Analysis of plant pattern using water balance and cimogram based on oldeman climate type

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Abstract. The transfer of land has an impact on the decreasing of the agricultural land area, so it is necessary to plan the right cropping pattern as an effort to increase the productivity of agricultural cultivation. Also, Climate is one of the factors influencing the determination of cropping pattern in a region. Analysis of climatic characteristics in the determination of cropping pattern not only based on oldeman climatic classification. At the same time, the study of groundwater availability for plants and climogram of climatic elements is needed in determining planting schedule which is suitable for planting and determination of irrigation water supply, either the right amount of time. This study aims to identify and build spatial of the oldeman climate classification. It also determines the cropping pattern for seasonal crops based on the calculation of water balance and climogram (rainfall and air temperature) in each type of oldeman climate district of Cirebon and surrounding areas. Data used monthly rainfall data period 1981-2010 from BMKG Jatiwangi station and air temperature data, plant coefficient and the base map of Cirebon region. The analysis method includes classification of Oldeman climate type, spatial data processing, water balance calculation by Thorntwaite & Matter method and making climogram (rainfall and temperature) with: k = p₀ + p₁/FC; p₀ = 1.000412351; p₁ = -1.073807306 and determination of planting pattern of each type of oldeman

Keywords: Water Balance, Oldeman Climate, Plant, Climogram

1. Introduction
The agricultural sector is a mainstay sector for Cirebon district is shown from the contribution of agriculture to Gross Regional Domestic Product of West Java Province. According to Statistics Indonesia (BPS). In Cirebon, agricultural sector accounted for 30% of total GRDP with 53 thousand hectares of land, of the 45 thousand hectares is the annual crop of paddy and ‘palawija’ (corn, soybean, yams, and beans, vegetables, etc.) [1]. The conversion of agricultural land for development has decreased with the size of agricultural land from time to time, so it is necessary to plan the right cropping pattern as an effort to minimize the risk of failure in agrarian cultivation to increase the productivity of agricultural commodities. Climate is one of the factors influencing the determination of cropping pattern [2] in a region, analysis of climatic characteristics in determining cropping pattern not only based on oldeman climatic classification [3]. According to this, the study of groundwater [4] availability for plants and climogram of climatic elements is needed to assess planting schedules, crop type paddy and ‘palawija’ suitable for planting and determination of irrigation water supply, either the right amount of time so that it can be done efficiently. Plant growth and productivity are limited by water requirements and other climatic elements[5]. Water balance is a method that can be used to see the availability of groundwater for plants at a particular time[6], and the rainfall and air temperature climogram is one of the guidelines for the adjustment of spatial plants [7][8] in the region Cirebon and surrounding districts. Therefore, in this paper, we discussed the plan of cropping pattern for seasonal crop farming[9] with water balance and climogram method in every type of oldeman climate in Cirebon and surrounding regency. Oldeman’s climate classification system for practical purposes is beneficial, especially in the classification of agricultural land for food crops in Indonesia using rainfall elements. The criteria are based on the calculation of wet (DW) and dry months (DM) which considers the opportunities for rain, sufficient rain, and water requirements for crops. Oldeman’s concepts are: (I) Paddy will require regular water per month 145 mm in the rainy season. (ii) ‘palawija’ needs 50 mm average water per month during the dry season. (iii) The expected monthly rainfall has an opportunity of 75% or equal to 0.82 times the average monthly rain minus 30. (iv) Useful rain for paddy rice is 100%. Also (v) Effective rainfall for crops with closed plant canopy of 75%.

