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# Estimation of Irrigation Water Requirement for Land Preparation of Ricefield in Irrigation Modernization

**Andri[1], Murtiningrum[2]✉, Ngadisih[2]**

[1]Magister of Agricultural Engineering Study Program, Department of Agricultural Engineering and Biosystems, Faculty of Agricultural Technology, Universitas Gadjah Mada, Yogyakarta, INDONESIA.
[2]Department of Agricultural Engineering and Biosystems, Faculty of Agricultural Technology, Universitas Gadjah Mada, Yogyakarta, INDONESIA.

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✉Corresponding Author:
tiningm@ugm.ac.id

**ABSTRACT**

*Irrigation water requirement for irrigation for land preparation is the highest water requirement in rice cultivation therefore it was essential to determine it based on recent condition in order to support the irrigation modernization. This research aimed to determine the irrigation requirement and tillage specific drafts based for various water ponding level in rice field as well as to determine parameters of irrigation requirement for land preparation to support irrigation modernization. Determination of irrigation water requirement is computed based on equation developed by Van de Goor and Zijlstra (1968) with variation of water volume supplied for saturation and ponding level. Variation of water supplied during land preparation resulted in the variation of tillage specific drafts according to empirical formula developed by Kisu (1972). Water level ponding of 0 mm, 5 mm, 30 mm, and 74 mm resulted in water requirements for land preparation (Project Water Requirement/PWR) of 112 mm, 122 mm, 139 mm, and 198 mm, respectively. The mentioned water ponding level resulted in the tillage specific draft of 1.131 kg/cm2, 1.101 kg/cm2, 0.886 kg/cm2, and 0.954 kg/cm2, respectively. The thicker water ponding in the rice field, the more water requirement for land preparation, but the less energy needed for tillage. Recommended irrigation requirement for land preparation was 139 mm with 15-day duration of land preparation.*

## 1. INTRODUCTION

The discussion on modernization of irrigation has basically been mandated in Presidential Regulation Number 18/2020 on the 2020-2024 National Medium-Term Development Plan, which states that Indonesia's irrigation modernization is an effort to increase the efficiency and performance of irrigation systems, and to provide water for high-value agricultural commodities. Strategies for increasing the efficiency and performance of irrigation systems by applying the concept of irrigation modernization through the construction of new irrigation networks, rehabilitation of irrigation networks, increasing the capacity of irrigation institutions, increasing the effectiveness of irrigation water allocation, and using sub-optimal land through revitalizing swamps. The aim of irrigation modernization in Indonesia is to improve irrigation services to support farming productivity in order to increase agricultural production in the context of national food security and farmer welfare. Irrigated agriculture globally consumes about 90% of water use, and between 1950 and 2006, food production doubled, while agricultural water consumption tripled (Richter *et al*., 2013). Rice plants that require a lot of water are increasingly difficult to maintain due to the impact of climate change, rainfall patterns, silting of rivers and reservoirs, damage to irrigation canals which result in rice plants often experiencing drought (Tabri, 2009). In the Director General of Water Resources Circular Letter No 1/2019, modernization of irrigation in Indonesia is defined as an effort to establish a participatory irrigation management system that is oriented towards fulfilling irrigation service levels effectively, efficiently and sustainably, irrigation modernization involves five pillars namely water availability, irrigation infrastructure, institutions, management systems, and human resources (Kementerian PUPR, 2019).

Rice plants as a staple food source that are widely cultivated in Indonesia use irrigation water in quite large quantities. One of the stages in rice cultivation that consumes the most water is the tillage stage. One method that has been used for a long time for land preparation was the method developed by Van de Goor & Zijlstra (1968). This method used a lot of water for processing rice fields with a system of saturating the soil and making it inundated (Kementerian PUPR, 2019). The results of the research developed by Mohanty *et al*. (2004) stated that the loss of water through seepage plus percolation is significantly higher without mudding than through the mudding stage. The main problem of water conservation-oriented agricultural practices was increasing the efficiency of using rainfall and irrigation (Zheng *et al*., 2014). In an effort to save water to support Irrigation Modernization in Indonesia, one of the efforts that has been made was to minimize the reporting time of irrigation operations using the web-based software Irrigation Operations Management System (SMOPI) (Sofiyuddin & Rahmandani, 2019). The problem of irrigation modernization to speed up the decision-making period is not an easy one, especially during the tillage period because the relationship between water demand and time is not linear. The amount of water needed for tillage will affect the accuracy of giving irrigation water, determining cropping patterns and applying the right method of tillage.

