Study the Efficiency of Irrigation in Rice Field Efforts to Increase Rice Yield in Irrigation Area Krueng Jrue

[1] Rahmi Putri Yanti, [2] Alfiansyah Yulianur BC, [2] Maimun Rizalihadi

[1]Masters student of Civil Engineering, Faculty of Engineering, Syiah Kuala University, Banda Aceh 23111, Indonesia; [2]Lecturer of Civil Engineering, Faculty of Engineering, Syiah Kuala University, Banda Aceh Aceh 23111, Indonesia.

Abstract. Irrigation water management problems will arise if there is a shortage of water in rice fields. Shortage of water in rice fields can be evaluated by the efficiency of existing irrigation.Based on the Indonesian's irrigation design criteria 65%, the project efficiency for Irrigation Planning is 65%. This value when compared to some countries in Asia was still much greater. This might be caused by undeterminating the water losses in the rice field. The study aims to determine the efficiency of irrigation in rice fields (Field Application Efficiency) is actually through direct measurements in the field, started at the land preparation up to the growth of rice plants. Measurements were taken at one tertiary JKr21Kr in Krueng Jreue Irrigation Region. To evaluate the efficiency of irrigation in rice fields used two methods of measurement. Inflow-outflow method for measuring the delivery of irrigation water in rice fields (Vf) which use the modified pipes that serves as the entrance and exit of water in the tertiary, the difference between incoming water and outgoing water is the amount of water used in rice fields. Water balance in the field is measured using Drum technique method with a diameter of 50 cm and height 125 cm. The drums are planted in the ground and a quarter of the height of the drum located above the surface. By this equipment, the evapotranspiration parameters, percolation and effective rainfall can be obtained. These results showthat the efficiency of irrigation in rice fields (Ea) of 65.29%. It means that actually the project efficiency is 42.44% far below than Indonesian's criteria.
Keywords. Drum technique, evapotranspiration, inflow-outflow, irrigation efficiency, percolation.

Introduction

In relation to the availability of irrigation water for rice irrigation can be assessed through the issues and factors that affect the management of irrigation water. Irrigation water management problems would arise if there is a shortage of water in rice fields. The need for water resources that are likely to increase in utilization is increasingly keen competition among the users in the agricultural sector itself. The answer to the shortage of water in rice fields with a look back at the efficiency of existing irrigation at this time. Efficiency itself arises due to loss of water during the irrigation water delivery (distribution losses) and during use (field application losses) caused any leakage, evaporation and others that the numbers vary depending on the circumstances and conditions of the channel.
In Indonesia the planning criteria (KP-03) value of the overall efficiency of irrigation water to rice fields only 65% of the intercepted water, where it is assumed that the water flowing through the primary channel will remain 90% of the intercepted water, the water flowing through the channel secondary will remain 90% of the primary channel of water that passes through the channel and the remaining 80% tertiary. This figure is generally in use as the value of efficiency in irrigation planning.

If compared to the efficiency of irrigation in some Asian countries like India in the State of the irrigation efficiency of 38%, State Malaysia the irrigation efficiency of 35-45% while in the State of Thailand the efficiency of 37-46% (LC Guerra, 1998), the value of efficiency irrigation in rice fields is used bigger than some countries in Asia. This is the problems that led to the possibility of failure of existing projects in the State of Indonesia where the efficiency of irrigation in rice fields specified in the plan is too high so that the implementation of the water provided is not enough given to areas downstream.

Regional Irrigation Krueng Jreue located in Aceh Besar district when viewed from in terms of water supply from the source at this time Krueng Jreue Irrigation feared it would be difficult to meet desired needs. Given the water crisis symptoms have started to appear where one indication of the decreasing water level irrigation Krueng Jreue 50% of 4 m^3 to 2 m^3. In addition the level of irrigation water use efficiency is still low.

In connection with the above problems it is necessary to study and consideration of re-evaluating the efficiency of irrigation in rice fields is used for this in order to meet the water needs of irrigation, especially in Krueng Jreue Irrigation Region and is generally in irrigated areas of Indonesia. Moreover, it can assist in making decisions in the future, especially in irrigation planning that leads to increased rice production. For that, we need a proper assessment of these factors on irrigation water demand fields.

