EurAsian Journal of BioSciences
Eurasia J Biosci 14, 683-697 (2020)

Value potential of dry land for future agricultural development in Bali

I Made Sukerta [1*], I Made Suryana [1], Anik Yuesti [1]

[1] Bali, INDONESIA
*Corresponding author: mdsukerta.unmas@gmail.com

Abstract

The calculation of crop water requirement for dry lands is expected to assist in policymaking and planning in Bali on the effective use of limited water resources to support food security and environmental conservation. Farmers need information that can assist them to use rainfall effectively, such as planting in the fixed time of plant growth phase with rain season or groundwater availability. The present research aims to (1) evaluate the potential of dry land in the research area, (2) develop water balance on dry land, (3) estimate crop water requirements of dry land, (4) develop alternative cropping calendar for pattern rotation cropping in a year and (5) simulate alternative crop rotation pattern in the most profitable year. Research sites with water balance in the Bali area included Gilimanuk, Banyuwedang, Celukan Bawang, Seririt, Buleleleng, Kubut additions, Kubu, Banjar Bunutan, Padangbai and Sanur. The amounts of rainfall and evapotranspiration yearly were approximately 1723.9 and 1833.7 mm, respectively. The amount of rainfall in the last five months from December to April was 1394.5 mm, whereas that from May to November was substantially low at only 329.4 mm. Water supply from January to April was surplus only, whilst that from May to November was deficient. These findings indicated the following conclusions. (1) Bali has a particularly hilly land condition and clay soil. As dry land farm has low soil fertility and sources water only from rainfall, cultivated plants include maize, cassava, beans, turi, banana, papaya, coconut, mango, oranges, sugar apple and teak. (2) Thornthwaite and Mather indicated that water surplus occurs from January to April whilst deficit occurs from May to November based on the water balance for Bali. High rainfall (1394.5 mm) occurs from December to April, whereas low rainfall (329.4 mm) occurs from May to November. (3) Crop water requirement in the root zone of cassava monoculture (1087.34 mm) were lower compared with those of intercropping cassava + maize (1088.89 mm) and cassava + maize − groundnut (1109.99 mm). (4) The pattern of crop rotation intercropping cassava + maize − groundnut can be planted from October 22 until June 21. Fresh tuber yields of cassava intercropping with maize and groundnut are 22.54 t ha^{-1}. (5) Cassava can be planted from October 22 to 29, sweet potatoes can be planted from February 3 to 17 and groundnut and maize can be planted from February 3 to March 17. The revenue of intercropping cassava + maize − groundnut is 25.3% larger compared with that of cassava monoculture.

Keywords: agricultural, dry land, multiculture, monoculture

Sukerta IM, Suryana IM, Yuesti A (2020) Value potential of dry land for future agricultural development in Bali. Eurasia J Biosci 14: 683-697.

INTRODUCTION

The development of dry land farming in Indonesia faces various obstacles, including socioeconomic and biophysical constraints, such as low soil fertility and limited availability of soil moisture in a year. Therefore, the availability of soil moisture, which is an important factor in the management of dry land agriculture, is determined by rainfall and the capability of the soil to store water (Yonky et al. 2003).

Opportunities to increase crop production in dry land agriculture are focused on efforts to maximise production per unit of water. A relationship exists between the water needs of plants and yields (Al-Jamal et al. 1999, Rockstron 2001). The relationship between the amount of available water and the yield of a plant is complex and can vary in frequency and intensity (Upton 1996). In addition, high temperatures, unevenly distributed rainfall and soil susceptibility to erosion will add to the complexity of the problem. Socioeconomic constraints that determine the development of dry lands include poverty, ignorance and weak infrastructure (Agung 2005).

According to Munandar (1994), the main obstacle in attempting to farm on dry lands is the unavailability of a definite source of water when needed. The unavailability

Received: April 2019
Accepted: March 2020
Printed: March 2020

of water causes frequent crop failures and low yields because conducting intensification is generally difficult for farmers, and low cropping intensity and patterns would tend to become a monoculture. The incomes of farmers and their level of welfare are also low due to low land productivity. Farmers were unable to use sufficient production inputs under these conditions. The knowledge and skills of farmers are also low, contributing to the difficulty in implementing advanced agricultural technology. Agung (2006) and Munandar (1994) explained that the low participation of farmers in agricultural development efforts leads to the limitations of existing farming facilities and infrastructure.

The development paradigm that promotes economic growth has prompted the excessive use of natural resources; thus, the exploitation of natural resources increased with population and human needs (Barine and Victor 2016, Yonky et al. 2003). As a result, natural resources are increasingly scarce, and their quality and quantity are declining.

Land and water, as vital resources for human life and development, are not immune to physical and chemical degradation. This degradation is caused by several factors, such as pollution, agricultural activities that ignore the sustainability of ecosystems and changes in the function of water bags. Furthermore, development activities have an impact on increasing erosion. Erosion can reduce land productivity at the site (*onsite*) and increase sediments in the downstream area (*offsite*) (Asdak 1995).

The utilisation of land and water resources is intended to improve the quality of life and well-being of humans, but efforts to keep these resources from being damaged are occasionally forgotten. The recent floods, droughts and landslides in Indonesia show indications of unwise use of land and water resources (Asdak 1995, Merit, 2005). The exploitation of land by planting certain types of unsuitable plants, mining activities, lack of awareness for conservation and other factors induce soil degradation. Degraded land can have an impact on the quantity, quality and continuity of water availability (Agung 2006, Yonky et al. 2003).

Critical land is difficult to utilise as a productive agricultural land due to its limitations. Maintaining adequate groundwater in areas with damaged land is also difficult. This difficulty results in the complexity of obtaining water during the dry season. Damaged soils cannot store water during the rainy season; therefore, rainwater mostly becomes surface runoff, which can cause surface erosion (Buckman and Brady 1982).

According to the BPS data for 2017, the total area of agricultural land in Indonesia is around 73.4 million ha, of which around 65.7 million ha (90.5%) and 7.7 million ha (9.5%) are in the form of dry lands and paddy fields, respectively. For dry land, the details are as follows: dry land in the form of tegal, gardens, fields or huma around 14.9 million ha, large plantations (private and BUMN) of 19.6 million ha, yards around 5.6 million ha, ponds/ponds around 760 thousand ha and others (planted with wood and or temporarily not cultivated and grasslands) with 2.9 million ha. The vast dry land area is a sizeable resource that has not been fully utilised optimally.

Based on the availability of water sources according to Munandar (1994), the typology of dry land can be distinguished as follows: (1) dry land with water sources only comes from rainwater; (2) dry land with potential groundwater sources (shallow, medium or deep) and rainwater; (3) dry land with potential surface water sources, including rainfall (as well as rivers/drainage channels, lakes and springs that appear on the surface of the ground); (4) dry land with potential ground and surface water sources; and (5) dry land with potential ground or surface water sources that have been developed. However, this irrigation water cannot be reached for some reason.

Bali generally has a longer rainy season than the dry season, with average peak rainfall occurring in January and the lowest in August. An overview of climate types according to Oldeman indicates that in the province of Bali, almost all the north, east coast and part of the west coast, from Gilimanuk, Banyuwedang, Celukan Bawang, Seririt, Buleleleng, Kubut additions, Kubu, Banjar Bunutan, Padangbai to Sanur, have climate type D3 (Wet month = 3-4 months, Dry month = 4-6 months), except for Tejakula with type D4 (Wet month = 3-4 months, Month dry = 7-9 months). By contrast, southern Bali is mostly C3 (Wet month = 5-6 months, dry month = 4-6 months), except for Kuta beach with type C4 (wet month = 5 months, dry month = 7 months) and Dawan with type E4 (month wet = 0-2 months, dry month = 7-9 months) (BMKG 2006).

Farmers can only perform intercropping planting once a year. The second crop often fails when planting is performed twice due to the lack of water (Santosa 2006). Planting in the third planting season has never been conducted by farmers due to the high risk of crop failure. Dry land farmers mostly only use annual crops in the rainy season (Baharudin 1997). Current crop rotation patterns are cassava, corn + peanuts − fallow and cassava, corn + soybeans − fallow. The water shortage problem occurs in the second and third growing seasons (Santosa 2006). Planning cropping patterns according to land quality and water efficiency is needed to use water optimally.

The calculation of crop water requirements for dry lands is expected to help the South Bali region in policymaking and planning regarding effective ways of using limited water resources to support food security and environmental preservation. Farmers are in dire need of helpful information in terms of using rainwater effectively; for example, adjusting the phase of plant growth with the availability of rainwater or groundwater (Prijono 2008).

Dry land agriculture is faced with complex constraints, such as erratic rainfall that runs the risk of drought. The status of soil fertility is generally relatively low, which results in low land productivity. The research area is a dry land related to the existing land and agro-climatic conditions. Determining the potential of the land for future agricultural development, especially for profitable crops, is necessary. The development of new plants at this time has not been conducted by farmers. Therefore, investigations through direct experiments in the field or by simulations must be conducted to determine the adequacy of groundwater for plants.