2. Literature Preview

2.1. Water Balance

In the concept of the hydrological cycle [10] that the amount of water in a specific area on the surface of the earth is influenced by the amount of water entering (input) and out (output) at a particular time. The balance of input and water output in a place is known as the water balance [11]. Since water is dynamic, the water balance value changes from time to time[11] so that somewhere there may be surplus or deficit. If the advantages and disadvantages of this water in extreme circumstances can undoubtedly lead to disasters, such as floods or drought. Disasters can be prevented or overcome if done proper management of land and the environment. According to Nasir [12], Water balance can be categorized by:

1. General Water Balance
The General Water Balance uses useful climatological data to determine the onset of wet months (months where the amount of rainfall exceeds the amount of water lost by evaporation from the soil surface[13] or evaporation or evaporation of the crop or transpiration system, the combination of the two known as evapotranspiration).

2. Land Water Balance
The Water Balance of Land is a combination of climatological data with soil data, especially the water content in Field Capacity (FC), groundwater content at Permanent Lands Point (PLT), and Water Available (WHC=Water Holding Capacity). Field capacity is a sufficiently moist soil condition indicating the most amount of water that the ground can withstand gravity. Plant roots will continuously absorb water that can be retained soil or evaporate so that the soil becomes more and drier. At one time the origins of the plants are no longer able to absorb water so that plants wither. The water content in the field capacity is measured at a voltage of 1/3 bar or 33 kPa or pH 2.53 or 346 cm
water column. Permanent wilting point is a condition of groundwater content where the roots of the plant are no longer able to absorb groundwater, so the plants wither. Crops will still wither in the day or night. The water content at the permanent wilting point is measured at a voltage of 15 bar or 1,500 kPa or pF 4.18 or 15.849 cm high water column. The water available is the amount of water available to plants that are, the difference between the capacity of the field and the permanent wilting point.

2.2. Climogram

At least two factors are affecting the growth of plants [14], rainfall and high places on the sea surface. In addition to these two factors, plant production is also affected by solar radiation and temperature[15][16]. Plants require climatic conditions following the terms of growth. To test the compatibility of plants with the climate used several ways such as by analyzing its suitability by using Climogram. The climogram is a graph depicting the average monthly precipitation point (in millimeters) against the average monthly temperature or other meteorological elements. In the field of agriculture, climograms are used as a benchmark or guidance adjustment of a plant species of a region.

3. Application

The data used in this study using the average monthly rainfall 1981-2010 from BKMG Station Jatiwangi. However, we are using monthly air temperature data for 1995-2002. To fill the air temperature data of the point of observation of the helpful post is calculated based on the interpolation of the height of the place using Oldeman theory (1982). Namely: $T_h = T_{ho} - 0.5h$ with $Th =$ temperature at altitude h meter from sea level, and $Tho =$ temperature at ho height (reference station). The availability of groundwater was calculated using the Thornwaite and Matter groundwater balance method [17] the following stages of analysis: Phase Evapotranspiration Calculation as follows:

1. Calculate the hot index (i) monthly:
   
   $i = \left( \frac{t}{5} \right)^{1.514}$; $t =$ Average of Temperature
   
2. Calculates the number of annual hot index (I) from January to December
   
   $I = \sum_{j=1}^{12} i ; j=1, 2, ..., 12$
   
3. Calculating ETP:
   
   $ETP = 16 \left( \frac{10\alpha}{T} \right)^a$
   
   With: $\alpha = 675 \times 10^{-9}T^3 - 771 \times 10^{-7}T^2 + 1792 \times 10^{-5}T + 0.49239$

4. Standard ETP correction using day length (for latitude 0, 1 day = 12.1 hours) and number of days per month = 30 days, then:

   $ETP = \left( \frac{X}{30} \right) \left( \frac{Y}{12.1} \right) ETP$

   With $X =$ Number of day in Month; $Y =$ Hours

Thorn Thwaite & Mather Calculation Phase as follows:

