Modeling of Soil Water Availability for Agricultural Planning at Pelaga Village, Badung Regency, Bali, Indonesia

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Abstract. Pelaga Village is located in Badung regency which has the advantage in agriculture with the cultivation of coffee plants, oranges, carrots, cabbage, and chili. The physical condition of Pelaga Village which has high rainfall, bumpy areas, and sandy-sandy ground texture causes air to air to be available for plants. Based on these questions then conducted a study to determine the comparison between the available water and water requirement for agriculture. Available water was difference field capacity and permanent wilting point method and crop water requirement was using Blaney-Criddle method. The results from this research was deficit between available air and crop water requirements. Available water was 12,12% and crop water requirement in initial stage, dev. Stage, mid-season stage, and late season stage respectively, coffee 11.28%, 24.19%, 35.49%, 29.04%; cabbage 19.58%, 19.58%, 33.10%, 27.74%; carrot 14.82%, 28.61%, 28.61%, 27.95%; Orange 14.82%, 28.61%, 28.61%, 27.23%; chili, 17.37%, 17.37%, 34.80%, 30.46%. Soil management that must be done is by short-term land management by sprinkling long-term soil management by means of organic material valuation, irrigation making, and terracing making.

Key words: Soil water hydrological, Water requirement, Agriculture Planning.

1. Introduction
Water is very important for plants grow because it is the main component in the cells to making up the plant tissue. The amount of water in the plant ranges from 80-90 percent of the dry weight of the plant. This percentage will become even greater in the parts of the plant that are actively growing [1]. Water requirement for every plant is deferent depends on the shape, type, age, planting medium, environmental conditions around the plant and season so that each plant has a certain water content limit for its growth. In soil the presence of water is indispensable to the plants that must be available to meet the need for evapotranspiration and as a solvent, together with dissolved nutrients to form a soil solution to be absorbed by plant roots. The crop water requirement is highly dependent on the water available in the soil for the growing process of soil’s ability to retain water. The crop water requirements are based on crops evapotranspiration [8].

The ability to hold water on soil differs according to the texture and the pore count. In general, dominant clay textured soil has the ability to hold and store high water, because the water molecule is strongly absorbed on the surface of the soil. While on the sand-textured soil has the ability to hold and
store water is very low. Good water supply is 60-80% of field capacity [1]. Pelaga Village is an administrative area of Petang District, Badung Regency. The topography of the area is bumpy to hilly with temperatures of 20-30°C (Pelaga website). Based on the regional spatial plan, Pelaga Village is planned to plant horticultural crops, garden plants and food crops. Planning serves to improve the economy of the community. Plants planned for horticulture plants and gardens adapted to the plants that have been planted by the Pelaga Village community. The plants are cabbage, carrots, chili, tomatoes, and oranges and coffee. The types of plants to be planted will be greatly influenced by the hydrological nature of Pelaga Village. So, it will be very important to know the needs of water plants and water available in the soil. Based on the above description, the authors are interested to conduct research with modeling of available water for and planning of horticultural plants and mixed plantations. The usual plants that planted by the farmers in Pelaga Village are coffee, cabbage, carrots, orange and pepper. The results of this study aim to find out the needs of water for horticultural plants associated with water available in the soil and planning of agricultural planning as input to the community in Pelaga Village, Petang District, Badung Regency, Bali, Indonesia.

2. Methodology

2.1. Area of Study

The research was conducted in Pelaga Village, Petang District, Badung Regency. Total area of pelaga village is 3545.204 Ha with height 1017 meter above sea level. Average temperature 20° - 30° C with population of 5903 people [10]. Pelaga Village is located in 8.30561 Latitude South and 115.21399 Longitude east.