The crops cultivated by farmers today are annual crops (corn, peanuts, soybeans and cassava). Thus, intensive exploitation, including determining the planting time and applying the appropriate crop rotation pattern, is needed. The problems in the field that must be analysed are as follows: (1) suitability of dry land, (2) water balance in dry land, (3) crop water requirements, (4) determination of planting time and preparation of cropping patterns and (5) analysis of cropping patterns. Agricultural activities in the future will be intensive. Therefore, the following five basic aspects must be fulfilled: (1) conducted by the community and in accordance with local agro-ecological conditions, (2) economically beneficial in the economic conditions of rural areas, (3) snot in conflict and can even encourage the motivation of farmers, (4) friendly and safe for the environment and (5) able to open opportunities to encourage regional economic growth in a sustainable manner (Setyaningsih and Sumarno 2009).

CONCEPT OF DRY LAND DEVELOPMENT

The development of dry lands is faced with various biotic and socioeconomic constraints and limiting growth factors, such as low soil fertility and the unavailability of water throughout the year. The limited amount of rainfall is usually the only source of water in dry lands to meet the needs of plants. Dry land farming is often attempted only once a year because of poor water management. This monoculture causes low productivity and considerably high risk of failure, thus leading to substantially low incomes of farmers (Munandar 1994).

Focusing on the condition of the soil, climate and plants is important to realise intensive planting. The availability of groundwater is a crucial soil condition and depends on the climate (i.e. rainfall). Thus, regional, land and groundwater balance were obtained on the basis of calculations through the CropWat software.

The water needs of plants is the element that must be considered. Plant water requirements are influenced by plant coefficients (Kc) and reference evapotranspiration (ETo), which is largely determined by climate elements, such as temperature, humidity, wind speed and exposure time (Penman-Monteith; Islami 1995). Determining the groundwater balance and crop water requirements will help dry land farming in determining the appropriate planting time and patterns. Production is hoped to be increased to boost the income of farmers.

METHOD OF DRY LAND DEVELOPMENT

The development of dry lands in the Bali area, from Gilimanuk, Banyuwedang, Celukan Bawang, Seririt, Buleleleng, Kubut additions, Kubu, Banjar Bunutan, Padangbai to Sanur, was conducted. This development was performed from October 2018 to July 2019 through observations, interviews and field experiments. Observations and interviews were conducted to determine the farming system performed by farmers, whilst field trials were performed to examine the development pattern of dry land-based agricultural land water balance. The initial preparation included consultations with relevant agencies to determine the location of the study. A literature study on previous research on dry land moisture balance and cropping patterns was also conducted at Udayana University Central Library, Central Mahasaraswati University Library and other related institutions during the preparation stage. A trial version of CropWat for Windows was used to analyse reference evapotranspiration, crop water demand and estimated crop yield reduction.

RESULTS OF DRY LAND DEVELOPMENT

Vegetation in the Location of Dry Land Development

The types of plants that grow in the dry land development area are maize, peanuts, cassava, waluh, oranges, papayas, mangoes, srikaya, turi and teak. These plants grow together to form vegetation beds. Based on direct observations on the field during dry land development, vegetation is uneven and rather rare and infertile during the dry season, whilst that during the rainy season appears green but is overgrown with weeds. Such a phenomenon is dominant due to the limited availability of water. The types of cultivated plants are generally annual, semi-annual and annual plants. Annual crops include maize, cassava and beans. Semi-annual plants are banana and papaya, and annual plants are coconut, mango, orange, srikaya, teak and turi. The observations in the field indicate that all lands in Bali are dry land, no water source other than rainwater is available and local farmers only plant once a year. Moreover, food crops are planted monoculture with minimum tillage, seeds are only spread out and a considerable amount of potential land is left overgrown with grass and weeds. Some places have land with hard limestone, making planting impossible. A considerable amount of lot for agriculture has been converted to villas and other tourism facilities.

Table 1. Farmer Income per Hectare of Each Series Planting Pattern

Plant	Varieties	Period Growing Crop	Yield (t ha^{-1})	Farmer Income (Rp.)
Cropping pattern 1: Monoculture				
Cassava	Adira-1	22 Oct–21 Jun	24.19	2.833 million
Cropping pattern 2: Intercropping Corn Cassava +				
Cassava	Adira-1	22 Oct–21 Jun	22.94	11.1905 million
Corn-3	Pertiwi	22 Oct–26 Jan	5.44	
Cropping pattern 3 : Tumpangsari Cassava + Maize – Peanut				
Cassava	Adira-1	22 Oct–21 Jun	22.54	11.3855 million
Corn-3	Pertiwi	22 Oct–26 Jan	5.44	
Peanut	hare	3 Feb–May 5	0.17	

Table 2. Farmer income per year per planting area of each planting pattern

no.	Planting Pattern Planting	Area (Ha)	Period (Day)	Farmer income (Rp.)
1	Cassava	38	242	107,654,000
2	Cassava + Corn	38	242	425,239,000
3	Cassava + Corn − K. Land	38	242	432,649,000

Regional Water Balance (Thornthwaite-Mather Method)

Tables 1 and **2** respectively present a surplus month from January to April and a deficit month from May to November. The amount of rainfall and evapotranspiration yearly is 1723.9 and 1833.7 mm. High rainfall only lasts five months from the month.

Water Balance Simulation with the Method *CropWat for Windows*

Simulation is performed using the model *CropWat for Windows* according to FAO proposed by Smith (1992). The data are taken from the climatology data from 2010-2017 from the Meteorology Centre for Climatology and Geophysics Region III Ngurah Rai station.

Analysis of Planting Patterns

Economic value

Cassava intercropping plants + corn − peanut have the highest economic value, with an income of Rp. 11,385.00 ha^{-1}, followed by cassava intercropping + corn with Rp. 11.1905 million ha^{-1}. Cassava has the smallest monoculture (UK) Rp. 2,833,000 ha^{-1}.

Table 2 shows that the third cropping pattern of cassava + corn − peanuts (UKJKT) has the highest profit of Rp. 432,649,000, followed by the second cropping pattern (UKJ) of Rp. 425,239,000. The lowest profit is the cassava monoculture (UK) cropping pattern of only Rp. 107,654,000. If the calculated profit per day for the third cropping pattern is Rp. 299,038 for a planting area of 38 ha, then the second cropping pattern and the cassava monoculture planting pattern would respectively be Rp. 1,181,219 and Rp. 1,201,802. Thus, the third and second intercropping cropping patterns can be chosen because they provide larger benefits compared with those of monoculture planting patterns.

The selected cropping pattern has a high profit with production costs. Local farmers aim to apply the selected planting pattern to increase their farming yields and maintain food security. Whilst farmers in the village of Pecatu plant food crops by monoculture and only plant once a year during the rainy season, the remaining land is left overgrown with grass and weeds. Therefore, establishing demonstration plots in the field as a means of socialisation is necessary. These plots can help farmers determine their cultivation techniques and encourage participation in farming by intercropping. Thus, their farming businesses can yield high economic value.

Planting calendar

Planting time trials are conducted in dry land fields to evaluate the effect of planting time on plant growth and yield. The simulation analysis results showed that cassava can only be grown from 22 to 29 October (**Table 3**), as obtained from the estimation of linear regression equation y = 0.093x + 0.289 with R^2 = 0.99. In this equation, obtained plants were planted on October 22, actual plant evapotranspiration (ETc) was 1070.0, maximum evapotranspiration (ETm) was 1133.5 mm and water shortage was 63.5 mm to meet maximum ETc needs and realise a reduction in yield of 6.2%.

When the planting time was delayed to October 29, the actual plant ETc and ETm decreased to 1047.4 and 1142.2 mm, respectively. lack of water of 94.8 mm to meet the ETm; thus, the reduction is 9.1%. If the planting time is delayed again until November 5, then the actual ETc is 1019.3 mm, the ETm is 1151.8 mm, the water shortage is 132.5 mm and the reduction in results that passed the threshold above 10% is 12.7%. These conditions are caused by the effect of the increasing level of groundwater deficit in the root zone, which is indicated by the value of the low ETc/ETm ratio. The low value of the ETc/ETm ratio indicates that the availability of groundwater is insufficient to meet crop water needs.