Identification of Problems

Based on this background in mind that the adequacy of paddy water, frequent water shortages or excess water in the supply of irrigation water which indicates the provision of irrigation water is less efficient. If seen in the fields of irrigation efficiency are set or used in the design is too large when compared with countries in Asia. Estimated consumption or use of irrigation water in irrigated fields and imprecise in the rice supply can cause a decrease in rice production.

Purpose and Benefits Research

Purpose of the study was to determine the value of irrigation efficiency in rice fields (Field Application Efficiency) by direct field measurements of surface irrigation systems in Krueng Jreue Irrigation Region.

The benefits of research is to give the information on irrigation efficiencyof Regional Irrigation Krueng Jreue, and can be input to the relevant parties in making policy on the provision of irrigation systems to overcome the problem of lack of irrigation in rice fields .

Scope of Research

The study was conducted directly in the field for one growing season in Aceh Besar regency. Provision of irrigation using measurements of the inflow (inflow) and outflow (outflow) in the fields. Measurement of evapotranspiration and percolation in rice fields using drum techniques that are placed in tertiary fields, so it really represents the condition of the actual nature. Condition of the soil used to fill the dram in the study are according to soil conditions in the surrounding rice acreage as land preparation and plant growth. The data obtained will be analysed irrigation needs and irrigation efficiency during land preparation until plant growth.

Materials and Methods

In this study uses the method to be used in analysing the efficiency of irrigation on the fields. This method involves collecting data, methods of measurement and analysis of data on the efficiency of irrigation on rice terraces and the factors affecting water loss during cultivation and growth of rice plants.

Research sites

The research was conducted in rice fields Krueng Jreue Irrigation Region is administratively located in the district Want Jaya, Gani Village, Aceh Besar district. The study lasted for 4 (four) months i.e. by June 2011 to September 2011.

Data collection

Data collection methods used in this study is the collection of secondary data and primary data collection. Secondary data collection in this study is the documentation method used to obtain data from relevant agencies, consisting of our situation Krueng Jreue Regional Irrigation, Irrigation Krueng Jreue network maps and rainfall data and climatological data obtained from Blang Bintang Station.

Primary data consisted of direct measurement data in the field. Direct measurement of the field consisting of inflow-outflow measurements in fields, the daily rainfall measurements and measurements of evapotranspiration and percolation in rice fields by using a manual rain measuring instrument and drum rice.

Measurement procedure

Observation of the Growth of Rice Plants

Growth of rice plants were observed in two phases (vegetative phase and generative phase). Vegetative phase is the growing season until the puppies, the puppies until the puppies and the maximum is the maximum phase of generative tillers up to flowering, during flowering to full maturity, so that this observation results obtained from the length of time (days) from planting until the harvest.

Measurement of the Provision of Irrigation Water in Rice Fields

Measurement of the provision of irrigation water on rice fields during tillage performed up to the growth of rice plants. Material used is plastic gutter pipe diameter of 3 inches and a bucket capacity of 10 litres. The difference between incoming water and the water that comes out is the amount of water supplied or used on the fields. Inflow-outflow through the techniques in this study can be obtained irrigation water used on rice fields by the following equation:

$$Q=Q_{inflow}-Q_{outflow} \quad (3.1)$$

Measurement of Evapotranspiration, Percolation and Effective Rainfall

Evapotrasnpirasi measurements, percolation and precipitation using the method of drumming techniques. The equipment used includes the manual for measuring rain gauge rainfall, and 3 (three) drum diameter of 50 cm with a height of 125 cm, the drums are planted in the ground and a quarter of the height of the drum located above ground level.

In the first drum (drum A), has a lower base to obtain the value of evapotranspiration. Mechanism to obtain the value of evapotranspiration measurements is shown in Equation 3.2 Where the drum water level C1 on the first day on the water level is reduced to A2 on the day the second drum, drum water level difference in C1 and A2 show the value of evapotranspiration drum, when it rains and the provision of irrigation water the height of water in the drum C1 coupled with the provision of irrigation and rain water daily as shown in equation 3.3. These measurements can be shown by the following equation:

$$Etc=C_1-A_2 \quad (3.2)$$

$Etc=C_1+\text{daily rainfall}+\text{irrigation water}-A_2$.. (3.3)