Tillage in the cultivation cycle in paddy fields is one of the most energy-consuming processes. The reduction in the energy required for plowing was obtained from increasing the working width with shorter couplings because there was an increase in working capacity, on the other hand the working depth of plowing increased energy expenditure and fuel consumption (Moitzi *et al*., 2013). In paddy field tillage, the soil is saturated and flooded to reduce the energy required for plowing, but saturation and flooding cause significant water loss. Efforts to increase the efficiency of water use can be obtained by processing shallow soil (Cabangon & Tuon, 2000).

This study discusses how large the need for irrigation water is in preparing agricultural land, by proving that the Van de Goor & Zijlstra (1968) method is still relevant for use in today's irrigation modernization when more efficient use of water is needed. By taking into account the measurable characteristics of the soil and measuring the amount of water given to the process of preparing agricultural land. This study aims to: i) measure the tillage water requirements at various water thicknesses in the field, ii) measure the plowing draft under various water conditions in the field, iii) determine the parameters in the tillage water requirement equation for irrigation modernization.

## 2. MATERIALS AND METHODS

### 2.1. Framework

The approach used to measure the required amount of water for land preparation (Project Water Requirement, PWR) can be determined based on the depth and porosity of the soil in paddy fields. The equation that can be used to estimate water requirements for land preparation is shown in Equation (1).

$$PWR = \frac{(Sa - Sb)N.d}{10^4} + Pd + F1 \tag{1}$$

where, *PWR* is water requirement for land preparation (mm), *Sa* is degree of soil saturation after land preparation begins (%), *Sb* is degree of soil saturation before land preparation begins (%), *N* is soil porosity in % at the average value for soil depth, *d* is assumed soil depth after land preparation work (mm), *Pd* is depth of inundation after land preparation work (mm), *F1* is loss of water in paddy fields for 1 day (mm).

Calculation of the water requirement for the tertiary unit area being treated (*A*, ha) receives a volume of water in the time period dt of $I{\cdot}A{\cdot}dt$, with a discharge of *I* ($L.s^{-1}.ha^{-1}$). Of this amount, some of the water ($M{\cdot}y{\cdot}dt$) is used to maintain the water layer on the land that is already saturated (*y*, ha), while the rest ($S{\cdot}dy$) is used to saturate the new area of *dy* (additional tillage area, ha).

$$I\ A\ dt = M\ y\ dt + S\ dy \tag{2}$$

where *M* is topping up requirement (mm/day), *I* is rate of water administration (mm/day), *T* is length of land preparation period and from the start of watering until planting (d), *S* is amount of water needed to saturate the soil and create a layer of puddles (mm).

Calculation of irrigation needs during land preparation uses the method developed by Van de Goor & Zijlstra (1968). The developed method is based on a constant water rate in 1/s during the land preparation period with equation (3).

$$IR = \frac{Me^k}{(e^k - 1)} \tag{3}$$

$$k = MT/S \tag{4}$$

With *IR* is need for irrigation water at the rice field level (mm/d), *M* is water requirement to replace or compensate for water loss due to evaporation and percolation (for saturated paddy fields $M = Eo + P$ (mm/d)), *Eo* is evaporation of open water taken 1.1 ml/d, *Eto* during land preparation (mm/d), *P* is percolation, *T* is land preparation period (d), *S* is water requirement for saturation plus a layer of standing water.

In the research that has been carried out by calculating the water requirement for tillage at various thicknesses of water in the field and measuring the plowing draft of each water thickness and analyzing it by providing variations in the period of land preparation and variations in the value of the water requirement for saturation plus a layer of water can produce the new *IR* value (mm/day) from the development of the Van de Goor & Zijlstra (1968) method.

### 2.2. Research Site

Measuring the need for soil treatment water was carried out in an irrigation modernization demonstration plot developed by the Department of Agricultural Engineering and Biosystems, Faculty of Agricultural Technology, Gadjah Mada University, which receives water from the Jatigulung Secondary Canal in the Bedegolan sub-Irrigation Area (DI). Administratively, the demonstration plot is in Prasutan Village, Ambal District, Kebumen Regency, Central Java. The implementation of this research took place from September 2021 to February 2022.