Sweet potato plants are planted in the rainy season from October 22 to November 12 with a yield of 0% reduction, whilst those planted in the dry season I can only be planted on February 3-17 (**Table 4**) based on the estimation of the acquired linear regression equation y = 0.294x −3.075 with R^2= 0.98. Plants planted on February 3 had actual crop ETc and ETM of 543.3 and 570.7 mm, respectively, lacked water by 27.4 mm and a yield reduction of 5.3%. If the planting time is delayed on October 29, then the actual ETc and ETm are 496.1 and 536.3 mm, respectively, the water shortage is 40.2 and the reduction is 8.3%. If the planting time is delayed until November 5, then the actual ETc and ETm respectively decrease by 457.3 and 502.5 mm, water shortage is reduced to 45.2 mm to meet the ETm and the resulting reduction is 9.9%. If the planting time is delayed again until February 24, then the actual ETc and ETM are respectively decreased by 398.0 and 451.2 mm, water shortage is 53.2 mm and the reduction in the result is 13%. These phenomena are caused by the influence of the increasing level of groundwater deficit in the root zone. This influence is demonstrated by the value of the

Table 3. Balanced groundwater and yield reduction in the rainy season (MH) by reversing planting time

Pattern	Crop Into1	Planted	Effective Rain (mm)	ETc (mm)	ETc/ETM (%)	SMD end (mm)	Reduction Results (%)
UK + (J − KT)	Cassava	22/10	1022.3	1070.0	94.4	47.7	6.2
		29/10	990.0	1047.4	91.7	57.5	9.1
	+	5/11	955.2	1019.3	88.5	64.0	12.7
		12/11	919.5	987.5	85	67.9	16.5
	Corn	22/10	337.7	348.5	100	10.8	0
		29/10	340.0	342.7	100	2.7	0
		5/11	331.0	339.7	100	8, 7	0
		12/11	324.7	340.1	100	15.4	0
JG + (KT − KT)	Corn	29/10	309.8	320.1	100	10.3	0
		29/10	312.5	315.1	100	2.6	0
	+	5/11	304.5	312.8	100	8.3	0
		12/11	299.0	313.7	100	14.7	0
		19/11	311.8	317.5	100	5.8	0
		26/11	311.8	323.9	100	12.1	0
	K Land		22/10 290.6 300.9 100 10.3 0 29/10 293.2			, 3	0
		12/11	279.2	294.3	100	15.1	0
		19/11	292.0	298.0	100	5.7	0
		26/11	291.7	304.1	100	12.4	0
UJ + (J − KT)	Sweet potato		22/10 495.2 504.5 100 9.3 0 29/10 503.0	510.0	100	11.6	0
		19/11	510.3	514.6	100	4.4	0
		26/11	511.6	520.6	100	9.0	0
	Corn	22/10	301.1	309.1	100	8.0	0
		29/10	301.6	303.5	100	2.0	0
		5/11	294.0	300.4	100	6.4	0
		12/11	288.7	300.2	100	11.5	0
		19/11	298.7	303.1	100	4.4	0
		26/11	299.1	308.5	100	9.4	0
JG + (KT − J)	Corn	22/10	309.8	320.1	100	10.3	0
		29/10	312.5	315.1	100	2.6	0
	+	5/11	304.5	312.8	100	8.3	0
			12/11 299.0 313.7 100 14.7 0 19/11 311.8				
	K Land	22/10	290.6	300.9	100	10.3	0
		29/10	293.2	295.7	100	2.5	0
		5/11	285.0	293.3	100	8.3	0
		12/11	279.2	294.3	100	15.1	0
		19/11	292.0	298.0	100	5.7	0
		26/11	291.7	304.1	100	12.4	0

low ETc/ETm ratio. This low ratio indicates that the availability of groundwater is insufficient to meet crop water needs.

Peanuts can be grown in the dry season I (MK I) from February 3 to March 17, as obtained by the estimation regression equation $y = 0.20x + 0.052$ with $R^2 = 0.99$. For the dry season I, in addition to the peanut crop, the corn plant evaluation from the simulation results indicate

Table 4. Groundwater balance and yield reduction in the dry season (MK)

Plants **to 2**	**Planting**	**Effective Rain (mm)**	**ETc** **(mm)**	**ETc / ETm (%)**	**Final SMD (mm)**	**Reduction of yield (%)**
Peanuts	3/2	348.6	356.7	100	8.2	0
	10/2	336.6	350.8	100	14.2	0
	17/2	340.7	346.4	100	5,7	0
	299.3 311.2		24/2	100	12.0	0
	3/3	602.1	333.7	100	18.1	0
	10/3	564.7	329.7	97.9	36.0	1.5
	3/17	526	313.9	91.9	44.6	5.7
	3/24	445.9	293.1	84.3	46.0	11
Corn	3/2	408.1	417.3	100	9.2	0
	402.3 418.4		10/2	100	16.2	0
	2/17	413.2	419.6	100	6.4	0
	2/24	398.7	412.2	100	22.5	0
	3/3	385.9	423.9	100	38.0	0
	10/3	356.7	427.9	100	71.2	0
	3/17	325.3	423.4	97.6	98.0	2.9
	294.3 395.7		24/3	89.8	101.5	12.7
Sweet potato	483.1 543.3		3/2	95.2	60.3	5.3
	10/2	433.4	496.1	92.5	62.7	8.3
	17/2	391.2	457.3	91	66.1	9.9
	329.9 398.0		24/2	88.2	68	13

that corn plant can also be planted from February 3 to March 17, as obtained by the estimation regression equation $\hat{Y} = 0.283x - 0.019$ with $R^2 = 0.99$.

Plants planted on February 3 had an actual ETc and ETm of 543.3 and 570.7 mm, respectively, water shortage of 27.4 mm and yield reduction of 5.3%. If the planting time was delayed on October 29, then the actual ETc and ETM were respectively 496.1 and 536.3 mm, water shortage was 40.2 mm and yield reduction was 8.3%. If planting time was delayed again until November 5, then the actual plant ETc and ETM also respectively decreased by 457.3 and 502.5 mm, water shortage would be 45.2 mm to meet the ETm and the resulting reduction would be 9.9%. If the planting time is delayed again until February 24, then the actual ETc and ETm are respectively decreased by 398.0 and 451.2 mm, water shortage is 53.2 mm and the resulting reduction is 13%. These phenomena are caused by the effect of the increasing level of groundwater deficit in the root zone. Such an effect is indicated by the value of the low ETc/ETm ratio. The low value of the ETc/ETm ratio indicates that the availability of groundwater is insufficient to meet crop water needs.

Calendar planting according to the evaluation results of the balance of groundwater and a possible decline in the results of the most secure if taken resignation at planting possible risk of deficit of soil moisture will increasingly threaten (Prijono 2010)

The cropping pattern of structure planning can be used as a basis for subsequent research. Preparation of this cropping pattern is a choice of possible cropping patterns, which have the opportunity to be attempted with the safest level of yield reduction to increase the usability of dry land. The most important plants used are varieties of those that are resistant to the dry, short life and high production.

DISCUSSION

Farmers in the South Bali region, especially in Bali, generally only plant once a year during the rainy season and grow food crops in a monocultural manner. They also hardly perform land management. The land is hilly with some rocky areas (limestone), the clay soil is dusty and the nutrient content and soil organic matter are low. The typology of land includes type A, in which the source of water comes from rainfall. A rapid change in the function of land, which was once an agricultural land and has been turned into non-agricultural lands, such as properties, hotels, villas and other supporting tourism, has been observed in the last few decades. This phenomenon is dominant due to the limited availability of water. Thus, local farmers are reluctant to conduct farming activities.

The climatology data obtained at the Ngurah Rai climatology station indicated that the irradiation, radiation and evapotranspiration patterns were low during the rainy season and increased during the dry season. By contrast to humidity, wind speed and rainfall and rainy days, the pattern was reversed. The mean daily evapotranspiration during the study period was 3.32-5.17 mm day^{-1}, the number of evapotranspiration during the study period was 1266.2 mm and the amount of rainfall was 2109.6 mm. This finding shows that during the study period, the amount of rainfall that entered the study area was larger than the water that came out through evapotranspiration.

The results of the regional water balance calculation from Thornthwaite-Mather (from the data for a period of 10 years, namely, from 2010 to 2017) show the presence of a water surplus from January to April and a water deficit from May to November. The average amount of rainfall in a year is 1723.9 mm and its evapotranspiration is 1833.7 mm. High rainfall only lasted for five months (December-April) of 1394.5 mm, whereas rainfall (May-November) was considerably low at 329.4 mm. The amount of evapotranspiration for seven months reached 1126.4, demonstrating a water deficit of 797 mm. Doorenbos and Kassam (1986) indicated that the occurrence of water deficits in plants will result in *water stress*, which affects plant evapotranspiration and crop yields. Moreover, the effect of water deficits on plant growth and yield considerably varies depending on plant species and the period of plant growth. Water is a natural material that is needed by plants in sufficient quantities at the right time. Excess or lack of water easily leads to disasters. Plants experiencing drought will have an impact on quality degradation or crop failure. Excess water can impact *leaching*, erosion and flooding, which also results in the risk of crop failure.

Water balance simulation results using the model *CropWat for windows* with climatological data from the past 10 years (from 2010 to 2017) found that in the water balance in monoculture Ubikayu, water needs of cassava intercropping + corn and cassava intercropping + corn − peanuts planted during the rainy season (MH) considerably vary. Peanuts and sweet potatoes are planted monoculture in the dry season I (ICM) with four different planting times. In the water balance, not all patterns are found in the reduction results when planting conditions are the same. Evapotranspiration on monoculture cassava plants was 911.6 mm, that on cassava + corn intercropping was 938.4 m and that on cassava + corn-peanut intercropping was 949.6 mm. The absorption of groundwater to meet the highest demand for evaporation is observed on cassava intercropping + corn - peanut. This finding means that the potential for the highest water deficit in intercropping cassava + corn-peanut will disrupt plant development and yields.

Simulation results on plants planted in the rainy season did not experience problems because the yield reduction was below 10%; that is, 7.3% for monoculture cassava, 8.3% for cassava + corn intercropping and 8.8% for cassava intercropping + corn − peanuts. By contrast, in plants planted in the dry season I (MK I), peanut plants still provided good results. If peanut plants are planted in the second, third and fourth weeks of February, the yield reductions are 6.1%, 10.3 % and 15.2%, respectively. All treatments for crop reduction yields above 10% indicate that planting sweet potato plants in the dry season I is unsuitable because a decrease in yield by 35.6% is observed with planting beginning in February alone. Thus, sweet potatoes are suitable if planted in the rainy season (MH).