2.2 Tools and Material

The material used in this research are spatial datas as follows:

- Pelaga Village map 1: 25,000
- planning map 1: 25,000
- soil sample

While the tools are:

- Computer or laptop used to process the spatial data
- GPS (Global Positioning System) to determine the coordinate point of observation.
- Camera
- Stationary
- Abney level
- Ring sample
- Double ring infiltrometer
- Soil munshel color chart
- Soil drill

2.3 Methods and Implementation of Research

The method used in this research is observation method with direct observation in field and laboratory analysis. Research done in accordance with several stages namely; (1) preliminary planning and preparation of land surveys aimed at finding out the location points of soil sampling, (2) soil sampling, (3) analysis of some soil hydrological characteristics such as permeability, infiltration, moisture capacity, permanent wilting water point, water available, and water requirement, (4) data analysis with descriptive method.

2.4 Field Survey and Soil Sampling

The location of the study is a located in a land that is not cultivated. In the research area some sample points were taken. Soil samples obtained in the field were mixed composites and analyzed in the laboratory. Soil sampling was done at the degradation layer with a depth of 0-30 cm. Soil samples are
taken in disturbed and undisturbed form. Soil sampling in the form is disturbed for texture observation, particle density, moisture content of field capacity, moisture content of permanent wilting point and organic matter. Direct observation in the field to observe: infiltration, soil structure, soil color, effective soil depth, slope, slope direction, soil moisture depth, and growing vegetation.

Field observation was done on the soil of each sample point sampling in Pelaga Village, Petang District, Badung Regency. Parameters observed include Infiltration, using double ring infiltrometer. The term infiltration refers specifically to entry of water into the soil surface. The movement of water into the soil by infiltration may be limited by any restriction to the flow of water through the soil profile [5]. The area of study and the soil sample location can be seen in Figure 1.

![Figure 1. Area of Study and Sample Location](image)

2.5 Soil Analysis Method
Soil analysis is done in Soil Laboratory, of Udayana University. Parameters analyzed include:
1. Soil text with pipe method
2. Water content of field capacity with gravimetric method.
3. The water content of the permanent wilting point by looking at the change of color change limit (Atterberg's determination) of the soil paste becomes dry, then searched the water content by gravimetric method.
4. Permeability of soil by constant head permeameter method
5. Soil organic matter with Walkley and Black method.

2.6. Water Requirements

Water requirements for crop calculated based on the water needed for crop to replace the water loss due to evapotranspiration process. The water requirements include the calculations of available water content, evapotranspiration rate and consumptive water requirement for crops based on plant coefficient.

2.6.1. Available Water content. Available Water content calculation is available by the formula of equation (1).

\[
\text{Available Water Content} = \text{Field Capacity Water Level} - \text{Permanent Wilting Point} \tag{1}
\]

2.6.2. Evapotranspiration. Evapotranspiration is calculated using Blaney-Criddle method with the formula on equation (2)

\[
Eto = p \cdot (0.46t + 8.13) \tag{2}
\]

\(p\) = comparison of the average length of day time for a particular month with the amount of time spent in the day of the year
\(t\) = daily average temperature (°C)

Mean Daily Percentage (p) of Annual Daytime Hours for different latitudes, listed in Table 1 [8].

