Study of Water Balance in Arjasari Agricultural Land (A case study of Intercropping System of Corn and Chilies)

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Abstract. Development of food crops is not only addressed to a momentary increase in production but also attention to the aspect of land conservation in order for the system of production can be sustainable. Intercropping system is one way of managing agricultural land which can minimize the risk in the utilization of dry land for the development of food crops. The availability of water on dry land are generally affected by rainfall and the ability of the soil to retain water. The potential water resources available in the ground is indispensable in agricultural hydrology and water management in the framework of developing food crops. This study aims to determine the moisture content of the soil and water balance of the land in the region of Arjasari, Bandung Regency. The methods used in this research is a descriptive analysis. The research was carried out from March until November 2015. The results of this study showed that the moisture content of the soil in the study ranged from 314.2 mm/m up to 472 mm/m with the moisture content of the soil which can be utilized by the plant a maximum of 185 mm/m.

1. Introduction

Seeing the extent of dry land in Indonesia, dry land has the potential to be developed into productive agricultural land. Data of 2013 states that Indonesia has dry land used as a garden or moor of 11,876,881 ha of about 148 million ha [1]. Data show that dry land utilized is still less than 10% of available land. Potential water resources in the form of water savings available in the soil are indispensable in agricultural hydrology and water management in the framework of developing food crops, especially since the water demand for most agricultural cultivation in Indonesia is still dependent on rainwater. Given this, then the water management must be done optimally.

Multiple cropping system is one way of managing agricultural land that can minimize the risks in dry land use for food crop development as food crop development is not only aimed at instantaneous production improvement but also attention to land conservation aspect so that production system can be sustainable. In addition, according to [2], the combination of legume and non-legume crops in the intercropping system can generally increase the productivity of agricultural land.

One of the plants that has considerable national demand is chili. According to [3], the average consumption of chili per capita of Indonesia population reached 14,235 kg. Maize is one of the strategic commodities for Indonesia. Corn is a staple food in some areas such as Madura and Nusa Tenggara. The national corn demand for food, feed and industry continues to increase every year. The current use of corn commodities is dominated by animal feed industry by 51% [4]. With a large national demand and tends to increase every year, its fulfillment must be sought from domestic production.

Increased productivity can be pursued by maximizing the growth and development of plants, so the plant is expected to give maximum results. Crop water requirements are one of the most important aspects for plant growth and development. Crop water requirement is the amount of water needed by plants to grow optimally which can also be interpreted as the amount of water used to meet the
evapotranspiration process of plants. With the fulfilment of water needs of plants, plants are expected to grow and develop to the maximum so as to increase productivity.

By analysing the groundwater content, water use can be optimized so that irrigation water supply for plants can be optimized. Water balance (agriculture), i.e. analysis with respect to the nature and behaviour of the soil to the atmosphere, and as a support required physical data soil, especially water content at the level of field capacity and permanent wilt point [5]. Water balance is closely related to groundwater availability. This becomes important for agricultural activities because groundwater can be utilized to meet the needs of plant water.

Arjasari Sub-district is geographically located at 107° 30’ to 107° 40’ east longitude and 7° 30’ to 7° 50’ south latitude. The area of Arjasari sub-district is 49,35 km² or 4935,30 ha. The area is divided into several categories such as the area of wetland farmland, the area of non-rice farming land and the area of non-agricultural land. Based on the topography of most areas in the district of Arjasari is an area of plains and slopes or ridges with varying heights from 700 m to 1000 m above sea level. Arjasari Subdistrict is flooded by river Cipalasari and Citalugtug river. According to BPS (2014) data, Arjasari rainfall in 2013 is 1885 mm / year with an average of 5.08 mm / per day, the highest rainfall recorded in April, November and December. The climate is very cool temperatures ranging between 18° - 26° Celsius [6].