The model *CropWat for Windows* can simulate complex plant-soil-climate phenomena on land to predict crop evapotranspiration and irrigation scheduling by solving the water needs of crops in various cropping patterns. The dynamics of groundwater content and deficit in rooting areas are important information for decision making on water resource management. The model calculates plant reference evapotranspiration, crop water requirements and estimated decline in crop yield due to crop water stress. The yield reduction threshold is calculated to be a maximum of 10% (Santosa 2006, Shahamat et al 2015).

Research shows that the average groundwater storage on the roots of cassava plants with a monoculture cropping pattern (UK) showed that during the growth period, rainfall occurred at 2416.50 mm, *run-off* 507.96 mm and total changes in groundwater storage (□S) of 821.20 mm. Total evapotranspiration of 1087.34 mm is the difference between total rainfall, *run-off* and changes in groundwater storage during cassava growth in monoculture (UK) cropping patterns. The total evapotranspiration illustrates the large water needs of cassava plants with a monoculture planting pattern (UK) at the study site. Cassava crop yields with monoculture (UK) cropping patterns are 24.19 t ha^{-1}. Compared with the potential yield of cassava plants in the Muara variety with a mean wet tuber of 38.2 t ha^{-1}, the yield of fresh tubers in this experiment is low (Department of Agriculture, Food Crops and Horticulture, Badung Regency, 2009).

Total groundwater storage in the roots of cassava plants with control treatment was 7.30, 8.76 and 11.00 cm at 60 days after planting, 83 days after planting and at the end of planting (*late season*), respectively, in Nigeria (Kehinde et al. 2011). Research conducted by Odubanjo *et al*. (2011) showed that the highest average groundwater storage in the cassava root zone occurred in the *mid-season* (144 days). Cassava plants are plants resistant to water stress. According to Nassar and Ortiz (2007), if soil moisture decreases, then cassava plants will shed their leaves; if water becomes available, then cassava plants will sprout again and produce their leaves. Furthermore, the vegetative growth of cassava plants lasted for five months, and then the root development and tuber filling occurred and stopped at the plant age of 7-9 months.

The water requirement of cassava plants is relatively low (Odubanjo et al. 2011, Omonona and Akinpelu 2010) because excess water can cause spoilage in tubers of cassava plants (Fasinmirin and Reichert 2011). Omonona and Akinpelu (2010) stated that cassava plants are generally planted in areas with rainfall <800 mmyear^{-1} and four to six months dry month. Although cassava plants are classified as plants that are tolerant of water stress, tuber yields will decrease if water stress is sufficiently long. The decrease rate of which tuber yield depends on the duration of water stress and the phase at which water stress occurs. The critical period for water stress in cassava is one to five months after planting (Alves 2002 *in* Omonona and Akinpelu, 2010). Water that occurs for two months on its growth can reduce tuber yield of cassava plants by 32%-60% (Connor et al stress. 1981). Other studies mentioned that high water stress can affect the vegetative and generative growth of cassava plants (Laban et al. 2013). Furthermore, water stress is more influential in decreasing the fresh weight of tubers than that on vegetative growth. When water stress occurs, cassava responds by covering the leaf stomata such that transpiration decreases (El-Sharkawy 2012, Odubanjo *et al*. 2011, Ogutundea and Alatisea 2007).

Groundwater balance in the mint root corn with cropping patterns of cassava + corn intercropping (UKJ) shows total rainfall of 1073.30 mm, *run-off of* 239.81 and total changes in groundwater storage of 385.59 mm. These data indicated the water needs of corn (ET) plants with cassava + corn (UKJ) intercropping patterns of 447.90 mm. Frimpong *et al.* (2011) stated the water needs of corn plants during growth between 350-450 mm. The critical period of maize plants is during the phases of *tasselling* and seed filling in corncobs (Thimme et al. 2013). Groundwater balance in the roots of cassava plants with cassava + maize intercropping (UKJ) cropping pattern shows total rainfall and *run-off* similar to monoculture cassava (UK) cropping patterns, but the total change in groundwater storage (□S) is low at 819.65 mm. Thus, the water requirement of cassava (ET) cropping with cassava + corn (UKJ) intercropping pattern is lower than that of monoculture (UK) cassava cropping pattern (UK) at 1088.89 mm. Groundwater deposits are influenced by components of precipitation, irrigation, capillary pore suction to the roots, *run-off*, inward percolation, evaporation and transpiration (Hartman 1983). Intercropping planting patterns will cause competition in the use of water; thus, groundwater storage will be lower than monoculture planting patterns (Daellenbach et al. 2005).

The yield of fresh cassava in the cassava + corn (UKJ) intercropping pattern was 23.94 t ha^{-1}. The results were lower than the monoculture cassava (UK) cropping pattern, which was 24.19 t ha^{-1}. Daellenbach et al. (2005) concluded that the yield of fresh cassava tubers and total biomass production in cassava intercropping decreased compared with that in monoculture cropping patterns in Rio Cabuyal. By contrast, Hartojo and Widodo (1991) reported that hybrid maize intercropped with cassava did not affect the yield of fresh cassava plants in Indonesia. The dry weight yield of corn shells ka12% is equal to 5.44 t ha^{-1}. This result is slightly lower compared with the average corn production of Arjuna varieties in Bali at 5.64 t ha^{-1} (Department of Agriculture, Food Crops and Horticulture, Badung Regency, 2009). Intercropping cropping patterns can cause competition in the use of nutrients, water and light (Daellenbach et al. 2005) needed in plant growth and yield. Water stress can reduce corn production by 50%-60% (Banziger et al. 1997 *in* Sahindomi *et al.* 2013). Water stress that occurs during the flowering and *tasselling phases* can reduce corn production by 40%, whilst stress that occurs during the filling of seeds on the cobs can reduce corn production by 66%-93% (Bruce et al. 2002, Cakir 2004).

Balance sheet groundwater in the corn root mintakat with cassava intercropping + corn − peanut cropping pattern is the same as cassava + corn intercropping cropping pattern. Groundwater balance on groundnut roots with cassava intercropping + corn − peanut cropping pattern shows that total rainfall is 1169.40 mm, *run-off is* 250.52 mm and total changes in soil moisture storage (□S) is 439.14 mm. The water requirement for peanut (ET) in the study site is 479.74 mm. Idinoba *et al.* (2008) indicated that the water requirement of the peanut plant was 302.5 mm during its growth. Groundwater balance in the roots of cassava plants with cassava intercropping + corn − peanut cropping pattern shows that rainfall and *run-off are the* same as monoculture cassava cropping patterns. Meanwhile, the total change in groundwater storages in the cassava root crop with cassava intercropping + corn − peanut cropping pattern is lower than that in the monoculture cassava and cassava intercropping cropping patterns at 798.55 mm. Therefore, the water needs of cassava cropping with cassava intercropping + corn − peanut cropping pattern is 1109.99 mm. Crop water requirements increased in intercropping cropping patterns compared with the UK monoculture planting patterns. Intercropping planting patterns have advantages and disadvantages; one of the effects of intercropping planting patterns is competition in the use of nutrients, light and groundwater (Daellenbach et al. 2005).

The yield of fresh cassava plants with the cropping pattern was 22.54 t ha^{-1}. The tuber yield in this treatment was lower than the tuber yield in treatment. Cassava intercrops + peanuts in India also cause a decrease in tuber yields of cassava (Amanullah et al. 2007). The cropping pattern of intercropping has an impact on the yield of cassava. This finding is consistent with the research results of Moriri et al. (2010), which showed that rotating cropping patterns increased the growth of *Cowpea* plants as a secondary crop but inhibited the growth of the main corn crop. Njoku and Muoneke (2008) found that the yield of fresh tuber cassava plants intercropped with *Cowpea* in Nigeria was higher than that of fresh cassava tubers planted in monoculture. This finding is expected because *Cowpea* can fix N to increase the availability of N in the soil. Amanullah et al. (2007) also concluded that cassava intercropping and legume species could improve nutrient status in soils. The yield of dry shelled corn on cassava + corn − peanut intercropping is the same as cassava + corn intercropping treatment. The same results were also found in Adeniyan and Ayoola (2006), where the yield of cassava and maize were insignificantly different from the treatment of several cropping patterns of maize + cassava + soybean intercropping. Furthermore, the differences in the cooking phase (*maturity time*) and the growth character of each plant considerably determine yield productivity in intercropping systems. The yield of dried bean patterns is 0.17 t ha^{-1}, which is lower compared with the average yield of Kancil variety in the form of 2 t ha^{-1} (Balitkabi 2010). This finding is expected due to competition in the use of nutrients, light and groundwater (Daellenbach et al. 2005) in intercropping cropping patterns. Peanut production results are strongly influenced by soil moisture. According to Rahmianna *et al.* (2007), peanut production will decrease by 15% if peanuts suffer from water during the vegetative phase but experience water stress on pod filling until the end of planting. Furthermore, peanuts will experience a 41% decrease in production under water stress after the pod filling until the end of planting. This finding is supported by Aboamera (2010), who explained that the critical phase in *Cowpea* legume plants is in the flowering and pod filling phases, with a potential yield reduction of 35%-69%.

