A Study of Crop Water Needs and Land Suitability in the Monoculture System and Plant Intercropping in Arjasari

Edy Suryadi[#], Dwi Rustam Kendarto[#], Bambang Aris Sistanto[#], Dedi Ruswandi[*], Sophia Dwiratna[#]

Department of Agriculture and Biosystem Engineering, Faculty of Agricultural Industrial Technology, Universitas Padjadjaran
[*]Department of Agrotechnology, Faculty of Agriculture, Universitas Padjadjaran
Jl. Raya Bandung – Sumedang Km.21, 43563 Jatinangor Sumedang, Indonesia
E-mail: edy_suryadi2010@yahoo.co.id

Abstract— **Arjasari is an area with dry land characteristics developed for the cultivation of palawija crops. The main problem with dry land is the limited availability of water. Hence, it is necessary to know how much water needs of the crops and the suitability of the crops of palawija crops developed in this region in order to make efficient use of water. The research method used is descriptive analysis method for assessing the availability of climate data to calculate the crop water requirement. The estimation of water needs of this plant uses Blaney Criddle methods with air temperature data measured directly in the field, while the determination of land suitability uses the method of arithmetic matching of land characteristics, to the land suitability class for the requirements of growing corn crops. The analysis showed that the amount of corn water requirement was 418.9 mm / season, soybean was equal to 349.6 mm / season, and sweet potato of 350.55 mm per season. The results of the land location analysis are very suitable for corn crops. The results of land suitability classification analysis for corn plant. The results of planting trials use a water demand scheme with land suitability in a predetermined monoculture system resulted in an average productivity of maize crops in the intercropping system of 3.84 tons.ha^{-1} and sweet potatoes of 2.1 tons.ha^{-1}. In addition, the average yield of corn productivity in the soybean-corn intercropping system is 4.16 ton / ha and soybean is equal to 0.248 tons.ha^{-1}. Provision of water according to the needs of plants is able to produce high productivity of crops with the more efficient use of water.**

Keywords— **crop water requirement; land suitability; monoculture system; plant growing requirements; palawija plants intercropping**

I. INTRODUCTION

Arjasari is a sub-district included in the administrative area of Bandung Regency West Java. The region's main resource is from the agricultural sector. The main commodities produced are corns and rice. Corn crop production in Arjasari currently only reaches 1 to 1.5 tons per hectare, from the harvest target of maize per hectare determined by the province of West Java is at 3-4 ton.ha^{-1}, while for rice crop in Arjasari reaches 3.5 - 4 ton.ha^{-1} of the harvest target set by the province of West Java at 6 tons per hectare. The amount is still far below the standard yields of expected corn and rice crop yields. The obstacle faced by the productivity of agricultural products in Arjasari is because most of this area is a dry land area (*arid zone*); the width of Arjasari sub-district is 6.49 ha, with agricultural land equal to 3.16%, with the relatively high percentage of dry land. The problem of cultivation on dry land is the limited amount of water available to support agricultural activities within a full year. According to Pereira, Oweis, and Zairi [1], the current water conditions to support

agricultural activities are increasingly scarce, not only in dry areas (*arid zone*); but also in areas that have high rainfall.

Agricultural productivity on dry land is not as large as in wetlands, agricultural cultivation on dry land is still needed to meet consumption needs, especially corn and some other crops. Corn is a commodity with high demand in Indonesia, import of corn reaches 1.6 million tons [2]. According to Central Bureau of Statistics data, corn production in West Java reached 959.933 tons of dry pepper, decreased by 87.144 tons compared to maize production in 2014 which reached 1.047.077 tons of dry kiln [3]. The decrease of maize production in 2015 was due to the decrease of 16.14 hectares of the harvested area from 142.96 hectares in 2014 to 126.83 hectares in 2015. Meanwhile, corn productivity reached 75.69 quintals per hectare increase compared to productivity in 2014 which reached 73.24 quintals per hectare. The area of harvest and production of sweet potatoes in West Java in 2015 reached 28.62 ha with a production of 389.851 tons, and productivity reached 136.23 quintal.ha^{-1}. To meet the needs of crops, especially maize, the government made a policy of maize development by utilizing 71% of dry land in

Indonesia [4]–[6]. West Java Province utilizes 126.83 ha of dry land for the development of maize crops [6].