The second drum (drum B) do not hold down to get the value of percolation, percolation is obtained based on the daily difference between the high water in the drum A and B. These measurements can be shown by the following equation:

$$\text{Percolation}=A-B \quad (3.4)$$

The third drum (drum C) do not hold down, just this drum has an outlet pipe that is placed at intervals of 0.5 cm from the face of the ground. Measurement mechanisms for effective rain are when rain falls. Excess water in the drum C will flow out through the outlet pipe. Water discharged from the outlet pipe is called effective precipitation or surface runoff. Difference between the water content in the drum and the drum C B is not effective rainfall, rainfall values obtained are not effectively be reduced with daily rainfall that occurred to get the value of effective rainfall. Daily rainfall in this study using ordinary rain gauge (manual rain-gauge). These measurements can be shown by the following equation:

$$CH_{not\ effective}=B-C \quad (3.5)$$

$$CH_{effective}=CH_{daily}-CH_{not\ effective} \quad (3.6)$$

Data analysis

Analysis of the Provision of Water in Rice Fields

Provision of water in rice fields of the measurement results obtained using the inflow-outflow technique is to follow the method of field measurements on land preparation up to the plant growth. Data provided irrigation water and coming out of the rice terraces were analyzed by using Equation 3.1.

Analysis of Water Demand in the Rice Fields

Water needs to replace or compensate for the loss of water due to evapotranspiration, percolation and effective rainfall measurement technique can be through the drum in the processing of land up to the plant growth. The data can be analysed using the Equation 3.3, Equation 3.4 and Equation 3.6

Analysis of The Efficiency of Irrigation Water in Rice Fields

Evapotranspiration, percolation, effective rainfall and irrigation water discharge is a parameter which greatly affects the efficiency of delivery of irrigation water in rice fields. Efficiency of irrigation water in rice fields can be calculated using Equation 2.7, which compares water demand in rice fields (Vm) for the provision of irrigation water in rice fields (Vf).

Fields criss water needs are the need of water used for saturation and flooding during the rocessing of land, while evapotranspiration and percolation to the plant growth through the method of measuring drum technique. Provision of irrigation water is water that is given to the rice terraces through the inflow-outflow measuring method.

By comparing the calculated irrigation water needs and the provision of irrigation water in the field it can be seen the efficiency of irrigation on rice fields are actually in the field. Expected later in the delivery of irrigation water is not excessive where excess irrigation water that can be used to overcome the shortage of rice acreage to expand water or agricultural land.

Results and Discussion

Results are expected in this study is the efficiency of irrigation in rice fields obtained from field measurements. The results of field measurements include the provision of irrigation water in rice fields and water requirements in rice fields to get the value of irrigation efficiency in irrigated rice fields and the real efficiency. Which in turn can be determined whether there is excess or shortage of water in the Irrigation Areas Krueng Jreue.

Field Observations and Measurements

An observation is runduring the land preparation to the growth of rice plants. Provision of irrigation water carried 4 times for 38 days.The growth period of rice plants to distinguish between the vegetative phase and generative phase. Generative phase began planting seedlings up to a maximum period of 45 days, while the generative phase begins from the time of maximum tillering up to the fully mature grain (ready to be harvested) for 42 days. In the vegetative phase of plant height reaching ± 70 cm and the generative phase of plant height reaching ± 94 cm. Data of plant growth can be seen in Table 1.

Table 1. Data for Rice Growth

Fase	Date	Total Days	Height (Cm)
processing of Land	28 May 2011 up to 05-July-11	38	-
Vegetative			
Planting	6 July 2011		
Puppies	1 August 2011	25	40,10
Max. Puppies	20 August 2011	20	70
Generative			
Flowering	6 September 2011	17	87,6
Fully ripe (harvest)	30 September 2011	24	94

Provision of Irrigation Water in Rice Fields

Comparison of the amount of irrigation water supplied to the rice terraces in principle adapted to the conditions of soil tillage and crop growth period of rice field. Thus the discharge of irrigation water is not always fixed, wherein the amount of irrigation water in rice fields is varied between 4.56and 8.90 litres/sec /ha.