2. Methods

This research is done by descriptive analysis method. By analysing and describing the state of the object being studied. This research was conducted from March until November 2015 at SPLPP field of Universitas Padjadjaran located in Arjasari Village, Arjasar Subdistrict, Bandung Regency. The tools used are, Ring Sample, Palu, Hoe, and Notebook. The materials used are rainfall data from 3 weather stations that is Cileunca Station, Cisondari and Cipaku. In addition to rainfall data, also used climatological data obtained from BMKG Station Bandung for the last 10 years as well as maps of Citarum watershed area and plant data referring to FAO Irrigation and Drainage Paper no. 56 of 1989.

2.1. Soil Sampling and Testing

In relation to water balance calculations, an analysis of soil samples was performed. The method used in sampling is the Undisturbed Samples method. After soil sampling is done, soil physical properties analysis to find the value of field capacity, the value of permanent wilting point, infiltration rate and the level of soil dryness at the beginning of the planting period. Sample of soil taken as many as 6 pieces around the land used for cultivation activities. The stages of soil sampling are as follows;

- First ground surface is cleaned first from grass and garbage. Dig the soil up to 30-40 cm deep or until the soil is free from the root zone of the plant.
- Place the first sample ring on the ground with the pointed portion below. Immerse the ring to approximately ½ tall rings using hammers and wooden planks.
- Place the second sample ring at the top. Then immerse it until the second ring goes down to ¼.
- Take both sample rings from the ground and split the part between the two samples carefully. This is done to avoid any disturbance that can damage the soil sample.
- Close the sample ring and label the soil sample. Then the sample was tested in the laboratory.
- Sample of soil that has been taken from the field of research was further tested in the laboratory of Indonesian Ministry of Agriculture Land Research Centre in Bogor, West Java.
2.2. Data collection
The required data is climatological data obtained from the Water Resources Management Agency, West Java Province, the data used is the rainfall data station closest to the research location, such as Cipaku station, Cisondari station and Cileunca Station for the last 10 years. In addition, temperature data, humidity, radiation time, evaporation of each of the last 10 years and value of plant evapotranspiration coefficient are also needed. And also required data in the form of maps to measure the extent of polygon area for the calculation of data Rainfall region.

2.3. Data processing
The collected data is then processed to obtain potential evapotranspiration value. The climatology data used is the regional rainfall data. To calculate the area rainfall data used method polygon Thiessen. This method requires at least 3 stations to work on.
After the rainfall data obtained region, then the data is processed in conjunction with the climatological data of Bandung obtained from the Meteorology, Climatology and Geophysics. The several stages of data processing are as follows;
1. Calculate the average rainfall value of the region each month to obtain 80% chance rainfall using the following equation;
   \[
   R_{80} = \frac{n}{5} + 1
   \]
   Where: \( R_{80} = \) Rain Opportunity 80% \( n = \) amount of data
2. Calculate potential evapotranspiration value by using Cropwat 8.0 for Windows software by entering climatological data in accordance with the available column of software, until finally the potential evapotranspiration value is automatically obtained.

2.4. Determination of Water Holding Capacity Value
Determination of WHC value is based on groundwater content that has been tested previously in the laboratory of Soil Physics, Land Research Center, Ministry of Agriculture, Republic of Indonesia. The WHC value of soil is the average value of the difference between soil moisture test results at pF 2.54 and pF 4.2

2.5. Needs of crop water
Crop water requirements are defined as the amount of water provided to offset the water lost by evaporation and transpiration. Evapotranspiration is a combination of evaporation from the soil surface or evaporation and evaporation from plant leaves or transpiration. The magnitude of the evaporation value is influenced by climate, variety, type and age of the plant. By incorporating plant efficiency (\( k_c \)), consumptive use of plants is a function of potential evapotranspiration of plants [7]. Consumptive usage can be calculated by the following equation:
   \[
   E_{tc} = E_{to} \times k_c
   \]
   Where: \( E_{tc} = \) Water Requirement Plants (mm / day),
   \( E_{to} = \) potential evapotranspiration (mm / day),
   \( k_c = \) coefficient of plant.