Farm yields that are less productive on dry land are due to limited availability of water, which can be solved by water use efficiency. Efficiency is done so that limited water, can be used for cultivation activities throughout the year because water has an important role in the growth and development of plants. Water is mostly used for evapotranspiration. Evapotranspiration is a process of evaporation in plants (transpiration) and in soil (evaporation). The water requirement of plants is considered equal to the amount of water used for the evapotranspiration process (ETc) [7], [8]. Plant water productivity is the ratio between the mass of the marketable yield and the volume of water consumed by the plant. The greater the productivity of crop water is, the better the water use efficiency [8]–[11]

The water needs of each plant vary according to the age of plants, air temperature, and plant system. The need of water in the intercropping system is higher than the monoculture system because there are more than one plant species. However, intercropping cultivation creates complex cropping agroecosystems, including interactions between similar and different species. Competition occurs when each, two or more plant species need the same necessities of life [12]. To get high crop productivity, environmental conformity factor becomes very important. Land to be used for agriculture, plantation and other uses requires first land evaluation to conform to the intended use.

Based on the above description to solve the problem of productivity of crops on dry land, especially in Arjasari area, it is necessary to study the suitability of the land for the development of corn plantation and the study of the needs of water plants in order to efficiently use water in agricultural cultivation activities, either in monoculture system or in intercropping system. Through this study, a picture of whether the Arjasari area is suitable for the development of corn crops as well as the total amount of water needed in one growing season to produce high productivity with efficient water use can be obtained.

II. MATERIAL AND METHODS

The research was conducted in SPLPP *(Sanggar Penelitian, Latihan dan Pengembangan Pertanian)* Universitas Padjadjaran, Arjasari, Bandung at 2016-2017. The method used in this research is descriptive analysis with observation and gathering of information data about research area. Land suitability class and crop water requirement based on the availability of climate data on the intercropping system of crops on Arjasari dry land. In this research, there are also experiments of corn planting as much as 86 lines using monoculture system and intercropping system between corn - sweet potato and corn-soybean to know its productivity. Water administration during plant growth was conducted based on the estimation of water requirement analysis were then studied.

The tools used in this study include beams, hoes, hose, a hygrometer, a meter, an ombrometer, a sample ring, GPS, and analytic scales. The materials used include corn seeds 86 strains and sweet potatoes, fertilizer NPK Phonska, also primary and secondary data. Primary data are Arjasari temperature data, data analysis of soil physical properties, slope, and plant data (plant height, leaf chlorophyll) and crop productivity. Secondary data were in the form of climatology data from BMKG Bandung station in 2007-2016, rainfall data of Cipaku Station, Ciherang Station and Cibeureum Station in 2007-2016, Rupa Bumi Indonesia Map, Bandung Regency Map, and Land Use Map of Bandung Regency. Stages of research conducted are as follows:

A. Data Collection Technique

Secondary data were obtained from climatology data of reference station BMKG station Bandung year 2007-2016 (consisting of maximum and minimum temperature, air humidity, wind speed, monthly rainfall and long sun exposure), rainfall data of region obtained from three stations nearest Arjasari namely Cipaku, Ciherang and Cibeureum stations in 2007-2016. Primary data were obtained from direct measurements in the field including air temperature, slope, plant height, leaf chlorophyll and crop productivity.

B. Land Preparation

Land treatment was done twice a week before planting. The soil was processed by hoeing, by turning the soil and breaking large chunks of soil into small pieces, clearing the weeds and flattening the land, at a depth of approximately 30 - 40 cm.