### 2.3. Research Design

The research was performed using a rice field demonstration plot owned by farmers measuring 65 x 20 m which was divided into 4 plots as shown in Figure 1. The size of plot P1 was 20 x 15 m while plots P2, P0, and P3 were each measuring 20 x 16.67 m . The four plots were saturated and then treated with inundation thickness for P0, P1, P2, and P3 with a thickness of 0 mm, 5 mm, 30 mm, and 74 mm, respectively, as shown in Table 1. The inundation thickness of 74 mm is an approximation. The thickness of the inundation that is usually done by farmers is 75 mm. As a variation, a smaller inundation thickness was chosen to see the effect on water demand and plowing draft. The demonstration plot is dry land that has not been cultivated and will be planted with rice. In the research demonstration plot, a Thomson measuring instrument and an Automated Water Level Recorder (AWLR) were placed at the intake and outlet, as well as an infiltrometer and AWLR Telemetry.

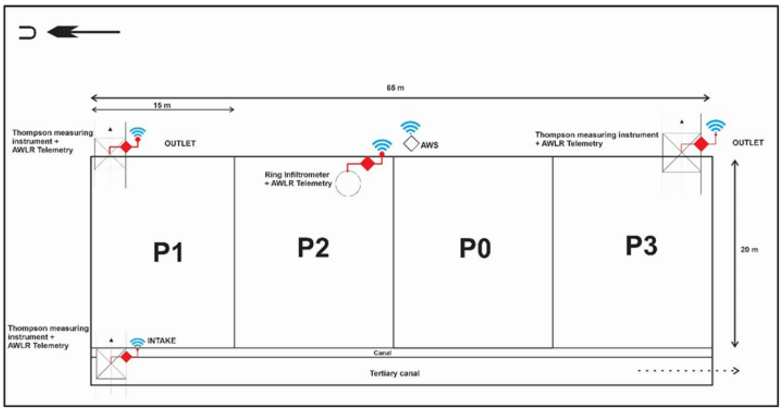


**Figure 1**. Experiment plot scheme

### 2.4. Data Collection

The data measured in this study included measuring irrigation discharge and surface runoff using a Thompson discharge measuring device. The percolation rate was measured using a double ring infiltrometer. The amount of evaporation is generated from the Penman-Monteith equation which uses the variables of solar radiation, air humidity, air temperature, and daily wind speed. Secondary data was obtained from the Progo Bogowonto Luk Ulo Water Resources Management Center (BPSDA Probolo), Kradenan station in 2021. Soil moisture and porosity measurements were carried out by taking undisturbed soil samples from the demonstration plot using a ring sampler and the specific draft for tillage was determined based on the empirical formula from Kisu (1972), which was measured using a set of Penetrometer SR-2. The specific draft of tillage is obtained by analyzing the cone index (*Ci*) and plasticity index (*Ip*) values of the soil samples.

### 2.5. Analysis

The values of variables in Equations (1) to (4) were calculated from primary and secondary data. Water requirement for land preparation using Equation (1). Open water evaporation is calculated using the Penman-Monteith equation as in Equation (5):

$$ET_0 = \frac{0.408\Delta(Rn - G) + \gamma\frac{900}{T+273}u2(es - ea)}{\Delta + \gamma(1 + 0.34u2)} \quad (5)$$

where, *ETo* is reference evapotranspiration (mm/d), *Rn* is net radiation on plant surface (MJ·m$^{-2}$·d$^{-1}$), *G* is soil heat flux density (MJ·m$^{-2}$·d$^{-1}$), *T* is air temperature at a height of 2 m (°C), $u_2$ is wind speed at 2 m (m/s), *es* is saturated vapor pressure (kPa), *ea* is actual vapor pressure (kPa), *es–ea* is saturation vapor pressure deficit (kPa), Δ is sloped vapor pressure curve (kPa/°C), and γ is psychometric constant (kPa/°C).

The specific draft (*Ds*) of tillage can be determined by the empirical equation of Kisu (1972) in Equation (6). In Kisu's (1972) empirical formula, the specific draft is affected by the modified tillage specific draft (*Ds'*), soil cone index (*Ci*), soil plasticity index (*Ip*), and soil clay content (*C*). Soil cone index obtained from measurements using a penetrometer at a depth of 5 to 60 cm for 7 repetitions.