2.6. Water Balance Sheet Analysis
Water balance calculation procedures according to [8] use the bookkeeping system with the following steps;

2.6.1. Rainfall column. Filling with the monthly rainfall data or rainfall with a certain chance that can represent the entire land. In this study used rainfall with 80% chance.

2.6.2. Potential Evapotranspiration Column (ETP). Populate with ETP value from local station in ETP priority sequence with empirical formula (Penman-Monteith) in Software Cropwat 8.0.

2.6.3. CH-ETP column. Filled with CH value difference with ETP.
2.6.4. Potential Accumulated Water Loss Columns for Evaporation (APWL). Fill with the sum of the negative CH-ETPs sequentially month after month.

2.6.5. Groundwater content column (KAT). Filling the kAT value where APWL occurs with the formula:

\[
KAT = TLP + \left[\frac{1,0041 - (1.07381 / AT)}{\text{APWL}} \times AT\right]
\]

Information:
- TLP: Permanent Late Point
- KL: Available Water Field Capacity
- \(|\text{APWL}|\): Absolute Value of APWL

2.6.6. Column Change of Ground Water Level (dKAT). The DKAT value of the month is the KAT of that month minus the previous month’s KAT. A positive value denotes a change in groundwater content that takes place at CH> ETP (rainy season), the addition stops when dKAT = 0 after the KL is reached. Conversely, if CH <ETP or dKAT is negative, then all CH and some KAT will be evapotranspirated.

2.6.7. The actual Evapotranspiration column (ETA). When CH> ETP then ETA = ETP because ETA reaches maximum; If CH <ETP then ETA = CH + \(|dKAT|\) because all CH and dKAT will all be evapotranspirated.

2.6.8. Deficit Column (D). Deficit means reduced water for evapotranspiration so that, \(D = ETP - \text{ETA}\)

2.6.9. Surplus Column (S). Surplus means excess water when CH <ETP so, \(S = CH - ETP - dKAT\)

3. Result and study

The research was conducted at Sanggar Penelitian, Latihan, dan Pengembangan Pertanian (SPLPP) Universitas Padjadjaran, located in Arjasari Village, Arjasari Subdistrict, Bandung Regency. SPLPP Arjasari stands on an area of 213.4 ha, with a type of latosol soil and has an elevation of about 950 masl. Arjasari village is located about 25 km from Bandung city. This research was conducted on an area of 226.8 m² with the length of research land used 75.6 m and width 3 m. The beginning of planting was done on the second ten day in April, and harvested on the second ten day in July 2015. The research was conducted by planting corn and chili crops intercropping with the distance between corn and pepper plant 70 cm. The distance between corn plants is 25 cm, while for the distance of pepper plant is 50 cm.

Hydrological data which is the daily rainfall data from 3 weather stations that is Cisondari Station, Cipaku Station and Cileunca Station. Daily rainfall data used is the data of the last 10 years, the period 2005-2014. Rainfall data obtained from the Department of Water Resources Development West Java Province. While the data used climatology taken from the Meteorology, Climatology, and Geophysics Bandung. The data used include the maximum temperature data, minimum temperature, average temperature, wind speed, air humidity and the duration of solar radiation for the last 10 years. Selection of climatology station Bandung is because it is the nearest station in the location of research. Some parameters are calibrated with certain methods so that it is expected to represent the situation in the research location.

The result of rain data measurement is a rainfall data of a point, whereas for the purpose of analysis is needed rain data of a region so that the data must be converted into the rainfall area first. According to [9], one of the methods used to calculate the rainfall of this region is the Thiessen method. Thiessen method is determined by making polygons between the rain heading in a watershed area, then the average rainfall flow rate is calculated from the number of multiplications between each polygon area and the rainfall height divided by the entire area of the watershed. The following is the rainfall data opportunity 80% of the research location.
Table 1. Rainfall Opportunity 80% chance at the study site. The data obtained from the processing of rainfall data for 10 years. The above data is calculated monthly using the equation: \( R_{80} = \frac{n}{5} + 1 \)

| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | TOTAL |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-------|
| Rainfall (mm) | 145.5 | 200.3 | 239.4 | 185.6 | 154.4 | 79.2 | 7.4 | 20.2 | 21.9 | 170.3 | 247.2 | 164.1 | 1635.4 |