Planting was done one week after the soil was processed. Planting was done in two periods. In the first period of planting sweet potatoes on February 27, 2017, then 14 Days After Planting (DAP) sweet potatoes done corn planting on March 11, 2017. This corn planting was done by using a plot to pierce the soil, with the depth of planting hole ± 5 cm. The spacing of maize and yam was 20 cm and 3 meters wide. Seeds were planted in prepared holes and covered with soil. Each row consisted of 10 planting holes, and each planting hole planted 2 seeds.

Fertilization was done in two stages by using Phosphor NPK fertilizer, the first stage (*basic fertilizer*) was given when the maize plant was 10 days old, and the second stage (*fertilizer after*) was after the corn plants aged 30 days. Fertilization was done by making fertilizer hole with *tugal* on the right and left planting hole of seed. Fertilizer used was phonska fertilizer with approximately 5 gram in each hole, and there were approximately 96 lines, and in each row, there were 10-15 holes.

Control of pests and diseases was conducted once a week; the pests observed were weeds, animal pests, and diseases, as well as the impact and extent of damage to the plant. In addition, plant height and crop production were observed.

C. Data Processing

1) Climatology Data Analysis: The analysis of climatological data for the last 10 years (2007-2016) includes, the maximum and minimum temperature data of each month (° C), air humidity (%), wind speed (m / s) and solar irradiance. The data were obtained from the Meteorology Climatology and Geophysics Agency Bandung. The area rainfall data used polygon thiessen method, with the following equation [13], [14]:

$$P = \frac{1}{n}\sum_{i=1}^{n} P_i \frac{A_i}{A} \qquad (1)$$

Where P is precipitation area (mm); Pi as rainfall of weather station i (mm); Ai as an area of i weather station (ha); A as total area (ha); and n as the number of data or weather station

2) Potential Evapotranspiration Calculation (ETP): This potential evapotranspiration calculation uses the Blaney Criddle method with the following equation [15], [16]:

$$ETP = c[p(0.46T + 8)] \quad (2)$$

Where ETP as evapotranspiration reference (mm / day); T as daily average temperature (°C); p as a percentage of monthly noon hour of the year; and c as correction factor f (minimum air humidity, long sunlight, estimated wind speed)

3) Calculation of Evapotranspiration Plant (ETc): The crop evapotranspiration was calculated by following formula [7], [17]–[19] :

$$ETc = Kc \; x \; ETP \quad (3)$$

Where Etc as Evapotranspiration of plants (mm / day); Kc as Coefficient of the plant; and ETP as potential evapotranspiration (mm/day)

4) Determination of Land Suitability: The determination of land suitability is done by calculating any land suitability characteristics that have been determined. The characteristics are temperature (t) using Braak method 1982, water availability characteristics (w) using FAO effective rainfall method, toxicity characteristics (x), erosion hazard characteristics using USLE method. The entire value of each of these characteristics will be matched in accordance with the class of land for growing corn crops. The presentation of land suitability results is shown in the form of a map based on its suitability class.

III. RESULTS AND DISCUSSION

A. Decryption Area

The research area is located at an altitude between 880 - 1175 masl with a sloping slope divided into 4 classes: flat (<3%); wavy (3 - 8%); wavy (8 - 15%); Hilly (15 - 30%). Most of the land is undulating (class II: 8 - 15%) with a total land area of 118.99 ha. Corrugated land scattered in the north and south of the location, while flat land has only 1.03 ha located in the middle of the study site.

B. Climatology Analysis at Arjasari

Climatology analysis is used to determine the crop water requirements of the three plants used in the study of corns, sweet potatoes, and soybeans. Temperature and humidity parameters are done by taking data directly in the field, while other climate data were obtained from the Meteorology Agency of Climatology and Geophysics Bandung for the last 10 years from 2007-2016.