$$Ds = \frac{80 \ x \ Ds\prime}{75{,}5 - Ip} \quad (6)$$

## 3. RESULTS AND DISCUSSION

### 3.1. Description of Research Locations

The service area of DI Wadaslintang is 31,853 ha, which covers 16 sub-districts in Kebumen and 7 sub-districts in Purworejo. Sub-District of Ambal in Kebumen Regency, Central Java, is located at 7°43'42.0" South Latitude 109°45'23.2" East Longitude. Ambal District has an area of 6,240.70 hectares (62.4 km$^2$) extending from north to south for ± 9 km and from west to east stretching for ± 7 km. According to the Central Statistics Agency (BPS, 2022) the land allotment for the Ambal sub-district is 2,837.05 hectares or around 45% of the total area is paddy fields, while 3,403.68 hectares or 55% of the total area is dry land. The results of laboratory measurements of soil texture in Prasutan Village resulted in an average percentage of clay fraction of 59.1%, an average of 5.8% sand and an average of 35.2% silt. Thus the soil is classified as a type of clay which causes the type of clay to store a lot of water (Intara *et al*., 2011). Laboratory analysis showed an average soil consistency value in the form of a Liquid Limit of 56%, a Plastic Limit of 24% and a Plasticity Index of 32% and a soil porosity of 29%. Clay soils that have high total pore space characteristics tend to have low unit weight (BV) values (Rahmawati *et al*., 2015). Loamy textured soils have a small soil volume weight and sandy textured soils have a large soil volume weight (Bintoro & Widjajanto, 2017).

### 3.2. Water Consumption for Soil Tillage

Primary soil preparation is carried out by adding water at a certain discharge as a treatment for inundation for the soil puddling process. Mudding with a certain thickness is obtained from the calculation of the water discharge in the Thompson (V-notch) weir. The thickness of the water in various treatments is shown in Table 1.

**Table 1.** Total water consumption (thickness) supplied for puddling

| Treatment | V-notch water level (mm) | Duration (s) | Flowrate ($m^3/s$) | Volume ($m^3$) | Field Area ($m^2$) | Standing Water (mm) | Total Water Consumption (mm) |
|---|---|---|---|---|---|---|---|
| P0 | - | - | - | - | - | - | 0 |
| P1 | 60 | 178 | 0,00195 | 0,35 | 300 | 1,16 | 4,76 |
| | 57 | 393 | 0,00172 | 0,67 | 300 | 2,25 | |
| | 50 | 329 | 0,00124 | 0,41 | 300 | 1,36 | |
| P2 | 70 | 134 | 0,00287 | 0,38 | 330 | 1,16 | 30,29 |
| | 68 | 391 | 0,00267 | 1,04 | 330 | 3,16 | |
| | 67 | 395 | 0,00257 | 1,01 | 330 | 3,08 | |
| | 75 | 392 | 0,00341 | 1,33 | 330 | 4,05 | |
| | 71 | 393 | 0,00297 | 1,17 | 330 | 3,54 | |
| | 69 | 396 | 0,00277 | 1,09 | 330 | 3,32 | |
| | 71 | 394 | 0,00297 | 1,17 | 330 | 3,55 | |
| | 68 | 395 | 0,00267 | 1,05 | 330 | 3,19 | |
| | 71 | 393 | 0,00297 | 1,17 | 330 | 3,54 | |
| | 70 | 197 | 0,00287 | 0,56 | 330 | 1,71 | |
| P3 | 88 | 394 | 0,00508 | 2,00 | 330 | 6,06 | 74,22 |
| | 100 | 392 | 0,00699 | 2,74 | 330 | 8,31 | |
| | 90 | 395 | 0,00537 | 2,12 | 330 | 6,43 | |
| | 95 | 392 | 0,00615 | 2,41 | 330 | 7,31 | |
| | 89 | 392 | 0,00522 | 2,05 | 330 | 6,21 | |
| | 95 | 391 | 0,00615 | 2,40 | 330 | 7,29 | |
| | 94 | 393 | 0,00599 | 2,35 | 330 | 7,13 | |
| | 93 | 394 | 0,00583 | 2,30 | 330 | 6,96 | |
| | 96 | 393 | 0,00631 | 2,48 | 330 | 7,52 | |
| | 93 | 396 | 0,00583 | 2,31 | 330 | 7,00 | |
| | 89 | 253 | 0,00522 | 1,32 | 330 | 4,01 | |

The need for water for preparing land (soil tillage) is influenced by the physical properties of the soil, and this is an important factor in determining the need for water during the preparation of paddy fields. The difference in results between estimated and actual inundation thickness is based on differences in soil surface in the study plots and the number of voids in the plots, so that some parts with voids will be filled in first. The movement of water in the soil or what is known as hydraulic conductivity, one of its types, is soil permeability which is influenced by pore characteristics, especially the stability of the soil aggregate. Pores contained in stable soil aggregates will accelerate the movement of water (Masria *et al*., 2018). The results obtained are in the form of land preparation water requirements (muddling and inundation) which are shown in Table 2.