The determination of climatic classification is based on the Schmidt-Ferguson and Oldeman Classifications. The use of two methods in this analysis is because the Oldeman climate classification is directed to food crops such as rice and secondary crop, while the use of the Schmidt-Ferguson climatic classification is used because other climatic classification methods are less suitable for the situation in Indonesia, especially regarding the techniques used to assess rainfall. Rainfall at the study sites based on Schmidt-Ferguson climatic type classification is included in Climate Type C, since it has a Q value of 37.5%. Meanwhile, according to the Oldeman climate classification, the rainfall at the study site falls into the E4 climate type. according to Oldeman this area is generally too dry, may only be once planted secondary crop, and even then depending on the rain.

The existence of limited climatological data in the District Arjasari require the use of climatological data from BMKG station Bandung City. Climatology data from BMKG Station Bandung City needs to be modified to be more in accordance with the conditions in the field research, modification of climatological data is done by using Braak method. Braak method in its use requires data in the form of reference temperature data, as well as elevation (elevation) station reference temperature and elevation of where the temperature value is sought. As for Braak formula approach ie;

\[
T = X - 0.0061 \times h
\]

Where \( T \) is temperature (℃), \( h \) is the difference between the reference station elevation and the searched station (masl) and \( X \) is the reference temperature value (℃). High reference station BMKG Bandung is 791 masl, while the elevation of SPLPP Unpad in the village of Arjasari is 950 masl. The following is the modified temperature data using the Braak method:

Table 2. Modified Temperature Data

| Month | Minimum Temp (℃) | Maximum Temp (℃) | Average Temp (℃) |
|-------|------------------|------------------|------------------|
| Jan   | 19.41            | 27.78            | 23.6             |
| Feb   | 19.18            | 27.79            | 23.49            |
| Mar   | 19.15            | 27.75            | 23.45            |
| Apr   | 19.15            | 28.25            | 23.7             |
| May   | 19.01            | 28.29            | 23.65            |
| Jun   | 18.65            | 28.19            | 23.42            |
| Jul   | 17.63            | 28.4             | 23.02            |
| Aug   | 17.64            | 28.43            | 23.04            |
| Sep   | 17.81            | 29.08            | 23.45            |
| Oct   | 18.57            | 27.5             | 23.04            |
| Nov   | 19.02            | 28.07            | 23.55            |
| Dec   | 19.27            | 28.09            | 23.68            |
As shown in table 2, the data at the study sites ranged from 17.63°C to 29.08°C with an average temperature of about 23°C. The lowest temperature was recorded in July at 17.63°C while the highest temperature was recorded in September at 29.08°C. The data is the average temperature for the period of 2005-2014.

Data of air humidity, duration of solar irradiation, and also used is air humidity data from BMKG station of Bandung City. This is done because of limited data at research sites where there is no climatology station available. All climatology data used is the average data during the period 2005-2014. Air humidity ranges from 73% to 84%. The highest air humidity, at 84%, occurred during the peak of the rainy season between November and February. The average wind velocity value of 1.68 m/s with the lowest wind speed of 1.5 m/s occurred in May and the greatest wind velocity occurred in January at 1.78 m/s. In general, the duration of solar irradiance ranges from 4.68 hours to 6.81 hours that occurred in August, while for the shortest irradiation occurred in January.