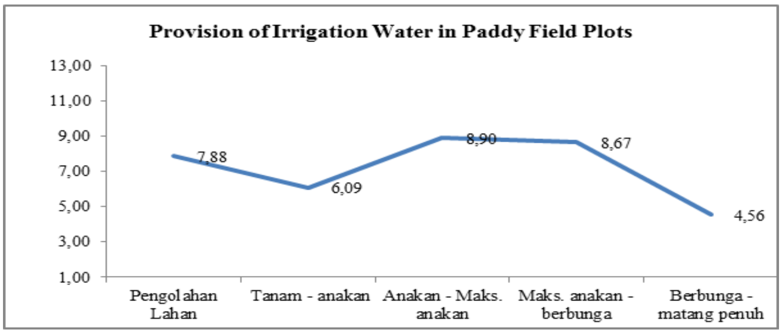

Figure 1. Provision of irrigation water in rice fields

In Figure 1 shows that at the time of land preparation requires more irrigation water for the flooding is 7.88 litres / sec / ha of the plant growth on average of 7.05 litres / sec / ha. Plant growth during the seedling phase of plant-provided irrigation water to the rice terraces is small, and then the provision of irrigation water in rice fields added gradually adapted to the plant growth. In the mature phase of flower-filled delivery of irrigation water began to be reduced gradually and the provision of irrigation water began to be stopped one week before harvest. It is intended that the provision of irrigation water can be used optimally in all areas of rice fields, so there is no shortage of water in rice field's downstream plots.

Water Company Neededthe Rice Plant

Rice crop water requirements are calculated in this study is the amount of evapotranspiration (ET) and percolation of the measurement results by using a drum.

In Figure 4.2 shows that the land preparation phase of 38 days during the evaporation plant water requirements of 3.88 mm / day and percolation 2:39 mm / day. In this phase shows a large value of evaporation due to the influence of weather in which the effective rainfall that occurred during the processing phase of land that is less 0.83 mm / day.

In the phase of planting - chicks for 25 days the crop water requirements for evapotranspiration 3:39 mm / day and the percolation of 2.64 mm / day. In this phase shows a smaller value due to the influence of weather that occurs where effective rainfall is greater than 0.93 mm / day.

At the seedling stage - max. seedlings for 20 days increased crop water requirements of paddy rice field phase due to begin before birth and the leaves begin to grow so that transpiration increases the evapotranspiration rate of 3.85 mm / day, percolation of 2.85 mm / day and 0.80 mm effective rain / day.

For phase max. Puppies - for 17 days flowering plant water requirements for evapotranspiration is 3.97 mm/day and the percolation of 2.88 mm / day. This phase in which the water needs of plants grew from the previous phase because of increasing rice leaf and to the flowering process takes quite a lot of water with an effective rain for 1:36 mm / day. For the flowering phase - a full-fledged 24-day water demand for crop evapotranspiration is 2:42 mm / day and the percolation of 2.68 mm / day, at this phase of the water needs of plants showed a smaller value where the rate of transpiration is reduced from the previous phase, so not much need water with an effective rain value of 2:14 mm / day.

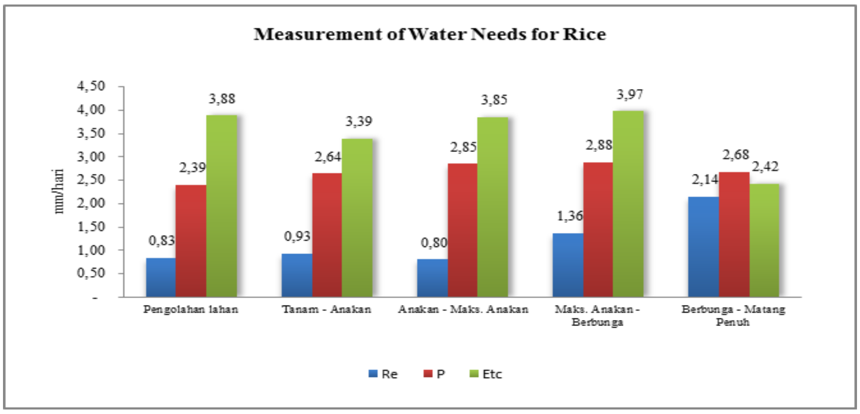

Figure 2. The results of measurements of rice crop water requirements

Water Needs in Plots

Most of the water requirements in rice fields in each phase of plant growth is not the same. This shows the level of crop water requirements at each different plant growth stages so that the water needs in rice fields should be maintained in its management in order to avoid water shortage.