C. Air Temperature

The air temperature was obtained by measuring directly at the study site. Temperature data collection was conducted periodically every month during the planting period starting from March to June 2017. Fig. 1 shows the maximum temperature, minimum temperature, and average measurement data at the study sites. The average air temperature obtained by the data successively from March to June 2017 is as follows: 29.09 ° C, 28.72 ° C, 29.31 ° C and 32 ° C.
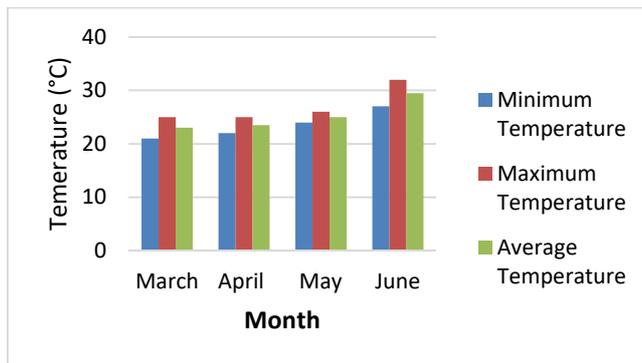

Fig. 1 Air temperature during research

Air temperature becomes one of the factors requiring growth of corn and sweet potato plants. The desired temperature as a requirement for growing corn crops ranges from 25 ° C-32 ° C [20], and for sweet potatoes ranging from 21 ° C-27 ° C [2], the mean air temperature at the research sites are eligible to grow for corn and sweet potatoes.

D. Humidity

The humidity data in Table 1. was obtained by measuring the air humidity directly at the study site. Air humidity measurements were performed using a digital Thermohygrometer tool. This moisture measurement was done every week during the planting period from March to June 2017. The humidity measured was the maximum and minimum humidity. Based on Table 1, the average humidity at the study sites ranged from 78 to 84%. Moisture is needed by plants to keep the body from drying quickly due to evaporation [12], [21]. Air humidity affects the evaporation of the soil surface and evaporation of the leaves.

E. Wind Velocity

Fig. 2 shows the average value of wind speed that is processed based on the last 10 years speed data (2007-2016 period)

TABLE I
RELATIVE HUMIDITY DATA IN SPLPP UNPAD ARJASARI RESEARCH AREA

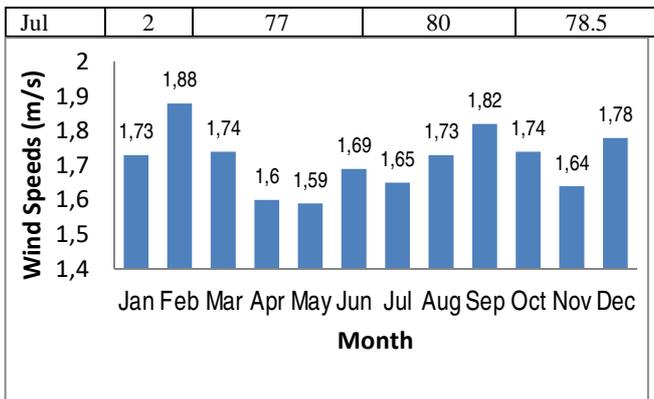| Month	Week	RH Min (%)	RH Max (%)	Everage of RH (%)
Mar	3	83	86	84.5
Mar	4	83	85	84
Apr	1	82	84	83
Apr	2	83	84	83.5
Apr	3	82	85	83.5
Apr	4	81	87	84
May	1	81	83	82
May	2	81	83	82
May	3	82	85	83.5
May	4	81	84	82.5
Jun	1	79	82	80.5
Jun	2	78	81	79.5
Jun	3	79	82	80.5
Jun	4	79	82	80.5
Jul	1	77	79	78

Jul	2	77	80	78.5

Fig. 2 Wind speed average (2007-2016)

The highest wind speed occurred in March at 1.74 m.s⁻¹ , and the lowest wind speed occurred in May at 1.59 m.s⁻¹., Wind speed can be useful for flowering, especially for corn crops. The wind is helpful in the pollination of plants [14]. Winds can affect the occurrence of flowering and natural hatcheries that occur in plants. In the case of high wind speeds, the presence of pollinating insects is reduced so that it will affect the success of breeding seeds and causing cross-pollination.

