnut [11]	First month	0-30	137-162	321-425
	Second month	31-60	128-154	
	Third month	61-90	56-109	
Cassava [12]	8 months			624

Dry land is synonymous with land whose water supply comes solely from rainfall, although irrigation is beginning to develop in some areas. The concept of ER is feasible, considering that not all rainfall is utilized by plants, it is lost through evaporation or surface runoff. Based on calculations, the ER for the first growing season was 1,160 mm, for the second growing season was 525 mm, and for the third growing season was 205 mm (Fig. 3).

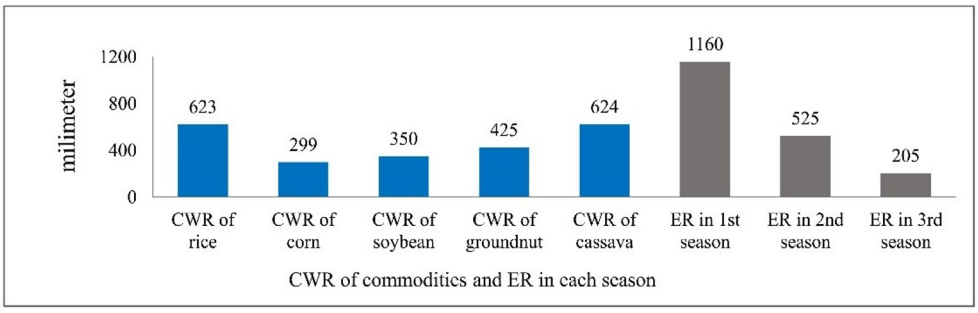

Fig. 3. CWR of commodities and ER in each season as basis for the determining CP in the dry land

CP are based on CWR and ER. Table 1 and Fig. 3 show that the first growing season is suitable for rice, corn, groundnut, soybean, and cassava. In the second growing season, water

is still sufficient for corn, groundnut, soybean, and cassava. In the third growing season, water is insufficient for plant growth, unless additional irrigation is provided.

3.3 Supporting by resources and technology

Amount and distribution of rainfall determine CP, related to CWR and ER. Resources and their management are essential for CP. Resources are utilized in integrated and optimal manner, with the application of appropriate technology to support plant growth and yield. Resources such as crop commodities, sunlight, water, fertilizer, manure, litter or harvest residue, household waste, pesticides, labor, and other are assets for present and future.

Technology is applied in resource utilization. Organic material from crop and livestock residues improves microbiological life in the soil [15]. Technologies that can be applied to improve soil properties and crop yields are fertilization and amelioration [16] [17], and the application of soil and water conservation technology [18]. Terraces will reduce surface runoff, increase soil infiltration capacity and retain sediment, reducing soil degradation [19]. Greenhouse gas mitigation can occur through carbon absorption in plant tissue [20], and use of organic materials for energy, which also avoids biomass burning [21]. Technology to optimize resources in supporting CP aims to provide optimal and sustainable results.

3.4 Sustainability of cropping pattern

Sustainable CP can be achieved by developing multi-objective functions, that maximize profits, improve social characteristics and do not cause environmental problems [22]. CP will always be closely related to physical, economical, social and environmental aspects. Physically, resources are managed to support CP. Economically, CP are low-cost, providing income and profits, so as the basis for developing CP. Socially, CP are foster cooperation, solidarity, and security for communities, so acceptable and provide support for community development. From an environmental perspective, CP ensure resource sustainability, ecosystem preservation, and mitigate climate change (Fig. 4).

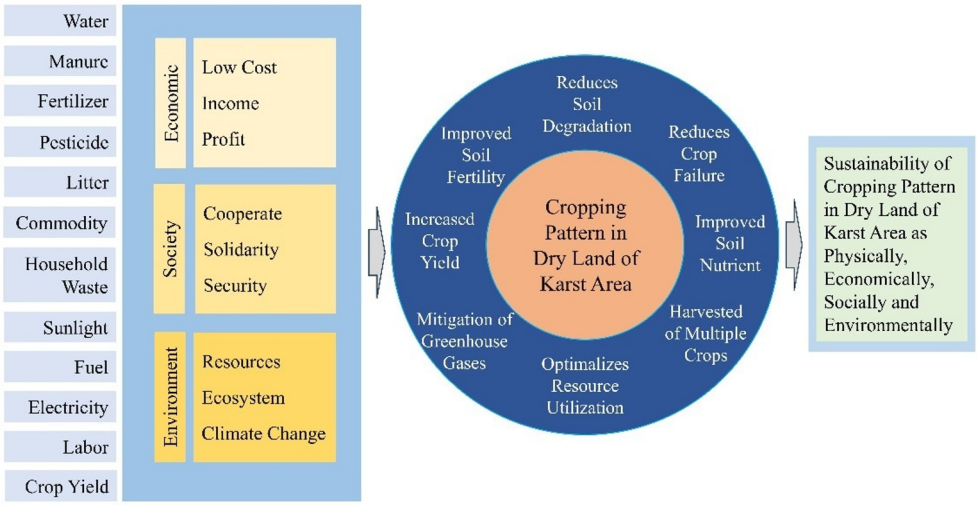

Fig. 4. Sustainability of CP in dry land of the Gunungsewu Gunungkidul D.I. Yogyakarta karst area

As shown in Fig. 4, the success of CP is determined by the resource optimization, increased crop yields, improved the soil fertility and soil nutrient, reduced the soil degradation and crop failure, diverse of crop yields, and the ability to mitigate greenhouse gases. These achievements indicate that CP is physically, economically, socially, and environmentally sustainable.

Dry land CP in the Gunungsewu karst area, with rice, corn, groundnut, soybean, and cassava as commodities, is managed appropriately, providing financial benefits, being accepted and strengthening community relationships, and no environmental damage. Proper management of animal waste, fertilizer, and litter or crop residue has increased soil fertility and nutrient, reduced soil degradation, and reduced of crop failure. Diverse crop yields are achieved through monoculture or intercropping. Greenhouse gas mitigation is achieved through carbon harvesting, carbon sequestration by plant, and without burning the litter and crop residue. The diagram in Fig. 4 is structured based on this condition.

4 Conclusion

Generally, rice, corn, peanut, soybean and cassava are cultivated in the dry land CP of the Gunungsewu Gunungkidul karst area. CP is supported by appropriate resource management. These findings indicate that CP will sustainable, because it is in harmony with the physical, economical, social and environmental conditions. Further research and the development of the cropping calendar based on local condition are needed for the CP development.

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