**Table 2.** Land preparation water requirement

| Treatment | Standing Water (mm) | Sa (%) | Sb (%) | d (mm) | Pdb (mm) | F1 (mm) | PWR (mm) (Puddling + Flooding) |
|---|---|---|---|---|---|---|---|
| P0 | 0,00 | 58,7 | 38,3 | 200 | 0,00 | 21,69 | 112 |
| P1 | 4,76 | 61,0 | 38,3 | 200 | 4,76 | 21,69 | 122 |
| P2 | 30,29 | 57,1 | 38,3 | 200 | 30,28 | 21,69 | 139 |
| P3 | 74,22 | 64,6 | 38,3 | 200 | 7422 | 21,69 | 198 |

Land preparation is first among many cultural practices in rice-based cropping systems. Within irrigated areas, cultivation of wetlands is a common practice in terms of preparing land for rice production. As described by Pascual *et al*. (2019) preparation of wetlands for rice production in the Philippines usually requires 21-30 days of several field operations which require a lot of water. The need for water for land preparation is influenced by several factors, including: soil characteristics, processing time, availability of labor and livestock, and agricultural mechanization (remove from discussion or move to introduction).

Based on Table 2, the water requirement for soil treatment is obtained at various thicknesses of water in the field. Mudding can reduce the bulk density of clay-textured soils, dusty clays and loamy clays by 11%, 16% and 10% respectively (Subagyono *et al*., 2004). Soil processing with mudding results in the breakdown of soil aggregates which causes porosity and distribution of pore spaces so that soil permeability decreases (Prasetyo *et al*., 2004). The higher the tillage intensity, the greater the damage to the soil aggregates. The inundation process will also have an impact on changes in the physico-chemical soil. In a study based on the application of irrigation water in various thicknesses of water in the field, the PWR values (muddling+initial flooding) in plots P0, P1, P2, and P3 were 112 mm, 122 mm, 139 mm, and 198 mm, respectively.

The PWR value of the research when compared with the calculations that have been carried out so far, namely the water requirement for land preparation is determined empirically at 200 mm + 50 mm (puddle) which is used for land preparation needs and the initial water layer after transplantation is complete, this is based on planning criteria KP 01 irrigation and for land types that have not been planted for more than 2.5 months increased to 300 mm, of course the results are very different where in the research conducted, the closest to the KP 01 planning criteria is plot P3, namely conditions close to flooding by local farmers.

### 3.3. Measurement of Plowing Draft in Various Land Conditions

The results of calculating the cone index are shown in Figure 2. From the calculation of the Cone Index, it shows almost the same trend, namely a pattern of increasing penetration into the soil, so the Ci value increases until it reaches a certain point where Ci decreases, then it will show an increasing pattern at a certain depth. Soil processing using a tractor takes the Cone Index data at a depth of 20 cm where at that depth the highest value corresponds to the depth of the tractor plow. This is in accordance with what was explained by Iqbal (2006) which states that the value of penetration resistance tends to increase with the treatment of the intensity of the track, where the weight of the tractor is still affected by soil compaction in the area of tillage at a depth of 20 cm, in the treatment of the track intensity (this is really suddenly a treatment like this appeared? whereas in the treatment method only the height of the inundation) still had a significant effect on the soil penetration resistance although the increase was not as high as at a depth of 5 and 10 cm.

Based on the empirical equation of Kisu (1972) the plasticity index is affected by the clay content of the soil. However, in this study the plasticity index was obtained from laboratory test results. By using the Atterberg limits of the paddy field soil samples, the average used for the calculation was obtained. The results of calculating the plasticity index are in Table 3.

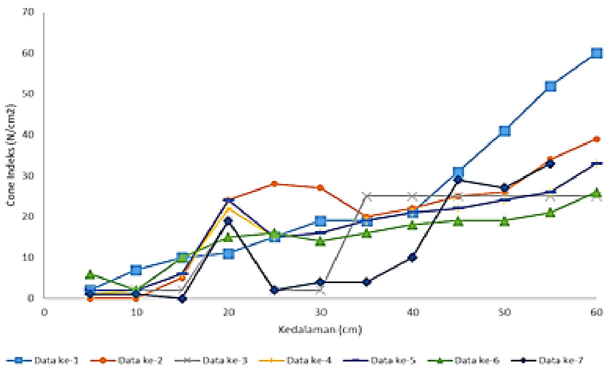


**Figure 2**. Relationship between soil depth (cm) and cone indeks (N/cm$^2$)

**Table 3.** Laboratory plasticity index values

| Treatment | Water Content (%) | Liquid Limit (%) | Plasticity Limit (%) | Sticky Limit (%) | Plasticity Index (%) |
|---|---|---|---|---|---|
| P0 | 55,6 | 59,7 | 25,0 | 35,3 | 34,7 |
| P1 | 59,6 | 55,0 | 22,3 | 32,1 | 32,7 |
| P2 | 58,5 | 52,7 | 24,0 | 32,0 | 28,7 |
| P3 | 66,5 | 58,3 | 26,5 | 36,5 | 31,9 |