F. Solar Radiation

The solar radiation data were obtained from the BMKG station of Bandung, as well as the previous climate data. This was due to the limited data climatology owned by the sub-district of Arjasari. Fig. 3 shows the solar radiation length during the growing season from March to June. The highest solar radiation occurred in July at 68% or for 8.16 hours, while the longest sun exposure occurred in March which was 48% or for 5.76 hours.

G. Regional Rainfall Data

The data source to conduct rainfall analysis at the research location was obtained from three closest stations namely, Cipaku, Ciherang, and Cibeureum Stations. The Thiessen Polygon method for determining the area to represent the study location was used.
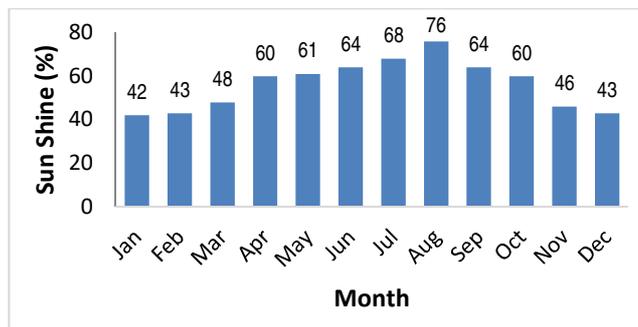

Fig. 3 The sun shines average from 2016 -2017

Fig. 4 Rainfall average

Fig. 4 shows the average regional rainfall chart with the highest average rainfall occurring in March at 287.58 mm per month, while the lowest average rainfall occurred in August of 13.8 mm per month. Corn plants require an ideal rainfall of about 85-200 mm per month during the growing period. Based on these data rainfall occurring in March, April, May qualifies the ideal rainfall for corn crops. Meanwhile, in June and July rainfalls are not available, so it is necessary to provide irrigation.

H. Needs of Crop Water

1) Potential Evapotranspiration: Result of potential evapotranspiration calculation using Blaney Criddle method based on climatology data of the last 10 years revealed the highest potential evapotranspiration value occurred in March of 3.8 mm.day⁻¹ or 117.8 mm per month, while the lowest evapotranspiration value during the growing season occurred in June of 3.5 mm.day⁻¹ or 105 mm per month. High evapotranspiration values indicate high evaporation; this will affect the increase in crop water requirements. Conversely, if the low evapotranspiration needs water, the plants will be small.

2) Crop Coefficients: Calculation of estimation of plant water requirement (ETc) was obtained from multiplication of ETo with Crops Coefficient (Kc).

The value of Kc used is presented in Table 2. based on the literature sourced from FAO Irrigation and Drainage Paper No. 56 Crop Evapotranspiration [22]. In the stage of plant growth, in general, there are four growing phases namely, the initial phase, the development phase, the middle phase and the final phase. In the table is known the values of Kc of the three plants namely corns, sweet potatoes, and soybean. Plant Kc values vary in each growth phase. The Kc value is used in the calculation of the crop water requirement (ETc) at a later stage.

TABLE II
COEFFICIENT CROPS (KC)

Corps	Crops Growth Phase				Crops Max Height
	Initial	Development	Mid Season	Late Season	
Corn	0.9	1.1	1.2	0.6	2
Sweet Potato	0.5	1.0	1.15	0.65	0.4
Soybean	0.4	1.15	1.15	0.5	-

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I. Plant Evapotranspiration

1) Corn Plant: Table 3 shows the estimation of the value of corn water requirement (ETc) in March - June 2017. The ETc value was obtained from the multiplication of potential evapotranspiration with the Kc value of the plant in each growing phase.