The obtained *land equivalent ratio* (LER) for cassava + maize intercropping plants is 1.49, whilst the results of LER for cassava intercropping + corn − peanut are 1.56. The calculation results of the LER indicate that cassava intercropping + corn − groundnut (UKJKT) has a higher value than cassava intercropping + corn. LER higher than one indicates that productivity per unit area achieved by planting together (intercropping) is higher compared with plants planted separately (monoculture). Value LER is higher in multicropping than that in monocultures as reported by Haymes and Lee (1999), Adeniyan and Ayoola (2006), Banik *et al.* (2006), Shehata *et al.* (2009) and Megawer *et al.* (2010). Islami et al. (2011) reported that all intercropping systems attempted had an LER larger than 1. The results show that the LER varied between 1.35 (cassava intercropping + upland rice) and 1.60 (intercropping cassava + peanuts and corn + peanuts). Thus, the efficiency of land use in intercropping is profitable, especially intercropping crops *legume*, such as peanuts. The high value of LER in-crop intercropping *legume* may be due to the low level of nitrogen competition in the soil (Dapaah et al. 2003).

Willey (1979) indicated that focusing on the sensitivity of plants to competition during their lifetime is necessary for the application of intercropping cropping patterns. Many plants in certain periods of their lives are sensitive to competition. Such sensitivity can affect plant growth and yield. Competition between the types of intercropped plants can be reduced as little as possible and must be regulated. Thus, the resources needed for each plant do not occur simultaneously. In the intercropping cropping pattern, one of the main factors that can inhibit plant growth and yield is the competition for sunlight for photosynthesis. Islami (1999) stated that in a shaded plant, the intensity of the light received will be reduced; thus, photosynthesis does not occur optimally. This condition will affect the amount of photosynthate produced. Failing to meet the amount of photosynthate necessary for plant growth and development will affect production. Ashadi and Arsyad (1991) reported that a decrease in light intensity to 40% resulted in a reduction in the number of books, branches, stem diameter, number of pods and protein content in soybeans. Buhaira (2007) stated that in the intercropping pattern of peanuts and corn, the height of peanut plants exceeds that of plants grown by monoculture (average of 68 cm). This excess is due to the response of shade plants to a high leaf and stem area (etiolation) in intercropping (Somaatmadja et al. 1985).

The evaluation of water requirements and effective rainfall using *CropWat for Windows* shows that from the cropping pattern of monoculture cassava (UK), the water needs are 1041.20 mm, 1050.50 mm for cassava + corn intercropping and 1070.00 mm for cassava intercropping + corn − groundnut water, with the same effective rainfall of 1076.65 mm. The evaluation results of *CropWat for Windows* indicate that water demand for plants during the research period in the field is smaller than that during the experimental period as calculated by the Hartman method. In cassava plants (UK), the need for water from the calculation *CropWat* is 1041.20 mm and that from Hartman is 1087.34 mm; for cassava intercropping + corn, the need for water from *CropWat* 1050.50 mm and that from Hartman is 1088.89 mm; for cassava + corn − intercropping plants, the need for water from *CropWat* was 1070.00 mm and that from Hartman was 1109.99 mm. The amount of water needed in the calculation using the Hartman method is probably because percolation was disregarded.

Balancing crop water needs and water supply from rainfall obtained during the growth and development of plants can determine the most appropriate planting time. From the balanced crop water needs and water supply from rainfall, water shortages, especially at planting time, are evident before and at the end of the rainy season. Rainfall distribution is also needed throughout the growth of plants because each type of plant has different growth phases with varying requirements of water availability. Each period of plant growth is specific to the condition of water shortage (*water stress*). Plants are also sensitive to the condition of water shortages in certain periods of growth. Water shortage usually occurs when the plant reaches its critical period. The critical period of the plant should be considered to determine the right planting time; that is, ensuring that the water needs of plants are met during critical periods (Agung 2005).

The groundwater content decreases exponentially towards the uptake area, rises again exponentially further from the rooting area and eventually decreases again. The decrease in water content in clay is slower compared with that in sandy soil. This result is due to the numerous micropores of clay that retain water strongly; thus, the capability of roots to absorb water in clay is high. Deep percolation in dusty clay is lower than that in sandy soil; thus, water loss due to percolation is low (Saleh 2000).

Cassava + corn-peanut intercropping has the highest economic value, with an income of Rp. 11,385,500 ha^{-1}, followed by cassava intercropping + corn Rp.11,190,500 ha^{-1} and monoculture cassava of Rp. 2,833,000 ha^{-1}. Thus, the third and second intercropping cropping patterns can be chosen because they provide larger benefits compared with those of monoculture planting patterns. This finding is consistent with the results of Tsay *et al.* (1988) and Fukai *et al.* (1990), in which the intercropping of cassava legumes is more productive than monoculture planting. This phenomenon is due to legumes, which can be harvested before high competition between two plants such that cassava can have enough time to recover. Abit (1979) found that intercropping with sorghum or corn did not affect cassava yields when cereals were planted simultaneously or one or two weeks after planting cassava.

The selected cropping pattern has a high profit with production costs. Local farmers aim to apply the selected planting pattern to increase their farming yields and maintain food security. Whilst farmers in the village of Pecatu plant food crops by monoculture and only plant once a year during the rainy season, the remaining land is left overgrown with grass and weeds. Therefore, establishing demonstration plots in the field as a means of socialisation is necessary. These plots can help farmers determine their cultivation techniques and encourage participation in farming by intercropping. Thus, their farming businesses can yield high economic value.

The simulation results of the development of planting time indicate that cassava can be grown only from 22 to 29 October, as obtained by the estimation of linear regression equation $y = 0{,}093x + 0.289$ with $R^2 = 0.99$. These equations obtained plants planted on October 22 with actual ETc and ETm of 1070.0 and 1133.5 mm, respectively, water shortage of 63.5 mm to meet the ETm needs and a reduction in yield of 6.2%. If the planting time is delayed on October 29, then the actual ETc and ETm respectively decrease to 1047.4 and 1142.2 mm, lack of water is 94.8 mm to meet the ETm and the resultant reduction is 9.1%. If the planting time is delayed again until November 5, then the actual ETc and ETm are 1019.3 and 1151.8 mm, respectively, the water shortage is 132.5 mm and the reduction in the results passing the threshold above 10% is 12.7%. These phenomena are caused by the influence of the increasing level of groundwater deficit in the root zone. This influence is demonstrated by the value of the low ETc/ETm ratio. This low ratio indicates that the availability of groundwater is insufficient to meet crop water needs (Islami at al. 1995).

Research on cassava planting time in Thailand (Tongglum et al. 2001) in Indonesia (Wargiono et al. 2001) found that cassava grown at the beginning of the rainy season has high fresh tuber yields (May-June in some countries but October-November for Indonesia). Research (Zhang Weite et al. 1998) indicates that tuber yield is positively correlated with rainfall received during 3-5 months.

The calculation shows that sweet potato is planted in the rainy season from October 22 to November 12, and the result is a 0% reduction. Sweet potato planted in the dry season I can only be planted on February 3-17 based on the estimation obtained by the linear regression equation $\hat{Y} = 0.294x - 3.075$ with $R^2 = 0.98$. Plants planted on February 3, actual crop evapotranspiration (ETc) of 543.3 maximum evapotranspiration (ETm) of 570.7 mm, lack of water by

27.4 mm, yield reduction of 5.3%. If the planting time is delayed on October 29, then the actual ETc and ETm are 496.1 and 536.3 mm, respectively, the water shortage is 40.2 and the reduction is 8.3%. If planting time is delayed until November 5, then that actual ETc and ETm respectively decrease by 457.3 and 502.5 mm, water shortage reduced by 45.2 mm to meet (ETm and the resulting reduction is 9.9%. If planting time is delayed again until February 24, then the actual ETc and ETm are respectively decreased by 398.0 and 451.2 mm, water shortage is reduced by 53.2 mm and the reduction in results passing threshold above 10% is 13%.

Peanuts can be grown in the dry season I (MK I) from February 3 to March 17, as obtained by the estimation regression equation y = 0.20x + 0.052 with R^2 = 0.99. For the dry season I, in addition to the peanut crop, the corn plant evaluation from the simulation results indicate that corn plant can also be planted from February 3 to March 17, as obtained by the estimation regression equation $\hat{Y} = 0.283x - 0.019$ with R^2 = 0.99.

Plants planted on February 3, actual crop evapotranspiration (ETc) of 543.3 maximum evapotranspiration (ETm) of 570.7 mm, lack of water by 27.4 mm, yield reduction of 5.3%. If the planting time is delayed on October 29, then the actual ETc and ETm are 496.1 and 536.3 mm, respectively, the water shortage is 40.2 and the reduction is 8.3%. If planting time is delayed until November 5, then the actual ETc and ETm respectively decrease by 457.3 and 502.5 mm, water shortage reduced by 45.2 mm to meet (ETm and the resulting reduction is 9.9%. If planting time is delayed again until February 24, then the actual ETc and ETm are respectively decreased by 398.0 and 451.2 mm, water shortage is reduced by 53.2 mm and the reduction in results passing threshold above 10% is 13%.