From Figure 4.3 it can be seen that the water needs of plants on land preparation phase is greater than the phase of plant growth, this is due to the relatively dry soil conditions so that the process of ploughing and more water is needed. Besides the low level of rainfall causing evaporation becomes greater than the phase of plant growth.

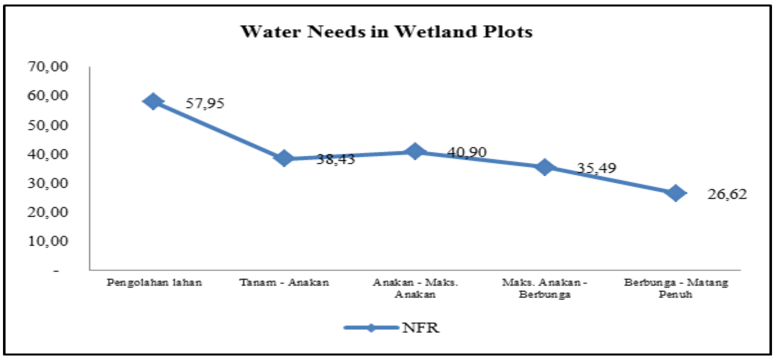

Figure 3. The need for water in rice fields under rice drum technique

In each phase of plant growth, it appears that the phase-maks.anakan puppies showed that the plant needs water are greater than the phases of the growth of other plants. Where in this phase of low rainfall levels lead to greater evapotranspiration due to rice in the rice growing and the leaves begin to give birth so that transpiration increases.

The results of field observations, in addition to water loss due to evapotranspiration and percolation are also due to the loss of water due to seepage in the fields. Seepage that occurs due to the hole/nest of rats in rice fields, resulting in leakage/seepage of water in the area of rice fields.

Irrigation Water Efficiency in Paddy Field Plots

Evapotranspiration, percolation and irrigation water discharge are the parameters of irrigation water use efficiency in rice fields. Based on the analysis of the calculation of the efficiency of irrigation in rice fields (Ea) as a whole still seems low of 65.29%, where the land preparation phase of the Ea of 85.17% and the Ea phase of plant growth by 60.32%.

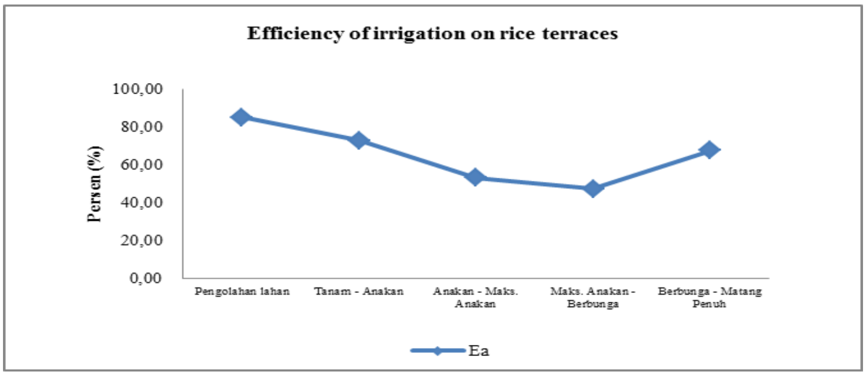

Figure 4. Efficiency of irrigation for each crop growth stage

Ea value of plant growth stage is smaller than the land preparation phase as shown in Figure 4. This is due to the higher rainfall that becomes smaller evapotranspiration during plant growth. Also note the loss of water due to seepage in rice fields where there are several small holes in the rice terraces as a result of pest rodents in the plant growth. Seepage in rice fields of the rat due to the amount of the provision of irrigation water causes the plant growth on a larger / occurrence of excess water which does not match the crop water requirements and water shortages downstream.