TABLE III
VALUE OF CORN WATER REQUIREMENT (ETC)

Crop Growth Stage	Kc	ETc (mm/day)
Initial	0.9	3.42
Development	1.0	3.6
Mid Season	1.2	4.5
Late Season	0.6	2.1

Based on Table 3, in the initial phase of maize growing from the first decade of March to the end of the second decade of April the water requirement of the corn crop was 3.42 mm / day. Then in the second decade of April to the end of the second decade, the corn plant entered the development phase, and the water requirement required by corn crops was 3.6 mm / day. After that, the corn plant enters the mid-season phase where it needed the most water during the growth phase of 4.5 mm / day. While in the final stage water requirement of corn plants was only 2.1 mm / day.

TABLE IV
VALUE OF SWEET POTATO WATER REQUIREMENT (ETC)

Crop Growth Stage	Kc	ETc (mm/day)
Initial	0.5	1.9
Development	1.1	3.96
Mid Season	1.15	4.125
Late Season	0.65	2.27

2) Sweet Potato Plants: Table 4 shows the estimated value of crop water requirement (ETc) for sweet potato plants at the study site from March to June 2017. The estimated value of water demand for sweet potato crops in March was 1.9 mm.day^{-1}, in April at 3.96 mm.day^{-1}, in May at 4.13 mm.day^{-1} and in June at 2.27 mm.day^{-1}. Based on Table 4, sweet potato plants required the most water in May (mid-season phase) of 4.125 mm.day$^{-1,}$ and the least required water occurred in June of 1.9 mm.day^{-1}.

3) Soybean Plants: Table 5 below describes the needs of crop water based on calculations made in March - June 2017.

TABLE V
VALUE OF SOYBEAN WATER REQUIREMENT

Crop Growth Stage	Kc	ETc (mm/day)
Initial	0.4	4.9
Development	1.15	4.6
Mid Season	1.15	4.5
Late Season	0.65	4.2

Based on Table 5 in March the estimated value of soybean water demand ranged from 4.9 mm.day^{-1}, then for

April at 4.6 mm.day^{-1}. In the mid-phase of May, it was 4.5 mm.day^{-1} and continued to decline in the final phase of June around 4.2 mm.day^{-1}. Soybean crop needed the most water in March at 4.9 mm / day and the least water in June of 4.2 mm.day^{-1}.

The estimation of crop water requirements is strongly influenced by the availability of climate data, such as temperature, wind, soil moisture, and sunlight. The temperature is directly affected by the intensity and duration of solar radiation. length of time of radiation for a tropical region like in Indonesia, and sun intensity for 12 hours per day. The wind speed is a factor will affect the evapotranspiration The greater the wind speed, the greater the rate of evapotranspiration will be.

In principle, plants can still grow and develop if only given water in accordance with the number of needs only. Therefore, estimation of crop water needs is beneficial in the efficient use of water on cultivated land, especially on dry land with limited water availability.

J. Land Suitability

1) Determination of Soil Sampling: Soil sampling was based on the Land Unit Map (SPL) made based on overlay results from land suitability parameters such as slope, parent material, soil type, and land use map at the study site. The overlay results produced 28 SPL. The next step was determining the number of soil samples to be taken for the characteristic test using stratified random sampling method. Based on the determination of the soil samples to be taken on the research field 10 samples were collected.

2) Land Suitability Class: The Land suitability class in this study was obtained based on the matching results of each parameter or characteristics on the SPL research field with the class of corn plant growth requirements from the literature. Characteristics used were temperature characteristics, water availability, rooting medium, erosion hazard, and flood hazard.

Judging from the characteristics of temperature using the Braak method, the resulting air temperature at the study site ranged from 23.98^{o}C - 24.97^{o}C. Based on these characteristics the entire SPL at the study was suitable for corn crops (S1). Based on the characteristics of water availability (w), the location of the study belonged to a very suitable class (S1) because it has an effective rainfall of 2.007 mm.year^{-1} with 5 dry months (rainfall below 75 mm. month^{-1}).