This water balance research required potential evapotranspiration (ETP) data, plant evapotranspiration (ETc), as well as actual evapotranspiration (ETA) values. The potential evapotranspiration value is calculated by Penman-Monteit method using Cropwat 8.0 software. The calculation of Penman-monteith evapotranspiration value requires data of maximum temperature value, minimum temperature, wind speed, solar irradiance time, and humidity value of air and coordinate research field. Here are the results of potential evapotranspiration calculations on Cropwat 8.0 software;

| Table 3. Potential Evaporation Value |
|-------------------------------------|
| Month                        | Jan | Feb | mar | Apr | mei | Jun | Jul | Agt | Sep | Okt | Nov | Des |
|-------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1st ten day                  | 38.5| 37.8| 34.3| 34.9| 33.1| 33.6| 36.9| 40.7| 42.8| 39.3| 36.1| 37.1|
| 2nd ten day                  | 38.5| 37.8| 34.3| 34.9| 33.1| 33.6| 36.9| 40.7| 42.8| 39.3| 36.1| 37.1|
| 3rd ten day                  | 42.35| 30.24| 37.73| 34.9| 36.41| 33.6| 40.59| 44.77| 42.8| 43.23| 36.1| 40.81|

The value of plant evapotranspiration (ETc) is the water required by plants. ETc value is the result of multiplication of evapotranspiration value with coefficient value of plant. Each plant has a different Kc value. The value of KC in plants is also different at each growth phase. The value of Kc in the intercropping pattern, in the development phase of Kc value is calculated using the equation 104 in FAO irrigation and Drainage Paper No. 56:

\[ KC_{Mid} = \frac{(f_1 x h_1 x K_1) + (f_2 x h_2 x K_2)}{(f_1 x h_1) + (f_2 x h_2)} \]

Where ; 
F1 = area of land cover by plant 1  
F2 = area of land cover by plant 2  
H1 = plant height 1  
K1 = Kc value of plant 1  
H2 = plant height 2  
K2 = value of plant Kc 2

The result of calculation using equation 1 for corn and chili plants obtained value of Kc equal to 1.13. This value is obtained by calculating the maximum height of corn crop as high as 1.5 m, while 0.7 m of chili pepper. The maximum planting height refers to FAO Drainage and Irrigation Paper No.56. For land cover by maize by 67% and pepper plant by 33%. Data of water requirement of plants can be seen in figure 1 below;
Crop Water Requirements closely related to potential evapotranspiration values and plant coefficients (Kc). Corn crops intercropped with pepper plants have a water requirement of 353.52 mm. This value is obtained by summing the crop water requirements from the beginning of planting, i.e. on the second ten day of April to the time of harvesting of plants in the second ten day in July. The need for water of this plant is the requirement of water of corn and chilli plants in the intercropping system conducted in Arjasari, Bandung regency.

Classification of soil types in research sites based on triangle of soil texture issued by USDA belong to clay type with composition 73% clay, 4% dust fraction and 23% sand fraction. This data is obtained from the results of examination of soil physical properties of land research conducted in Soil Physics laboratory, Soil Research Institute, Ministry of Agriculture, Republic of Indonesia in the city of Bogor.

Data of soil physical characteristic which is ground water content at each different phase is the result of sample test taken from the research field. The samples taken are as many as 3 pieces of samples to be taken average value on each phase. The average field capacity value in the research field was 47.2% or 472 mm / m. Field capacity value was obtained from soil moisture test at pF 2.54, while test of permanent wilting point value was done at pF 4.2 with average result 28.7% or 287.3 mm / m. Test result data can be seen in the following table;

| Sample | KL | TLP | AT |
|--------|----|-----|----|
|        | %  | mm/m| %  | mm/m| %  | mm/m|
| 1      | 48.5| 485 | 30.9| 309 | 17.6| 176 |
| 2      | 44.9| 449 | 26.2| 262 | 18.7| 187 |
| 3      | 48.3| 483 | 29.1| 291 | 19.2| 192 |
| Average| 47.2| 472.3| 28.7| 287.3| 18.5| 185.0|