| Table 1. P Factor of Blaney – Criddle |
|--------------------------------------|
| **Lat** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **June** | **July** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** |
| S | July | Aug | Sept | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | June |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 60 | 0.15 | 0.20 | 0.26 | 0.32 | 0.38 | 0.41 | 0.40 | 0.34 | 0.28 | 0.22 | 0.17 | 0.13 |
| 55 | 0.17 | 0.21 | 0.26 | 0.32 | 0.36 | 0.39 | 0.38 | 0.33 | 0.28 | 0.23 | 0.18 | 0.16 |
| 50 | 0.19 | 0.23 | 0.27 | 0.31 | 0.34 | 0.36 | 0.35 | 0.32 | 0.28 | 0.24 | 0.20 | 0.18 |
| 45 | 0.20 | 0.23 | 0.27 | 0.30 | 0.34 | 0.35 | 0.34 | 0.32 | 0.28 | 0.24 | 0.21 | 0.20 |
| 40 | 0.22 | 0.24 | 0.27 | 0.30 | 0.32 | 0.34 | 0.33 | 0.31 | 0.28 | 0.25 | 0.22 | 0.21 |
| 35 | 0.23 | 0.25 | 0.27 | 0.29 | 0.31 | 0.32 | 0.32 | 0.30 | 0.28 | 0.25 | 0.23 | 0.22 |
| 30 | 0.24 | 0.25 | 0.27 | 0.29 | 0.31 | 0.32 | 0.31 | 0.30 | 0.28 | 0.26 | 0.24 | 0.23 |
| 25 | 0.24 | 0.26 | 0.27 | 0.29 | 0.30 | 0.31 | 0.31 | 0.29 | 0.28 | 0.26 | 0.25 | 0.24 |
| 20 | 0.25 | 0.26 | 0.27 | 0.28 | 0.29 | 0.30 | 0.30 | 0.29 | 0.28 | 0.26 | 0.25 | 0.25 |
| 15 | 0.26 | 0.26 | 0.27 | 0.28 | 0.29 | 0.29 | 0.29 | 0.28 | 0.28 | 0.27 | 0.26 | 0.25 |
| 10 | 0.26 | 0.27 | 0.27 | 0.28 | 0.28 | 0.29 | 0.29 | 0.28 | 0.28 | 0.27 | 0.26 | 0.26 |
| 5 | 0.27 | 0.27 | 0.27 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.27 | 0.27 | 0.27 |
| 0 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 |

Southern Latitude: Apply 6 month difference as shown

2.6.3. Consumptive Water Requirements. Consumptive Water Requirements is calculated using Blaney-Criddle method [5] with the formula on Equation (3)

\[
CWR = K_c \cdot Eto \tag{3}
\]

\(CWR\) = consumptive water requirement (mm / 0.5 bln)
Kc = coefficient of plant
Eto = evapotranspiration (mm / 0.5 bln)

Values of The Crop Factor (Kc) For Crops and Growth Stage are listed in Table 2 [8].

| Crop         | Initial Stage | Crop dev. Stage | Min-season Stage | Late season stage |
|--------------|---------------|-----------------|------------------|-------------------|
| Coffee (bean)| 0.35          | 0.70            | 1.10             | 0.90              |
| Cabbage/Carrot| 0.45         | 0.75            | 1.05             | 0.90              |
| Orange       | 0.45          | 0.70            | 0.90             | 0.75              |
| Chili        | 0.35          | 0.79            | 1.05             | 0.90              |

3. Results and Discussion

3.1 Results

Results of direct observation in the field and laboratory analysis from each parameter in the assessment of available water and crop water requirements, physical and chemical parameters include texture, permeability, organic matter, water characteristic parameters include infiltration, field capacity, permanent wilting point, and available water. Soil texture analysis result is clay soil with soil type of Andisol vitrik, permeability 93.40 cm/hr with very fast category, soil organic material is 5.04%. While the result of infiltration water analysis is 39.60 cm/hour, field capacity 24.80%, permanent wilting point 12.58%, and available water content 12.12%.

Crop water requirements deferent by growth phase. The highest average water requirement is required by plants on the crop definitive stage and at mid-season stage. In coffee plants water demand increases in the crop definitive stage and continues to increase until mid-season stage, but decreases at the late season stage. This also applies to cabbage, carrot, squash, and pepper. Water requirement for each crop shows in Table 3. Water requirements for each crop of coffee, cabbage, squash, carrot, and pepper shows in Figure 2.

| CWR          | Coffee | Cabbage | Carrot | Squash | Pepper |
|--------------|--------|---------|--------|--------|--------|
| Initial Stage| 11.28  | 19.58   | 14.82  | 14.82  | 17.37  |
| Crop dev. Stage| 24.19 | 19.58   | 28.61  | 28.61  | 17.37  |
| Mid-season Stage| 35.49 | 33.10   | 28.61  | 28.61  | 34.80  |
| Late season stage| 29.04 | 27.74   | 27.95  | 27.23  | 30.46  |