Flood hazard analysis results obtained from on-site interviews showed that there was no inundation in the study site. Thus, the location of the study based on the level of flood hazard into the class is very suitable (S1). Based on soil texture, the research location is mostly textured clay with an area of 105.20 ha and dusty clay area of 95.75 ha. Land suitability on both types of soil texture is included in the appropriate. Based on the level of soil solidity in the study sites, including into the appropriate class (S2). The nutrient characteristic of the entire SPL is included in the appropriate class (S1). As for nutrient retention, it belongs to a low category.
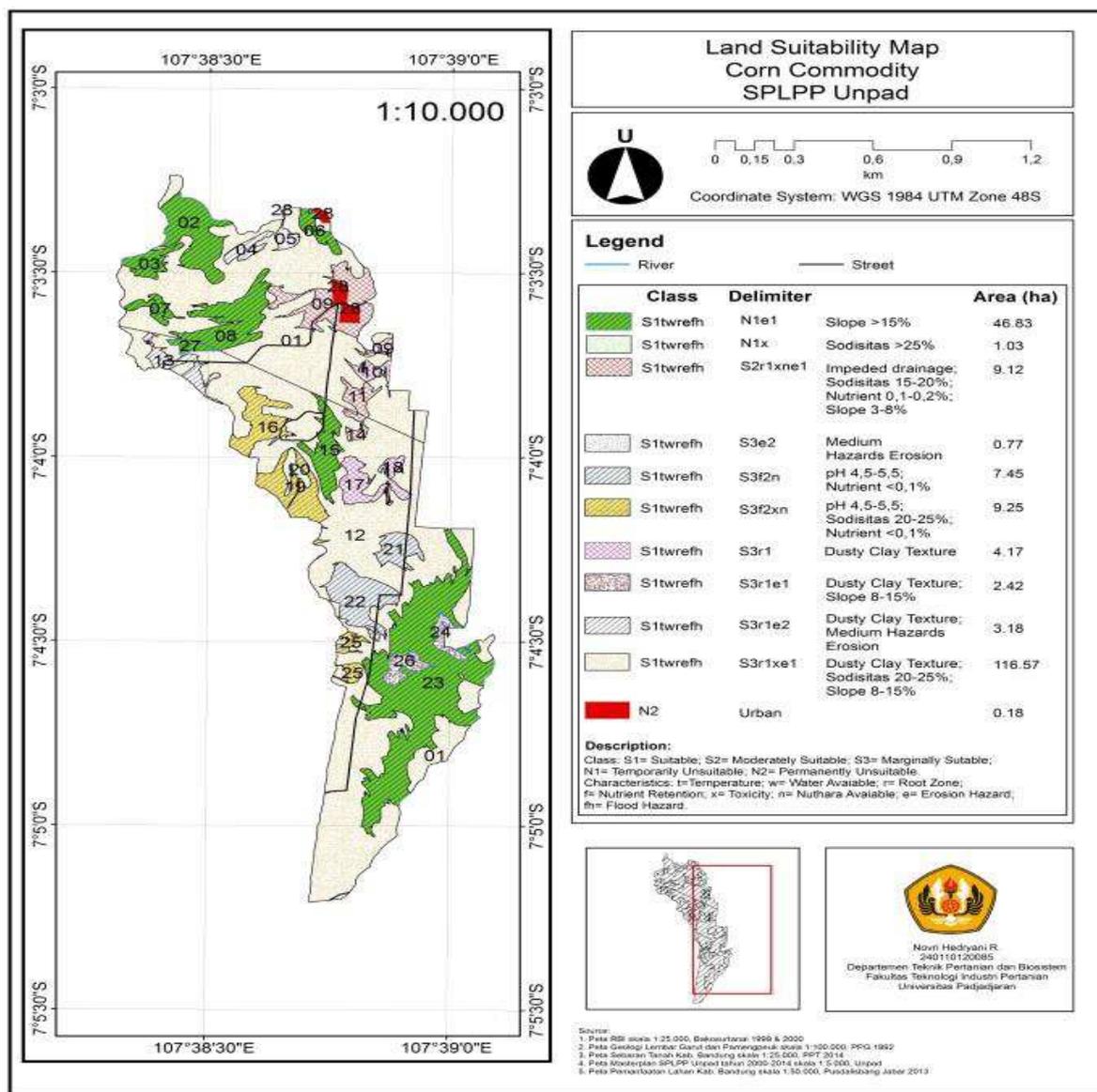
Fig. 5 Map of land suitability class of corn plant at SPLPP Unpad [13]