Water balance calculation is a combination of evapotranspiration value data with rainfall data, plant data, and soil physical properties data. Water balance analysis is done by using Thornthwaite-Mather method. The water balance analysis is conducted to observe the water conditions in the land on each ten day. This becomes important because information is needed whenever there is a water deficit, and whenever there is a surplus of water on the land. This can be useful as a handle to determine the beginning of the growing season so that the water deficit is not too large. One of the most influential factors to the surplus and the negative water in the research field is the high rainfall. As shown in Figure...
3, the water deficit in the field of research occurs in the third ten day period from July to the third ten day of September. The water deficit reached 65.3 mm in the third ten day of September. The largest water surplus in the research field occurred on the second ten day in November at 126.9 mm. The following general description of the water field research can be seen in Figure 2 below;

![Water Balance of Land Research](image)

**Figure 2.** Water Balance of Land Research

Result of soil moisture test on pH 2.54 and pH 4.2, got average value equal to 47.23% and 28.73%. So that the value of ground water content in the field capacity condition of 472 mm/m, while at the condition of permanent wilting point, ground water content of 287 mm/m. The difference between the groundwater value in the field capacity condition and the permanent wilting condition is the value of the groundwater content, meaning that the water that can be utilized by the plant is 185 mm/m. During the study period the water readily available in the soil is maintained at a value of 50%, from the available groundwater value of 185 mm, so the land considered to be water shortage if water is readily available in soil less than 92.5 mm.

![Graph of Earth Water Content](image)

**Figure 3.** Graph of Earth Water Content

Readily available water content is maintained at 50%, this means groundwater content in new research areas is considered to reach a deficit value when readily available water content has fallen by
50% from its original value of 185 mm or as much as 92.5 mm value of field capacity. The value of the groundwater content in the research field is experiencing a deficit when groundwater content has been less than 379.5 mm. The result of water balance analysis by using Thornthwaite-Mather method shows that water deficit in research field occurred in third period from July to third ten day in September.

Measurements on corn plants were conducted to collect some data such as plant height, stem diameter, length of segment, and number of leaves. Sample used for each parameter used 5 plants which will then be measured also the result of its production. In general, the uniformity of plant growth, in the second plot is better than the first plot. This can be seen from the growth of plant height and the number of leaves that plants have on the second replication is more uniform, but the development of corn crop is better in the first plot. This is seen from the height of the plant, the diameter of the stem, and the number of leaves owned by the plant on the first plot is large when compared with the second plot plant.

The productivity of the plants produced in each replication was measured by several parameters, namely the number of cobs, the weight of the ear, and the sugar content in the corn produced. The yield of corn plant has not reached its maximum potential. According to the description of the plant from the Seed Technology Laboratory Faculty of Agriculture, Padjadjaran University, this cultivated corn cultivar has a potential yield of 137.5 gr per cob because most have only weights of about 80-120 grams only, although there are 2 plants that produce corn that exceeds its potential. The use of sweet corn as the research object make sugar in corn as one of the parameters measured to determine the harvest both in quality and quantity. The corn produced has a sugar content ranging from 9.1 to 13.4 brix.

| Parameter                  | R 1       | R 2       |
|----------------------------|-----------|-----------|
| Crop Height (cm)           | 179       | 159.8     |
| Crop Diameter (cm)         | 16.6      | 14        |
| Number of Leaves           | 8.6       | 8         |
| Number of Cobs             | 1.2       | 1.2       |
| Cobs Weight (gr)           | 1040      | 900       |
| Cobs Weight w/o Skin (gr)  | 560       | 600       |
| Sugar level (Brix)         | 11.56     | 10.78     |

In addition to corn crops, the yields produced by pepper plants are also measured. The harvest time on both plots is done simultaneously. In some harvest time, there are plants that still have not produced chili fruit at harvest time. Chilies grown are Chilli varieties of Shakira obtained from Seed Technology Laboratory, Faculty of Agriculture, compared with chili varieties Rimbun 3 production of chili pepper varieties of this Shakira can compete with varieties Rimbun 3. Results from pepper plant of 4 times the harvest produces average chili weighing 1062 grams or about 265 grams each time the harvest.

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