The planting calendar according to evaluation results of the groundwater balance and the possibility of decreasing the safest yield; if planting presents a drawback, then the risk of soil moisture deficit will be increasingly threatening (Prijono 2010).

This arrangement of planting patterns can be used as a basis for further research. The preparation of this cropping pattern is a choice of possible cropping patterns with the safest level of yield reduction to increase the usability of dry land. The most important plants used are varieties of those that are resistant to the dry, short life and high production.

CONCLUSION

The Bali region has a hilly and clayey soil condition. The types of plants grown are corn, cassava, beans, turi, banana, papaya, coconut, mango, orange, sugar apple and teak, because agricultural land has low soil fertility and water is only sourced from rainfall. Water balance for the Bali region using the Thornthwaite and Mather method showed that water surplus occurs from January to April whilst deficit occurs from May to November. The planting pattern of intercropping cassava + corn − peanut can be recommended for planting by farmers in Bali. Further research must be conducted to test the opportunities for different cropping patterns by selecting plants that are drought resistant, short-lived and have high production.

REFERENCES

Aboamera MA (2010) Response of Cowpea To Water Deficit Under Semi-Portable Sprinkler Irrigation System. Misr J. Ag. Eng 27(1): 170-190.

Adeniyan ON, Ayoola OT (2006) Growth And Yield Performance Of Some Improved Soybean Varieties As Influenced By Intercropping With Maize And Cassava In Two Contrasting Locations In Southwest Nigeria. African Journal of Biotechnology 5(20): 1886-1889.

Agung I GAMS (2005) Dryland Agriculture, Neglected Potential. Speech of Inauguration of Permanent Professor Position in the Field of Agricultural Cultivation at the Faculty of Agriculture, Udayana University (scientific oration). Denpasar: Udayana University, March 5.

Agung I GAMS (2006) Concepts and Strategies for Dryland Agricultural Development. Paper presented at the National Seminar on "Development of Dry Land Agriculture Towards Prosperous Farmers" in Denpasar on 22 Julli 2006 in the framework of PS Anniversary of Dryland Agriculture Masters VII, Anniversary of the Postgraduate Program of Unud and Anniversary of Unud. 24 p.

Al-Jamal MS, Sammis TW, Ball S, Smeal D (2000) Computing the Crop Water Production Function for Onion. Agric Water Manag 46: 29-41

Al-Kaisi, MM, Broner I (2009) Crop Water Use and Growth Stages. Colorado State University Extension. Fact Sheet No.4715.

Allen RG, Pereira LS, Raes D, Smith M (1998) Crop Evapotranspiration: Guidelines for computing crop water requirements. Irrigation and Drainage Paper 56, Rome, Italy. 300 p.

Amanullah MM, Somasundaram E, Vaiyapuri K, Sathyamoorthi K (2007) Intercropping In Cassava - A Review. Agricultural Review 28(3): 179-187.

Anonymous (2010) Production Technology of Soybeans, Peanuts, Green Beans, Cassava & Sweet Potatoes. Bean and Tuber Crops Research Institute. Center for Food Crop Research & Development. Agricultural Research & Development Agency. Retrived from: www.balitkabi.litbang.deptan.go.id/publikasi/teknologi-inovasi.html, Accessed 30-30-2013.

Ariffin (2001) Basic Climatology. UB Faculty of Agriculture Publishing Unit. Malang.

Asadi DM, Arsyad HZ (1997) Breeding Soy for Tolerant Shade and Intercropping. Agrobio Bulletin 1(2): 15-20.

Asdak C (1995) Hydrology and Management of Watersheds. Gadjah Mada University Press. Yogyakarta: 571 pages.

Baharuddin AB (1997) Integrated Farming System in NTB Dry Land. Paper presented at the Technology Application Meeting for Improvement of Food Crop Sub Sector in Mataram: 12-14.

Bana S, Prijono S (2013) The effect of soil management on the availability of soil moisture and maize production in dryland. International Journal of Agriculture and Forestry 3(3): 77-85.

Banik P, Midya A, Sarkar BK, Ghose SS (2006) Wheat and chickpea intercropping systems in an additive series experiment: Advantages and weed smothering. Europ J. Agronomy 24: 325-332.

Barine KKD, Victor N (2016) The Particle Size and Thermal Properties of Flour from three Plantain (Musa Paradisiaca) Cultivars Grown in Nigeria. Journal of Food Technology Research, 3(1): 23-27.

Bauer A, Black AL (1992) Organic Carbon Effects on Available Water Capacity of Three Soil Textural Groups, Soil Science Society of America Journal 56(1): 248-254.

Bergamaschi H (2007) Maize yield and rainfall on different spatial and temporal scales in Southern Brazil, Pesq. agropec. bras 42(5): 603-613.

Blair G, Macleod D, Amdrews A, Sale P, Searle dan P, Aitken R (1984) Soil Fertility and Plant Nutition. Training Course Notes. AUIDP - Udayana University. Denpasar Bali.

Blum A (2009) Effective use of water (EUW) and not water-use efficiency (WUE) is the target of crop yield improvement under drought stress, Field Crops Research 112: 119-123.

Bono A, Alvarez DR (2012) Use of Surface Soil Moisture to Estimate Profile Water Storage by Polynomial Regression and Artificial Neural Networks, Agronomy Journal 104(4): 934-938

Brocca L, Moramarco T, Melone F, Wagner W (2013) A new method for rainfall estimation through soil moisture observations, Geophysical Research Letters 40(5): 853-858.

Buckman HO, dan NC Brady (1982) Ilmu Tanah. Terjemahan Prof. Dr. Soegiman. Bhratara Karya Aksara. Jakarta. 787 p.

Cakir R (2004) Effect of water stress at different development stages on vegetative and reproductive growth of corn. Field Crops Research 89(1): 1-16.

Chuanyan Z, Zhongren N. (2007) Estimating water needs of maize (Zea mays L.) using the dual crop coefficient method in the arid region of northwestern China. African Journal of Agricultural Research 2(7): 325-33.

Clarke D, Smith dan M, Askari KE (1998) CROPWAT for Windows: User Guide, Food and Agriculture Organization of The United Nations. Rome, Italy.

Condon AG, Richards RA, Rebetzke dan GJ, Farquhar GD (2002) Improving Intrinsic Water-Use Efficiency and Crop Yield, Crop Science 42(1): 122-131.

Critchley W, Siegert dan K, Chapman C (1991) A Manual for the Design and Construction of Water Harvesting Schemes for Plant Production, Food and Agriculture Organization of the United Nations. Rome.

Daellenbach PCK, Wolfec MS, Frossardb E, Finckhd DMR (2005) Plant Productivity In Cassava-Based Mixed Cropping Systems In Colombian Hillside Farms. Agriculture, Ecosystems and Environment 105: 595-614.

Danarti SN (1997) Palawija budidaya dan analisa usahatani. Jakarta: Penebar Produksi Jagung Direktorat Bina Produksi.

Dapaah HK, Asafu-Agyei JN, Ennin SA, Yamoah C (2003) Yield stability of cassava, maize, soya bean and cowpea intercrops. The Journal of Agricultural Science 140(1): 73-82.

Djaenuddin D, Marwan H, Subagyo H, Mulyani dan A, Suharta N (2003) Kriteria Kesesuaian Lahan untuk Komoditas Pertanian. Pusat Penelitian dan Pengembangan Tanah dan Agroklimat. Badan Penelitian dan Pengembangan Pertanian Bogor. 254 p.

Doorenbos J (1977) Guidelines for predicting crop water requirement. FAO irrigation drainage paper 24: Rome. 144 p.

Doorenbos J, Kassam DAH (1986) Yield Response to Water. Irrigation and Drainage. Paper 33, FAO, Rome, Italy. 193 p.

El-Sharkawy (2012) Stress-Tolerant Cassava: The Role of Integrative Ecophysiology-Breeding Research in Crop Improvement. Open Journal of Soil Science 2: 162-186.

Ervin EH, Koski AJ (1998) Drought avoidance aspects and crop coefficients of Kentucky bluegrass and tall fescue turfs in the semiarid west. Crop Science 38(3): 788-795.

Evans RO, Cassel DK, Sneed RE (1996) Soil, Water and Crop Characteristic Important to Irrigation Schedulling. North Carolina Cooperative Extension Service. Number AG. 452 - 1 (1996): 1-13.

Farahani HJ, Peterson GA, Westfall DG, Sherrod LA, Ahuja DLR (1998) Soil Water Storage in Dryland Cropping Systems: The Significance of Cropping Intensification, Soil Science Society of America Journal 62(4): 984-991.

Fasinmirin JT, Reichert DJM (2011) Conservation Tillage For Cassava (Manihot esculenta crantz) Production In The Tropics. Soil & Tillage Research 113: 1-10.

Franzluebbers AJ, Stuedemann JA, Franklin DDH (2012) Water infiltration and surface-soil structural properties as influenced by animal traffic in the Southern Piedmont USA. Renewable Agriculture and Food Systems 27(04): 256-265.