According to Budhu (2015) clay has a liquid limit of 40-150%, a plastic limit of 25-50%, and a plasticity index of 15-100% and this is in accordance with the lab test results shown in Table 3. The limits it indicates how the character of the soil when it is processed, starting from when it is liquid, when it is plastic, and when it starts to stick. The consistency of the soil is related to the texture of the soil, heavy clay soils have a consistency of very loamy, very firm and hard. Factors that affect soil consistency include soil water content, soil aggregate cementing materials, soil aggregate material and size, level of aggregation, and soil structure determinants (Holilullah *et al*., 2015). All soil samples from lab tests have passed the adhesive limit and plastic limit which indicates that the soil is plastic and has adhesive capabilities. In the three plots P1, P2, and P3 the moisture content has exceeded the liquid limit, this is because the three plots are given variations in the form of standing water. This is because the nature of clay has properties in dry conditions, the clay will shrink so that the soil becomes hard and when it is in wet/moist conditions, the clay will expand and become plastic. High soil consistency will affect tillage which is increasingly difficult (Gliessman *et al*., 1998).

From the results of calculating the specific draft of modified tillage (*Ds'*), soil cone index (*Ci*), soil plasticity index (*Ip*), soil clay content (*C*) with a value of 59.06% and using the formula in Equation 5, the Specific Draft value is obtained in Table 4.

**Table 4.** Value of specific draft for land preparation

| Treatment | Cone index (kg/cm$^2$) | Clay content (%) | Plasticity Index | *Ds'* (kg/cm$^2$) | *Ds* (kg/cm$^2$) |
|---|---|---|---|---|---|
| P0 | 1,763 | 59,06 | 35,00 | 0,573 | 1,131 |
| P1 | 1,879 | 59,06 | 33,00 | 0,538 | 1,013 |
| P2 | 1,967 | 59,06 | 29,00 | 0,515 | 0,886 |
| P3 | 1,952 | 59,06 | 32,00 | 0,519 | 0,954 |

It is shown from these calculations that the specific draft values decreased in plots P0, P1 and P2 along with the addition of water thickness in the field but increased in P3. The addition of 74 mm water thickness (plot P3) showed a decrease in specific draft from no additional water thickness (plot P0) but when seen from the addition of 30 mm water thickness to the addition of 74 mm water thickness it showed an increase in specific draft of 0.068. The trend of changes in specific draft with respect to the addition of water thickness can be seen in Figure 3. It can be seen that when water is continuously supplied to the land at a certain water thickness it will have a certain limit, which affects the amount of power that must be prepared to carry out tillage. can control so as not to be wasted. Sinaga (2016) states that the value of the draft is directly proportional to the value of the day after tomorrow the cutting of the plough. The greater the draft, the greater the energy required to carry out tillage (Ismail *et al.*, 2012). In terms of water efficiency, giving water at a thickness of 30 mm or land preparation water requirements with a PWR value of 139 mm is sufficient for the land preparation process.

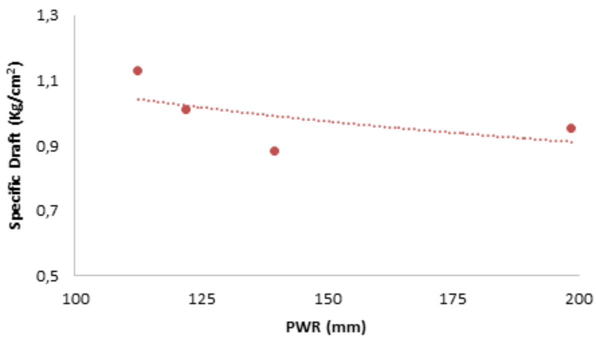


**Figure 3**. Relationship between PWR (mm) and change in specific draft (kg/cm$^2$)

### 3.4. Equation Parameters for Water Consumption for Soil Tillage

Technological development in the irrigation sector continues to be carried out in the framework of increasing the efficiency of water use and utilization of water productivity as the goal of irrigation modernization, namely meeting the level of service of irrigation effectively, efficiently and sustainably. This research develops by giving different treatment to the S value by adjusting the results of previous calculations based on the PWR value. In developing the parameters in the soil treatment water requirement equation for irrigation modernization, it is obtained by first determining the evapotranspiration (ETo) value by using Equation 4, and shown in Figure 4.