1. Rainfall(R): Average of Rainfall monthly
2. Evapotranspiration Potential (ETP) column obtained ETP correction to calculate the water balance of the land while to calculate the water balance of the plant multiply by the value of $Kc$ (plant coefficient)
3. Accumulation potential column for evaporation (APWL): The result of the negative result in step 3 is accumulated month by month as Accumulation Potential of Water Loss (APWL) value and filled in the corresponding column.
4. Ground Water Supply Column (KAT): First determine the field capacity (FC). Chilling of KAT column starts the first month of APWL based on calculation formula as follows: 
\[ \text{KAT} = \text{FC} \times k \left[ \frac{\text{APWL}}{\text{FC}} \right] \]
With: 
\[ k = p_0 + \frac{p_1}{\text{FC}}; \quad p_0 = 1.000412351; \quad p_1 = -1.073807306 \]
The first month of the KAT column in which a positive RF ETP is filled with: (KAT = Last K + RF ETP). Moreover, so on until KAT = FC is reached. Since the month during the rain is still extreme KAT value remains constant that is equal to FC.

5. KAT Change Column (dKAT): The KAT value of a month is deducted from the previous month's KAT.

6. Actual Evapotranspiration Column (ETA): If CH > ETP then ETA = ETP. In the month of APWL (CH < ETP) then ETA = CH + |dKAT|.

7. Deficit Column (D): D = ETP ETA.

8. Surplus Column (S): Surplus occurs when there is no D, then S = CH ETP dKAT.

Planning of cropping patterns such as planting schedule, crops (rice and ‘palawija’). Which suitable for planting and determination of irrigation water supply in each area of oldeman climate type are analyzed from the calculation of the water balance, rice water balance, ‘palawija’ (potato, legumes, grains and plant balance Corn, tomatoes, and chili). As well as climogram results (rainfall and air temperature) the planting schedule is determined by the conditions at which KAT is not less than 50% water are available. Irrigation is assigned if 50-85% of the available water has been used up. The types of plants are determined by looking at the conditions of groundwater availability and the conditions of the optimum climate elements for the growth and productivity of a plant species.

4. Analysis
Classification of Oldeman climate type for Cirebon and surrounding area can be seen in the following table 1 and figure 1. Based on the classification of Oldeman climate, Cirebon and surrounding regencies have five types, namely B2, C3, D3, D4, and E which are scattered throughout C3-type dominated by Cirebon area with 58.3% of the total rainfall post research. Climatic C3 type with agro-climate zone once rice field cultivation. Type C3 dominates in Cirebon Regencies and surrounding areas spread in the region: Bojong Wetan, Cangkol, Cangkring, Jati Seeng, Kepuh, Palimanan, Losari, Setupatok Sel, Seuseupan, Sindangjaya, Tukmudal, Wanasaba Kidul, and Jatiwangi. Climatic type B2 with agro-climate zone twice as short-dry season varieties is sufficient for a single crop. Type B2 climate is scattered in the region of Panongan with the distribution of climate type B2 rain post as much as 4.16% of the total rain posts used as research objects.

| Regency       | Type | Regency       | Type | Regency       | Type | Regency       | Type |
|---------------|------|---------------|------|---------------|------|---------------|------|
| Panongan      | B2   | Kepuh         | C3   | Tukmudal      | C3   | Gegesik       | D3   |
| Bojong Wetan  | C3   | Palimanan     | C3   | Wanasaba Kidul| C3   | Mundu Mesigit | D3   |
| Cangkol       | C3   | Losari        | C3   | Stamet Jatiwangi| C3   | Sedong        | D3   |
| Cangkring     | C3   | Setupatok Sel | C3   | Ambit         | D3   | Sindang Laut  | D3   |
| Cikeusik      | C3   | Seuseupan     | C3   | Arjawinangun  | D3   | Cangkuang     | D4   |
| Jati Seeng    | C3   | Sindangiaya   | C3   | Ciawigebang   | D3   | Karang Kendal | E    |