Frimpong JO, Amoatey HM, Ayeh EO, Asare DDK (2011) Productivity And Soil Water Use By Rainfed Maize Genotypes In A Coastal Savannah Environment. International Agrophysics 25: 123-129.

Gregory JH, Dukes MD, Jones PH, Miller DGL (2006) Effect of urban soil compaction on infiltration rate, Journal of Soil and Water Conservation 61(3): 117-124.

Guo R, Lin Z, Mo X, dan Yang C (2010) Responses of crop yield and water use efficiency to climate change in the North China Plain, Agricultural Water Management 97: 1185-1194.

Hakim N, Nyakpa MY, Lubis AM, Nugroho SG, Diha MA, Hong GB, Bailey DHH (1986) Dasar-dasar Ilmu Tanah. Penerbit Universitas Lampung. Lampung. 488 p.

Hanzen VE, Israelsen OW, Stringham DGE (1979) Irrigation Principles and Practices. 4th. ed. Cacho Hermanos. Inc. New York.

Hartman D (1983) Water Balance in the Field. S2 Program Soil Science. Gajah Mada Universty. Yogyakarta.

Hatibu N, Young MDB, Gowing JW, Mahoo HF, Mzirai DOB (2003) Developing improved dryland cropping systems for maize in semi-arid tanzania. Part 1: experimental evidence for the benefits of rainwater harvesting, Experimental Agriculture 39(03): 279-292.

Haymes R, Lee HC (1999) Competition between autumn and spring planted grain intercrops of wheat (Triticum aestivum) and field bean (Vicia faba). Field crop Res 62: 167-176.

Hillel D (1980) Application of Soil Physics. Academic Press. New York. 385 p.

Hoque MZ (1984) Cropping System in Asia. On-Farm Research and Management. IRRI. Los Banos, Laguna, Philippines. 196 p.

Hudson BD (1994) Soil organic matter and available water capacity, Journal of Soil and Water Conservation 49(2): 189-194.

Idinoba ME, Idinoba PA, Gbadegesin A, Jagtap DSS (2008) Growth And Evapotranspiration Of Groundnut (Arachis hypogaea) In A Transitional Humid Zone Of Nigeria. African Journal of Agricultural Research 3(5): 384-388.

Irianto G (2003) Drought manegement untuk meminimalkan resiko kekeringan. Harian Kompas 8 Agustus 2003.

Islami T (1999) Manipulasi Tajuk Tanaman Jagung Terhadap Hasil Tanaman Jagung dan Ubi Jalar dalam Pola Tumpang Gilir. Agrivita 21(1): 20-24.

Islami T, Guritno dan B, Utomo WH (2011) Performance of cassava (Manihot esculenta Crantz) based cropping systems and associated soil quality changes in the degraded tropical uplands of East Java. Indonesia. Journal of Tropical Agriculture 49(1-2): 31-39.

Jackson J (1989) Climate, Water and Agriculture in the Tropics. Second Edition. Longman Scientific & Technical Copublished in the United State with John Wiley and Sons, Inc. New York. 377 p.

Jin K, Cornelis WM, Schiettecatte W, Lu J, Yao Y, Wu H, ... Hartmann R (2007) Effects of different management practices on the soil-water balance and crop yield for improved dryland farming in the Chinese Loess Plateau. Soil and Tillage Research 96(1-2): 131-144.

Kakde JR (1985) Agricultural Climatology. Metropolitan Book. Co. Pvt. Ltd. New Delhi. 387 p.

Kammer PM, Schöb C, Eberhard G, Gallina R, Meyer R, Tschanz DC (2013) The relationship between soil water storage capacity and plant species diversity in high alpine vegetation, Plant Ecology & Diversity. https://doi.org/10.1080/17550874.2013.783142

Kehinde O, Yahaya O, Oloruntade AJ, Afuye DGG (2011) Effect Of Supplemental Irrigation On Growth, Development And Yield Of Cassava Under Drip Irrigation System In Akure, Ondo State Nigeria. Journal of Sciences and Multidisciplinary Research 3: 62-73.

Laban TF, Kizito EB, Baguma Y, Osiru DD (2013) Evaluation Of Ugandan Cassava Germplasm For Drought Tolerance. International Journal of Agriculture and Crop Sciences 5(3): 212-226.

Lakitan B (1997) Dasar-Dasar Klimatologi. PT. Raja Grafindo Persada. Jakarta. 175 p.

Lal R (1991) Current Research On Crop Water Balance And Implications For The Future. IAHS Publ 199: 31-44.

Lehane JJ, dan WJ Staple. (1965) Influence of soil texture, depth of soil moisture storage, and rainfall distribution on wheat yields in southwestern Saskatchewan, Canadian Journal of Soil Science 45(2): 207-219. 10.4141/cjss65-029

Loaiciga HA (2005) On the Probability of Droughts: The Compound Renewal Model. Journal of Water Resources Research 41, W01009m. https://doi.org/10.1029/2004/WR003075

Mamedov AI, Levy GJ, Shainberg I, Letey DJ (2001) Wetting rate, sodicity, and soil texture effects on infiltration rate and runoff, Australian Journal of Soil Research 39(6): 1293-1305.

Marica A (2010) Short description of the CROPWAT model. Retrieved from http://agromet-cost.bo.ibimet.cnr.it/fileadmin/cost718/repository/cropwat.pdf

Maynard GH, Orcutt DDM (1987) The Physiology of Plants Under Stress. John Willey dan Sons, Inc, New York. 206 p.

Mazaheri MR, Mahmoodabadi DM (2012) Study on infiltration rate based on primary particle size distribution data in arid and semiarid region soils, Arabian Journal of Geosciences 5(5): 1039-1046.

McGee EA, Peterson GA, Westfall DDG (1997) Water storage efficiency in no-till dryland cropping systems, Journal of Soil and Water Conservation 52(2): 131-136.

Megawer EK, Sharaan AN, EL-Sherif DAM (2010) Effect of Intercropping Patterns on Yield and its Components of Barley, Lupin or Chickpea Grown in Newly Reclaimed Soil. Egypt. J. of Appl. Sci 25(9): 437-452.

Michael AM (2008) Irrigation: Theory and Practice. Vikas Publishing House. New Delhi. 768 p.

Milly PCD (1994) Climate, interseasonal storage of soil water, and the annual water balance, Advances in Water Resources 17(1-2): 19 - 24.

Moriri S, Owoeye LG, Mariga IK (2010) Influence of component crop densities and planting patterns on maize production in dry land maize/cowpea intercropping systems. African Journal of Agricultural Research 5(11): 1200-1207.

Morison JIL, Baker NR, Mullineaux PM, Davies DWJ (2008). Improving water use in crop production, Phil. Trans. R. Soc. B 12 February 363(1491): 639-658.

Mulebeke R, Kironchi G, Tenywa DMM (2010) Enhancing water use efficiency of cassava and sorghum based cropping systems in drylands. Second RUFORUM Biennial Meeting 20 - 24 September 2010, Entebbe, Uganda.

Munandar S (1994) Pengembangan Tataguna Air pada Lahan Kering sebagai Alternatif Penanggulangan Kekeringan. Prosiding Diskusi Panel. Antisipasi Kekeringann dan Penanggulangan Jangka Panjang. Sukamandi, 26-27: 49-66.

Nassar NMA, Ortiz DR (2007) Review Cassava Improvement: Challenges And Impacts. Journal of Agricultural Science 145: 163-171.

Nel AA (2009) Grain yield and rainfall use efficiency responses of maize and alternative rotating crops under marginal production conditions in the western Highveld of South Africa,South African Journal of Plant and Soil 26(3): 164-169.

Nielsen DC, Vigil MF, Benjamin DJG. (2009) The variable response of dryland corn yield to soil water content at planting, Agricultural water management 96: 330-336.

Nielsen DR, Kirkham D, van Wijk DWR (1959) Measuring Water Stored Temporarily Above the Field Moisture Capacity, Soil Science Society of America Journal 23(6): 408-412.

Njoku DN, Muoneke DCO (2008) Effect Of Cowpea Planting Density On Growth, Yield And Productivity Of Component Crops In Cowpea/Cassava Intercropping System. Journal of Tropical Agriculture, Food, Environment and Extension 7(2):106-113.

Noellemeyer E, Fernández R, Quiroga DA (2013) Crop and Tillage Effects on Water Productivity of Dryland Agriculture in Argentina, Agriculture 3: 1-11.

Noggle GR, Fritz DGJ (1993) Introductory Plant Physiology. Second Edition. Prentice Hall, Inc. New Jersey. 627 p.

Obalum SE, Amalu UC, Obi dan ME, Wakatsuki T (2011) Soil Water Balance And Grain Yield Of Sorghum Under No-Till Versus Conventional Tillage With Surface Mulch In The Derived Savanna Zone Of Southeastern Nigeria. Expl Agric 47(1): 89-109.

Odofin AJ, Egharevba NA, Babakutigi AN, Eze DPC (2012) Drainage Beyond Maize Root Zone In An Alfisol Subjected To Three Land Management Systems At Minna, Nigeria. Journal of Soil Science and Environmental Management 3(9): 216-223.