3.2. Discussions

Water available in the soil tends to be low with 12.12% result. The results depend on the parameters of infiltration, organic material, soil texture and soil type in the study area. The soil type in the research area is Andisol. The soil properties of Andisol are thick, dark, brown to black, very porous, very loose, non-tough, and unsteady, crumb or granular structures, oily as they contain 8-30% organic matter [9]. This nature causes the water content available in Pelaga Village tends to be low, because the soil cannot store water for too long. Texture of clay soil with a more dominant percentage of dust causes water not to be infiltrated properly, because the pores of the soil are covered with dust, so that the falling rain water will become more of a surface runoff. Low organic matter with a value of 5.04%, causing soil aggregates not formed and water entering into the soil through rainwater cannot be stored.
Texture of clay soil has more dominant percentage of dust. Dust is a fraction of the soil that is very sensitive to erosion / easily eroded because of the rainfall, so it can close the pores of the soil so the falling rain will be converted into runoff. The level of organic matter that is relatively ideal for the soil can lead to the formation of a solid soil aggregate, but in the Andisol soil the role of organic matter in absorbing water is not optimal. Andisol soil has the ability to absorb and store water that cannot revert as previous when experiencing drought (irreversible drying). This irreversible nature causes a change in particle size, because the allophane mineral contained in Andisol soil will tend to form a pseudosand fraction of allophane aggregation with other particles including organic matter [11]. Allophane will increase the humus retention against microbiological decomposition so that humus does not bind water.

The water needs of coffee crops, oranges, cabbage, chilies, and carrots differed according to the growing period. The most water is needed during the crop definitive stage and mid-season stage. Water demand during vegetative and generative growth is very important. Water shortages in the vegetative growth phase cause cell development and division to become late which affects plant growth and production [3]. Water demand increases during this phase because the plant has begun to multiply the growth of its leaves and the plants begin to bloom and bear fruit. It causes more water are needed for evapotranspiration process. The availability of groundwater tends to deficit against the need for water for coffee, citrus, cabbage, carrots, and chilli in Pelaga Village when there is no addition of water from outside such as rainwater and irrigation. This water shortage can decrease the productivity of plants, but it is strongly influenced by the respective response of each type of plant to the water shortage [4].

To meet the needs of crop water should be done some long-term and short-term land management. Short-term management that must be done is by watering. To accelerate growth and improve crop yields need watering according to water requirements so that water can be utilized efficiently [2]. While long-term management that must be done is the provision of organic materials and making irrigation networks. Irrigation is limited largely by the available water supply. Relatively large quantity of water required to satisfy the needs of the crop and to supply conveyance, evaporation, and seepage lessees [5]. The role of organic matter to the physical soil is as one of the aggregate soil formers, which has a role as adhesive agent between soil particles to unite into soil aggregates, so that organic matter is important in the formation of soil structure [7]. Increased soil organic matter causes the water content to increase as well, adding organic matter will increase the soil’s ability to retain water so that the ability to provide soil-water for plant growth increases [10].

![Graph a. Coffee](image1)

![Graph b. Cabbage](image2)
Figure 2. Water Requirement for (a) coffee, (b) cabbage, (c) carrot, (d) squash, (e) pepper

4. Conclusions
Based on the results of statistical analysis and discussion, it can be concluded as follows:
1. Water available Pelaga Village is 12.12%. Soil texture analysis result is clay soil with soil type of Andisol vitrik, permeability 93.40 cm/hr with very fast category, soil organic material is 5.04% with low category. While the result of infiltration water analysis is 39.60 cm/hour, field capacity 24.80%, permanent wilting point 12.58%, and available water content 12.12%.
2. Crop water requirement for each planting period respectively was, coffee 11.28%, 24.19%, 35.49%, 29.04%; cabbage 19.58%, 19.58%, 33.10%, 27.74%; carrot 14.82%, 28.61%, 28.61%, 27.95%; Orange 14.82%, 28.61%, 28.61%, 27.23%; chili, 17.37%, 17.37%, 34.80%, 30.46%.
3. Comparison between water requirement and water available in the soil was deficit. Planning and management of the soil that can be done by watering, irrigation, giving organic materials and making terracing to reduce the water deficiency for the crops.

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