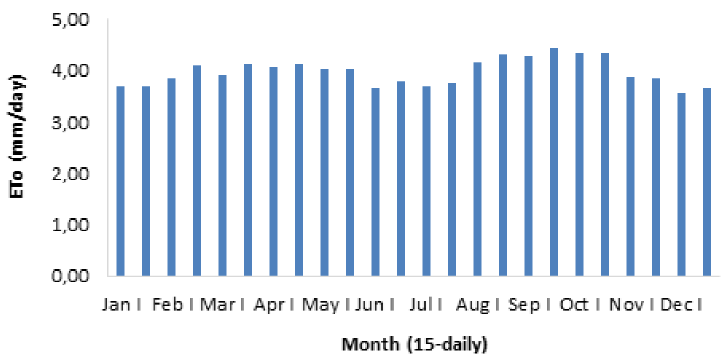


**Figure 4**. Monthly *ETo* for 2021 using the Penman-Monteith Method

Based on the ETo value, it is then used to calculate irrigation needs during land preparation using the method developed by Van de Goor & Zijlstra (1968), according to Equation (3). The calculation results are shown in Figure 5. For the calculation of irrigation water requirements during land preparation, an extension of the method developed by Van de Goor & Zijlstra (1968) was used. If seen in Figure 5. The evapotranspiration value is large, the need for water for land preparation is also large (Sulaecha & Setiawan, 2021). For tillage for the preparation of agricultural land in October by providing variations in the time period for preparing the land to 15 days which is usually done in the community for 30 days, some even up to 45 days and variations in the value of the water requirement for saturation plus a layer of water from the calculation results in Table 2 shows the value of irrigation water needs in paddy fields (mm/day) shown in Figure 6 and Table 5.