Irrigation efficiency in rice fields can be increased if the problem can be solved on the rice terraces. The efforts to do the rice terraces in order to improve the efficiency of irrigation on rice terraces, among others:

1. Prevention of pest rodents in rice fields can be done in several ways including:
   - Dismantling and cover the holes where the rats hide and catch mice.
   - Using the natural enemies of mice, the snakes.
   - Using rodenticides (rat extermination) or by placing poisoned bait, which is a slice of sweet potato or cassava that has been previously soaked with phosphorus. Poisoning should be carried out before flowering and seed paddy. In addition the use of poison should be careful - careful because too dangerous to livestock and humans.
2. Make the building a good rice field, can be done by considering some of the following:
   - Built using subsoil layer of soil or soil with high clay content to ensure impermeable to water and power are not easily collapsed or damaged. When the availability of funds permitting, the rice field can be made a permanent basis, especially for the parent dike or secondary channel.
   - Built instead of the log on the ground, but built from the ground which has been gradually silt up through layer after layer of the drying period. This technique serves to minimize macro pores.
   - Make use of the channel inlet and outlet PVC pipe planted in a rice field, so that the flow of water in and out is always constant and avoid the damage. To ensure a pool of water in accordance with the recommendation, then the outlet hole is made facing up (low drainage gate). When the height will be 10 cm then the outlet pipe is made as high as 10 cm
   - Not the rice field for planting, especially root crops, riding, because plant roots can trigger the macro pores are formed which can cause side flow (seepage) the greater.
   - It has a width and height of about 20 cm or more is approximately 10% of the mapped fields, thus the bund is still passable for pedestrians and clearly visible as a boundary.

Treatment and control embankment done once a month to fix a leaky dike, used or damaged rats nest and cleaned of weeds. These two activities can be done with the scheduling worked together organized by a group of farmers.

Irrigation Efficiency Evaluation

Based on the criteria for irrigation planning (KP.03, 1986), irrigation efficiency by 65% ie 90% on the primary channel, secondary channels 90% and 80% tertiary channels. This shows the value for irrigation efficiency is the way it works was limited to the irrigation network have not yet take into account the loss of irrigation water in rice fields. it should need to be re-evaluated when the value of the efficiency of existing irrigation needs to be multiplied again by the efficiency of irrigation on the fields. From the results of these multiplications can be known how much the actual value of irrigation efficiency in a irrigation area, so expect no excess and shortage of water in rice fields which can cause wilting of paddy rice production which come down.

Regional Irrigation Krueng Jreue irrigation efficiency values based on the results of planning by 68.3% with an area of irrigated rice fields by 5,440 ha. By multiplying the value of irrigation efficiency in the rice fields will be able to value the efficiency of irrigation as shown in Table 2.

Table 2. 6Irrigation efficiency

Fase - Fase Plant Growth	Ea(%)	Ej(%)	$E_{average}$(%)
processing of land	85.17	68.30	58.17
Planting - Puppies	73.05	68.30	49.89
Puppies - Max. puppies	53.19	68.30	36.33
Max. puppies - Flowering	47.40	68.30	32.37
Flowering - Fully Mature	67.63	68.30	46.19
Average	65.29	68.30	44.59

From Table 2 can be seen that the value of the irrigation efficiency can drop to 44.59%, then the area of irrigated rice fields is reduced. This condition can be increased again if the problems in the field can be prevented or solved, then the increase in irrigation efficiency can be restored to the position of the efficiency of irrigation plans based on the Standard Planning Irrigation Indonesia by 65% and can even be increased up to 68.30% by the Planning Irrigation Krueng Jreue. Improved irrigation efficiency and an increase in area irrigated rice fields can be seen in Table 4.7 where 1 is the repair of improvements made to achieve improved efficiency of irrigation return to the state according to Standard Irrigation Planning by 65%. 2 Repair is committed to achieving improved efficiency of irrigation return rises to 68.30% of the planning conditions.

Table 3. Improved irrigation efficiency and the broad fields that can be irrigated

Condition	Efficiency (%)	Improved Efficiency (%)	Area of irrigated rice field (ha)	Improvement Area of Wetland (ha)
existing	44.59	-	3,486	-
repair 1	65.00	20.41	5,082	1,596
repair 2	68.30	23.71	5,440	1,954

In Table 3 can be seen that the improvement of an increase irrigation efficiency of 20.41% where the vast rice fields can be irrigated or the addition of 5.082 ha area of 1.596 ha of existing conditions. Further improvement in 2 there was an increase of 23.71% irrigation efficiency, where the vast rice fields that are not irrigated area of 1.954ha can be irrigated back from the existing condition.

Prevention or repair can be done to improve the behaviour patterns of upland farmers in the use of irrigation water supplied is still wasteful. Peasant farmer behaviour resulted in downstream areas experiencing water shortages, so the distribution of water in upstream and downstream regions is uneven, especially in the dry season. In addition it is necessary for repairs to the foundation and walls that leak channels.