Table 1. Classification Climate
Climate type D3 with agro-climate zone only one-time crops, spread over the area: Ambit, Arjawinangun, Ciawigebang, Gegesik, Mundu Mesigit, Sedong, Sindang Laut, with D3 climate level rain heading of 29.16% of total rainfall post made the object of research. Climate type D4 with one-time agro-climate zone of rice or unique crops, spread over the area: Cangkuang, with D4 climate type rainfall post 4.16% of total rainfall post used as the research object. Climate type E with the agro-climate zone is only possible one-time ‘palawija’, scattered in the area: Karang Kendal, with the distribution of climate type E rain post as much as 4.16% of the total Rainfall Post as the object of research. Water balance and climogram describe the availability of groundwater and various climatic elements that affect the growth and production of plants. This information is essential to plan the cropping pattern by determining the planting schedule, the type of plant to be planted, and regulate the irrigation water supply both the amount and time according to the need. Analysis of water balance and climogram in Cirebon and surrounding districts for each type of Oldeman as follows:

### 4.1. B2 Climate Type

Based on the water balance, the water balance of rice crops, potatoes, legumes, grains and plant balance Corn, tomatoes, chili on Climatic type B2 Cirebon water content obtained in Figure 2. Based on the agro-climate zone, the type of climate type B2 can be used for two short-and low-cultivated lowland rice cultivation, but in determining the cropping pattern should consider the condition of groundwater availability for plants and other climatic elements. To ensure plant growth, water should be added if 50 -85% of the available water has been discharged. Based on this, the period of planting period is defined as the period at which KAT is not less than 50% of the water available.
Based on figure 3, the corresponding cropping pattern is to conduct two planting periods for 3-months paddy to harvest, an i.e. period I: Dec-Feb and period II: March-May. The period of June-August the condition of water content is unsupportive to get well rice cultivation in this period. As well as planted crops that do not require much water, so the period of June-August is expected and recommended the farmers plants such as legumes, potatoes, corn, tomatoes, chili. However, for corn, tomatoes, chilies, and seeds it is necessary to provide irrigation water in August so that soil water content conditions are available for plants so that the plants can grow and develop properly. Type B2 indicates that the period of paddy planting should be conducted when the temperature below or above the average with rainfall above 200 mm while the initial period of crops ‘palawija’ carried out where the temperature below average with bulk rain below 100 mm.

4.2 C3 Climate Type

Based on the water balance, the water balance of rice crops, potatoes, legumes, grains and plant balance Corn, tomatoes, chili on Climate C3 type Cirebon Regencies obtained groundwater content as follows:

Climate and temperature rain climograms in C3 Cirebon Regencies climate type as Figure 5.
Figure 5. Climogram Rainfall and Air Temperature Climate C3

Based on the climatic zone of climatic oldeman type C3 can be used once rice paddy, one-time ‘palawija’, and one dry system. However, based on KAT graph of climate type C3, it can be seen that the rice planting period can be done two times, namely period I: Dec-Feb and second period: March-May. Then for the period of Jun-August entering period of cultivation of ‘palawija’ or dry system, this period the farmer is expected to plant legumes. Because the KAT condition is above the PLT so that water is still available for the plant, while for the potato, corn, tomato, chili, and seed can be planted if there is an irrigation water supply in August for KAT conditions above PLT so that the plants can grow and develop properly. The relationship of rainfall climogram and air temperature to the adjustment of plant species on climate type C3. Shows that the period of rice planting should be done when the temperature below or above the average with rainfall above 200 mm while the initial period of crops ‘palawija’ done where the temperature below the average with rainfall below 100 mm.

4.3 D3 CLIMATE TYPE

Based on the water balance, the water balance of rice crops, potatoes, legumes, grains and plant balance Corn, tomatoes, chili in Climate D3 type Cirebon Regencies obtained groundwater content as follows:

Rainfall climogram and air temperature on climate type D3 Cirebon Regencies as follows:
Based on the agro-climate zone the type of climate D3 can be used for one time rice paddy or one time crops, but based on the water availability for the plants on the KAT climate type D3 for the period of paddy rice cultivation can be planted in the period of Feb-April. January is not recommended for planting rice because at the beginning of rice cultivation requires more water while KAT January is located far below Optimum. Periode May-July can still do period ‘palawija’ with the condition in July need irrigation so that KAT soil can be fulfilled for the plant to grow and develop well. Such as potatoes, legumes, grains, maize, tomatoes, and chilies. The rainfall and air temperature climogram to the adjustment of plant species on climate type D3 indicates that the beginning of rice planting should be done when the temperature below or above the mean by bulk rain above 200 mm while the initial period of cultivation of ‘palawija’ is done where temperature below or above average with rainfall below 100 mm.