Odubanjo OO, Olufayo AA, Oguntunde DPG (2011) Water Use, Growth, and Yield of Drip Irrigated Cassava in a Humid Tropical Environment. Soil & Water Res 6(1): 10-20.

Oguntunde PG, Alatise MO (2007) Environmental regulation and modelling of cassava canopy conductance under drying root-zone soil water. Meteorological Applications: A journal of forecasting, practical applications, training techniques and modelling 14(3): 245-252.

Oldeman LR (1975) An agroclimate map of java. Contribution Central Research Institute for Agriculture. Bogor. Indonesia 17: 22.

Oldeman LR (1980) The agroclimatic classification of rice-growing environments in Indonesia. World Meteorological Organization; International Rice Research Institute: Proceedings of a symposium on the agrometeorology of the rice crop: 47-55.

Omonona BT, Akinpelu AO (2010) Water, environment and health: Implications on cassava production. Cont J Agric Sci: 29-37.

Pascale SD, Costa LD, Vallone S, Barbieri G, Maggio DA (2011) Increasing Water Use Efficiency in Vegetable Crop Production: From Plant to Irrigation Systems Efficiency, Hort Technology 21(3): 301-308.

Pirastru M, Niedda DM (2013) Evaluation of the soil water balance in an alluvial flood plain with a shallow groundwater table, Hydrological Sciences Journal 58(4): 898-911.

Prijono S (2008) Evaluasi Kebutuhan Air Tanaman di 12 Kecamatan Wilayah Kabupaten Malang dengan CropWat for Windows. Jurnal Agritek 16(4): 600-780.

Prijono S (2009) Agrohidrologi Praktis. Cakrawala Indonesia. 168 p.

Prijono S (2010) Model Neraca Lengas Lahan Kering: Penetapan Kalender Tanam Lahan Kering. Retrieved from http://sugengprijono.files.wordpress.com/2010/01/makalah-das.pdf

Rahmianna, AT Yusnawan DE (2009) Pod Yield And Kernel Quality Of Peanut Grown Under Two Different Irrigations And Two Harvest Times. Indonesian Journal Of Agriculture 2(2): 103-109.

Rao M, Prasadini RP (1998) Profile water storage capacity of soils of scarce rainfall zone of Andhra Pradesh. Journal of the Indian Society of Soil science 46(3): 351-3.

Rawls WJ, Pachepsky YA, Ritchie JC, Sobecki TM, Bloodworth H (2003) Effect of soil organic carbon on soil water retention, Geoderma 116: 61-76.

Reichert JM, Albuquerque JA, Kaiser DR, Reinert DJ, Urach FL, Carlesso R (2009) Estimation of water retention and availability in soils of Rio Grande do Sul. Revista Brasileira de Ciência do Solo 33(6): 1547-1560.

Reinhart KG, Taylor RE (1954) Infiltration and available water storage capacity in the soil. Eos, Transactions American Geophysical Union 35(5): 791-795.

Rockstron J (2001) On food and nature in water scarce Tropical countries, Journal of Land and Water International 99: 4-6.

Saleh E (2000) Perubahan kadar air tanah sebagai fungsi kedalaman dan waktu. Artikel. Retrieved from http://www.ilmutanah.unpad.ac.id

Santosa I, Gede MA, Ketut I, Dinata K (2011) Dampak alih fungsi lahan sawah terhadap ketahanan pangan beras. Prosiding Seminar Nasional Budidaya Pertanian. Pengendalian Alih Fungsi Lahan Pertanian. Bengkulu, 7 July 2011.

Santosa IGN (2006) Perencanaan Pola Tanam Berdasarkan Kebutuhan dan Persediaan Air pada Lahan Kering di Bali Utara. Disertasi. Program Pascasarjana Universitas Brawijaya.

Saxton KE, Rawls WJ (2006) Soil water characteristic estimates by texture and organic matter for hydrologic solutions. Soil science society of America Journal 70(5): 1569-1578.

Scholes RJ, Dalal R, Singer S, Swift MJ (1994) Soil physics and fertility: the effects of water, temperature and texture. The biological management of tropical soil fertility: 117-136.

Setyana S (1983) Perkembangan penerapan pola tanam dan pola usaha tanam dalam usaha intensifikasi. Risalah Lokakarya Teknologi dan Dampak Pola Tanam Usaha Tani, Bogor, 20-21 June 1983. Puslitbang Tanaman Pangan. Bogor.

Seyaningsih E, Soemarno D (2009) Pengelolaan sumberdaya lahan dan air menunjang ketahanan pangan.PPSUB. Malang. 47 p.

Shahamat S, Alishahi M, Banaee M, Shahriali A (2015) Effects of Sub-lethal Concentrations of Atrazine on Some Oxidative Stress Biomarker in Various Tissues of Grass Carp (Ctenopharyngodon idella). Journal of Environmental Treatment Techniques, 3(1): 1-6.

Shata SM, Mahmoud A, Siam S (2007) Improving calcareous soil productivity by integrated effect of intercropping and fertilizer. Research Journal of Agriculture and Biological Sciences 3(6): 733-739.

Shiklomanov IA, Babkin VI, Balonishnikov ZA (2011) Water resources, their use, and water availability in Russia: Current estimates and forecasts. Water resources 38(2): 139-148.

Singh A, Aggarwal N, Aulakh GS, Hundal RK (2012) Ways to maximize the water use efficiency in field crops-A review. Greener Journal of Agricultural Sciences 2(4): 108-129.

Sir Elkhatim HA, Abdelhadi AW, Hussein DSA (2007) Water Requirements of the Main Crops in the Gezira. Proceedings of the Meetings of the National Crop Husbandry Committee 41th: 45-61.

Smith M (1992) CROPWAT, a computer program for irrigation planning and management, Irrigation and Draenage Paper 46, FAO, Rome, Italy. 133 p.

Smith M (2000) The Application of Climatic Data for Planning and Management of Sustainable Rainfed and Irrigated Crop Production. Agricultural and Forest Meteorology 103: 99-108.

Stroosnijder L, dan Widianto (1985) Agrohydrology, Komunikasi Ilmu Tanah. Unibraw Nr. 4. Jurusan Tanah Fakultas Pertanian Universitas Brawijaya. Malang. 190 p.

Suhardi SS, Sodjoko SA, Minarningsih DHD, Widodo DA (1999) Hutan dan kebun sebagai sumber pangan nasional. Departemen Kehutanan dan Perkebunan. Departemen Pertanian. Kantor Menteri Negara dan Hortikultura. Jakarta. 147 p.

Sulliva P (2003) Intercropping principles and production practices. NCAT Agriculture Specialist. Retrieved from http://attra.ncat.org/attra-pub/PDF/intercop.pdf

Thimme GP, Manjunaththa SB, Yogesh TC, Sunil AS (2013) Study on water requirement of Maize (Zea mays L.) using CROPWAT model in northern transitional zone of Karnataka. Journal of Environmental science, computer science and engineering & technology 2(1): 105-113.

Tim Pusat Penelitian Tanah dan Agroklimat (1993) Petunjuk Teknis Evaluasi Lahan. Pusat Penelitian Tanah dan Agroklimat. Kerjasama dengan Proyek Pembangunan Penelitian Pertanian Nasional. Badan Penelitian dan Pengembangan Pertanian. Departemen Pertananian.

Timm LC, Dourado-Neto D, Bacchi OOS, Hu W, Bortolotto RP, Silva AL, Bruno IP, Reichardt DK (2011) Temporal variability of soil water storage evaluated for a coffee field, Soil Research 49(1): 77-86.

Utomo WH (1985) Dasar-Dasar Fisika Tanah. Jurusan Tanah. Fakultas Pertanian. Universitas Brawijaya. Malang.

Van Duivenbooden N, Pala M, Studer C, Bielders CL, Beukes DJ (2000) Cropping systems and crop complementarity in dryland agriculture to increase soil water use efficiency: a review, NJAS - Wageningen Journal of Life Sciences 48(3): 213-236.

Van Hoof WCH (1987) Mixed Cropping of Groundnut and Maize in East Java. UPT. Perpustakaan Universitas Brawijaya. 156 p

Weldeslassie TA, Cornelis W, Nyssen J, Govaerts B, Raes D, Haile M, Deckers DJ (2011) Effect of conservation agriculture on soil water balance and crop yield for improved dryland farming on vertisols in Northern Ethiopia. International congress Water: Integrated water resources management in tropical and subtropical drylands. Mekelle, Ethiopia.

Willey RW (1979) Intercropping-its importance and research needs part-1 competition and yield advantages Field Crops Res 32: 1-10.

Wright E, Carr MKV, Hamer DPJC (1997) Crop production and water-use. IV. Yield functions for sugarbeet, The Journal of Agricultural Science 129(01): 33-42.

Yongki I, Pramono IB, Cahyono SA. (2003) Konservasi air lahan kering sebagai alternatif pengembangan lahan kering. InProsiding Seminar Hasil Penelitian dan Pengembangan Rehabilitasi Lahan Kritis, Banjarnegara (Vol. 6): 97-111.

Zhao BZ, Xu F, Zhao QG (1997) Influences of soil physical properties on water-supplying capacity. Pedosphere 7(4): 367-374.