Conclusions

Summary obtained from this study are as follows:

1. Irrigation water use efficiency in rice fields depends on several factors: the growing phase factors (age of plant), the weather, especially rain, the water delivery system (inflow and outflow).
2. Provision of irrigation water in rice fields in which values can be varied where the variation value of Vf is adapted to the processing of land for 7.88 liters/sec/ha and the growth of rice plants at 7.05 liters /sec/ha.
3. Water requirements in rice fields (Vm) using drum technique can be the difference in the value of Vm, the difference is because of differences in transpiration rate both during processing and during plant growth. Time of land preparation Vm value of 57.95 mm / day and the plant growth 35.36 mm / day.
4. Irrigation efficiency in rice fields (Ea) based on field measurements of 65.29%. This makes the project effeciency become 42.44% rather than using Indonesian's criteria of 65%, or existing project of 68,3%.
5. Improved irrigation efficiency values can be done if there is high awareness of the farmers to maintain irrigation channels and means that there is, also in the use of irrigation water according to water needs in the fields.

References

Arsyad, S. 1989. Konservasi Tanah dan Air. Penerbit IPB Press. Bogor.

Asdak, C. 1995. Hidrologi dan Pengelolaan Daerah Aliran Sungai. Gajah Mada University Press. Yogyakarta.

Bos, M.G & Nugteren, J. 1990. On Irrigation Efficiencies. Intern.Instit.for Land Reclamation and Improvement/ILRI. Wageningen, Netherlands.

Cropwat. 1989. Petunjuk Perhitungan Kebutuhan Air Irigasi.

Dalhar, M.A. 1989. Aspek Teknik Pengelolaan Air. Pelatihan Tata Guna Air. Cinea.

Dastane, N.D. 1974. Effektive Rainfall In Irrigate Agriculture, Irrigation and Drainage Paper Vol. 25 FAO. Rome.

Direktorat Jenderal Pengairan. 1986. Standar Perencanaan Irigasi. Departemen Pekerjaan Umum. CV. Galang Persada. Bandung.

Guerra, L.C., Bhuiyan, S.I., Tuong, T.P. dan Barker, R. 1998. Producing More Rice With Less Water From Irrigated Systems. International Water Management Institude (IWMI). Colombo, Sri Langka.

Hansen. 1986.Dasar-dasar dan Praktek Irigasi. Erlangga. Jakarta.

Kartasapoetra, A.G. 1991. Teknologi Pengairan Pertanian Irigasi. Bumi Aksara. Jakarta.

KP 03. 1986. Standar Perencanaan Irigasi. Badan Penerbit Pekerjaan Umum. Jakarta.

Linsley, R.K and Franzini, J.B. 1979. Water Resources Engineering, Mc Graw Hill Book Co. New York.

Partawijoto, A. 1984. Kapita Selekta Teknik Tanah dan Air.Departemen Mekanisasi Pertanian. Fateta IPB. Bogor.

Purba, W.F. 1974. Kebutuhan Air untuk Pertanaman Serta Faktor-Faktor yang Mempengaruhinya. Makalah Seminar Penerapan Teknologi Madya pada Industri Pertanian. FATEMETA IPB. Bogor.

Salim, M. 2007.Peranan Saluran Irigasi Bendung Pesayangan untuk Mencukupi Kebutuhan Tanaman Padi Petak Sawah di Kecamatan Talang Kabupaten Tegal. PhD skripsi. Universitas Negeri Semarang.

Sosrodarsono dan Takeda. 1976.Hidrologi untuk Pengairan. Pradnya Paramita. Jakarta.

Supriatno, M. 2003. Optimasi Sistem Pengelolaan Air Irigasi di Daerah Irigasi Krueng Aceh. Tesis. Universitas Syiah Kuala. Banda Aceh.

Vergara, S.B. 1976. Physiological anf Morphplogical Adaptability of Varieties to climate. In Climate and Rice, IRRI. Phillipines.

Yakub dan Nusyirwan. 1997. Reaktualisasi Pengelolaan Sumber Daya Air Kelembagaan Petani, PSDL, LP3ES. Jakarta.

Zainudin, L. 2009. Tanah, Lingkungan dan Pertanian.