4.4. D4 CLIMATE TYPE

Based on the water balance, the water balance of rice crops, potatoes, legumes, grains and plant balance Corn, tomatoes, chili in Climate Type D4 Cirebon Regencies obtained groundwater content as follows:

![Figure 8. Soil Water Content in Cirebon Type of Climate D4](image)

Rainfall climogram and air temperature in D4 Cirebon Regencies climate type as follows:
Based on the agro-climate zone, type of climate D4 can be used once rice or one-time crops. But based on water availability for plants in KAT type of climate D4 shows that the land can be planted 1 period of wetland rice that is Jan-Mar period and one period of ‘palawija’ is Apr-Jun expected in the month to be planted crops of ‘palawija’ such as legume, potato, corn, tomato, chili, and grain. Relations of rainfall climogram and air temperature to the adjustment of plant species on climate type D3 shows that the period of rice planting when the temperature below above average with rainfall above 200 mm while the initial period of cultivation of ‘palawija’ carried out where the temperature below the average with rainfall between 200 mm and 100 mm is moist month.

### 4.5 E Climate Type

Based on the water balance, the water balance of rice crops, potatoes, legumes, grains and plant balance Corn, tomatoes, chili on Climate E type Cirebon Regencies obtained groundwater content as follows:

**Figure 9. Climogram Rainfall and Air Temperature Climate D4**

Rainfall climogram and air temperature in climate type E Cirebon Regencies as follows:

**Figure 10. Soil Water Content in Cirebon (Type of Climate E)**
Based on the climatic zone of climatic oldeman climate type E. Soil is too dry and can only be planted one time only ‘palawija’. However, based on water availability for plants on KAT type climate chart E it can be seen that land can still be cultivated paddy rice that is in the period of Feb-April because at that period KAT is always above optimum it supports the cultivation of paddy rice and in the growth phase. The period of May-July can still be planted with crops such as Legume, Potatoes, Grains, Corn, Tomatoes, Chillies. Also, The relation of rainfall climogram and air temperature to the adjustment of plant species on climate type E Cirebon Regencies shows that the period of rice planting should be when the temperature under or above average with rainfall between 200 mm and 100 mm. While the initial period of cultivation of ‘palawija’ where the temperature above average with rainfall between 200 mm and 100 mm.

**Conclusion**

Oldeman climate classification in Cirebon and surrounding areas there are five types of climate such as B2, C3, D3, D4, E which spread in some districts in Cirebon and surroundings with C3 type dominating Cirebon region with the distribution of rain post about 58.3% which is the object of research. The Determination of cropping pattern in Cirebon based on water balance and climogram. It can be showed that climate type B2 and C3 have cropping pattern that is: 2 PS + 1 PL, while planting pattern of climate type D3, D4, E, i.e., 2PS + 1PL, obtained difference plant climate type C3, D3, D4, and E against the Oldeman agroclimatic zone. Based on the above discussion, the planting schedule for rice and crops in Cirebon can be seen on the following outline:

1. the rice planting period I
2. The rice planting schedule of the second period
3. Map of ‘palawija’ planting schedule

**Table 2. Classification Planting Based on Climate**

| Climate | Paddy I | Paddy II | ‘palawija’ |
|---------|---------|----------|------------|
| B2      | Dec-Feb | Mar-May  | Jun-Aug    |
| C3      | Dec-Feb | March-May| Jun-Aug    |
| D3      | Feb-April | -       | Mei-July   |
| D4      | Jan-Mar | -        | Apr-Jun    |
| E       | Feb-April | -       | May-July   |
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