Land suitability of the calculation results of all the characteristics considered earlier is shown in the form of land suitability maps as in the Fig. 5. Fig. 5. shows the limiting factor that has the largest area in the research location is in SPL 1 and 12 with a total land area of 116.57 ha. This factor is SPL with class according to marginal, that is a land boundary in the form of texture clay dust, the solidity of 20-25% and slope of 8-15%. Soil texture becomes the dominant limiting factor at the study site. Five of a total of 11 groups of SPL limiting factors have a soil texture as a limiting factor. Most of the land in the research area is clay textured (105.20 ha) covering 95.75 ha of dusty textured clay field. Corn plants are still tolerant with clay texture and clay dusty, then planting on the land with the texture is still considered in the appropriate category [10], [23].

3) Plant Growth and Productivity: After estimating the needs of plant water in corn, soybean, and sweet potatoes, the next stage was the planting testing process. Planting was done using 86 single maize strands and using intercropping pattern of corn-soybean, corn-sweet potato. This planting stage was carried out to apply the water supply to the plant only in accordance with the amount of water demand from the predicted needs of the previous plant. Planting was done in March - June 2017.

Observations made to determine the condition of plant growth in this study was to measure the height of the plant. Plant height was measured from the neck of the root to the end of the stem. Plant height is calculated from the base of the stem to the last stem segment before the flower [24]. Plant height is a plant size often observed as an indicator of growth as well as a parameter to measure environmental impact or treatment applied because plant height is the most easily visible growth measurement.

The average yield of maize at the end of observation (week 11 after planting) was 227.347 cm. whereas for average height of sweet potato was equal to 37.94 cm and soybean plant was 37 cm. The rate of maize plants has a correlation with plant height and tuna height, where tall plants tend to fall more easily than short plants [24], [25].

4) Plant Productivity: The harvests carried out in early July 2017 obtained the average yield of single maize. In the intercropping system of maize with sweet potato, corn productivity was 3.84 tons.ha^{-1}, and the average productivity of sweet potato itself was 2.1 tons.ha^{-1}, whereas the average productivity of maize in the intercropping system of maize with soybean was 4.17 tons.ha^{-1} and the average yield of Argomulyo varieties of soybean varieties in the intercropping system was 0.248 tons.ha^{-1}

IV. CONCLUSIONS

Based on the estimation analysis of water requirement of plants (ETP), water requirement for corn is 418.9 mm / season, soybean 349.6 mm / season, and sweet potato is 350.55 mm / season. The result of analysis of land suitability class for corn plant, research location entered in class is very appropriate (S1twrefh). The highest limiting factor in the N2 class is found in SPL 28 because it is intended for buildings of 0.18 ha, while the lowest limiting factor is that S2r1xne1 is in SPL 9.1 and 14 with an area of 9.12 ha.

The results of the planting test using the predicted water demand scheme indicate that the average productivity of maize crops in the intercropping system was 3.84 tons / ha and sweet potatoes was 2.1 tons.ha^{-1}. while the average of corn productivity in the intercropping system of corn with soybean was 4.17 tons.ha^{-1} and soybean was equal to 0.248 tons.ha^{-1}. The harvest result in this study proves that the application of intercropping cropping pattern does not decrease the yield of crop productivity, although, in the process of plant growth, a single pattern is better compared to the intercropping pattern. In addition, the existence of sufficient plant water needs in the pattern of intercropping becomes one of the factors that affect the yield of crop productivity, due to the fulfilment of water requirement.

The use of water in the cultivation of *palawija* crops can be more efficient so that the available water is expected to meet the water needs for year-round cultivation in the dry land in Arjasari District, Bandung Regency.

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