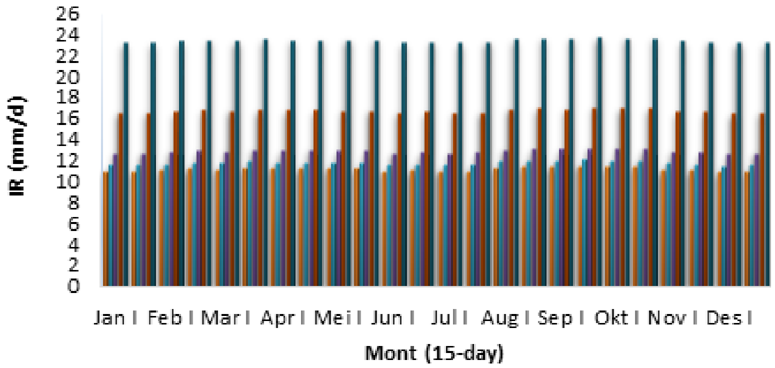


**Figure 5.** Water consumption IR (mm/day) at difrerent as variations (15-daily period)

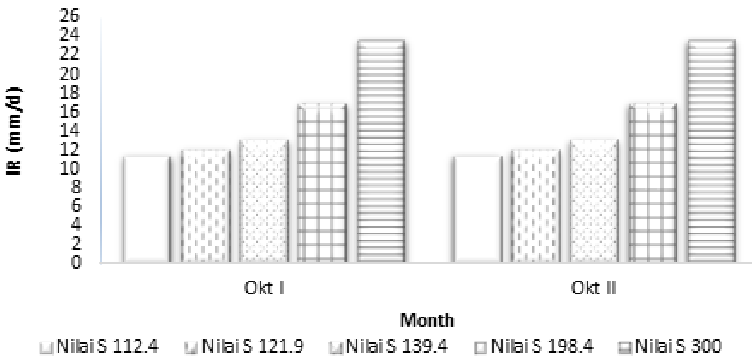


**Figure 6**. IR values for October based on 15-daily period

**Table 5.** IR values for October based 15-daily period

| Term | Unit | Oct I | | | | | Oct II | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *ETo* | mm/d | 3.76 | 3.76 | 3.76 | 3.76 | 3.76 | 3.63 | 3.63 | 3.63 | 3.63 | 3.63 |
| *Eo = ETo* × 1.10 | mm/d | 4.13 | 4.13 | 4.13 | 4.13 | 4.13 | 4.00 | 4.00 | 4.00 | 4.00 | 4.00 |
| *P* | mm/d | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| *M = Eo + P* | mm/d | 5.76 | 5.76 | 5.76 | 5.76 | 5.76 | 5.63 | 5.63 | 5.63 | 5.63 | 5.63 |
| *T* | d | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| *S* | mm | 112 | 122 | 139 | 198 | 300 | 112 | 122 | 139 | 198 | 300 |
| k = *MT/S* | | 0.77 | 0.71 | 0.62 | 0.44 | 0.29 | 0.75 | 0.69 | 0.61 | 0.43 | 0.28 |
| *IR* | mm/d | 10.74 | 11.34 | 12.47 | 16.31 | 23.01 | 10.66 | 11.26 | 12.39 | 16.24 | 22.94 |

The provision of this variation is based on technological developments that currently use plows so as to shorten processing time and based on calculations of the specific draft providing water for the most effective mudding and inundation processes of 139 mm is sufficient for primary soil processing for preparing paddy fields, as indicated by at the additional thickness of the water has the lowest specific draft which indicates the magnitude of the force to cultivate the soil is the smallest. As research conducted by Pascual *et al.* (2019) a 14-day period for wetland preparation is optimal in achieving high grain yields and less weed density in transplanted rice. This finding is important when water and human resources are limited in an area. From these results it can be illustrated that the calculation results for irrigation water needs at the rice field level, mm/day in several variations of processing time and the value of the water requirement for saturation plus a layer of water are shown in Table 6.

**Table 6.** Calculation results for irrigation water needs at the rice field level (mm/d)

| *M* = *Eo* + *P* | *T* (day) 15 | | | *T* (day) 30 | | | *T* (day) 45 | | |
|---|---|---|---|---|---|---|---|---|---|
| | *S* (mm) | | | *S* (mm) | | | *S* (mm) | | |
| (mm/d) | 139 | 250 | 300 | 139 | 250 | 300 | 139 | 250 | 300 |
| 5 | 12.01 | 19.29 | 22.60 | 7.59 | 11.08 | 12.70 | 6.24 | 8.42 | 9.47 |
| 5.5 | 12.31 | 19.56 | 22.87 | 7.93 | 11.38 | 13.00 | 6.62 | 8.75 | 9.79 |
| 6 | 12.61 | 19.84 | 23.14 | 8.27 | 11.69 | 13.29 | 7.01 | 9.08 | 10.11 |
| 6.5 | 12.92 | 20.12 | 23.42 | 8.63 | 12.00 | 13.60 | 7.41 | 9.42 | 10.43 |
| 7 | 13.23 | 20.41 | 23.70 | 8.99 | 12.32 | 13.90 | 7.82 | 9.77 | 10.77 |
| 7.5 | 13.54 | 20.69 | 23.98 | 9.36 | 12.64 | 14.21 | 8.23 | 10.12 | 11.10 |
| 8 | 13.86 | 20.98 | 24.26 | 9.74 | 12.96 | 14.52 | 8.65 | 10.48 | 11.45 |
| 8.5 | 14.18 | 21.27 | 24.54 | 10.12 | 13.29 | 14.84 | 9.08 | 10.85 | 11.79 |
| 9 | 14.51 | 21.56 | 24.83 | 10.51 | 13.63 | 15.16 | 9.52 | 11.22 | 12.15 |
| 9.5 | 14.84 | 21.86 | 25.12 | 10.91 | 13.96 | 15.49 | 9.96 | 11.60 | 12.51 |
| 10 | 15.17 | 22.16 | 25.41 | 11.31 | 14.31 | 15.82 | 10.41 | 11.98 | 12.87 |

## 4. CONCLUSION

From this study it can be concluded that with variations in the thickness of the inundation of 0 mm, 5 mm, 30 mm, and 74 mm, the water requirements for tillage (PWR) are 112 mm, 122 mm, 139 mm, and 198 mm, respectively. The treatment of variations in the thickness of standing water required specific plowing drafts of 1.131 $kg/cm^2$, 1.101 $kg/cm^2$, 0.886 $kg/cm^2$ and 0.954 $kg/cm^2$, respectively. The addition of puddles during plowing will increase the need for tillage water but reduce the plowing draft but will reach a certain value. Changes in the thickness of the inundation and reduction of the land preparation period resulted in smaller water delivery units in accordance with the aim of irrigation modernization to provide effective, efficient and sustainable irrigation services. The recommended water requirement for land preparation in this study is 139 mm with a land preparation time of 15 days.

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