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WATER FOOTPRINT ASSESSMENT OF PADDY CULTIVATION: QUANTIFYING DIRECT AND INDIRECT WATER CONSUMPTION

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Abstract: Water footprint quantification across product's life cycle has become increasingly prominent. Thus, this study was conducted focusing on developing a quantification approach for water consumption of paddy cultivation at each growth phase using ISO 14046 as a guideline. A case study applying the proposed methodological framework at Muda Rice Granary, Malaysia from the year 2012 to 2015 is presented in this paper. The total irrigation water of paddy planted on Muda Rice Granary ranges from 1800-2600 litres/kg gross paddy. The study was conducted on three phases of paddy growth cycle, which were vegetative phase, reproductive phase and mature phase. Vegetative phase was identified as the hotspot during paddy cultivation as it has the highest water consumption. The demand for rice in the year 2030 is expected to increase to 533 million tonnes to meet the public demand globally. Therefore, it is imperative to identify ways to increase paddy yield while reducing water irrigation to accommodate such a challenge. The outcomes from this research can provide guidelines to the agricultural development authorities, rice farm owners, government as well as farmers to develop a sustainable paddy cultivation at all levels of rice farming..

Keywords: Water footprint quantification, sustainable paddy cultivation, irrigation water consumption.

Introduction

Water and food are two fundamental necessities of life with water being the crucial key for producing food (Seckler & Amarasinghe, 2001). Rice is the major crop supplied to the world population especially to the countries in South Asia and Africa (Chapagain & Hoekstra, 2011). To satisfy the immense need for water used in paddy cultivation, a large amount of water is always the key to meet the irrigation needs. Hence, it is safe to say that water supplied to the rice industry is making it as one of the top consumers of water in the world (Chapagain & Hoekstra, 2011).

Water-related problems are expected to be among the threatening issues to humanity in the upcoming 50 years (Dong *et al*., 2013). Water pollution, water sanitation and water scarcity are only some of the expected water issues to become worse. Severe scarcity of potable clean water is happening in some of the poor Asian countries. The World Health Organisation (WHO) indicated that in 2012, 1.1 billion people were unable to access clean water globally (Onda *et al.,* 2012).

Studies showed that the demand for rice in the year 2030 will rise to 533 million tonnes to satisfy the global public. To accommodate such challenge, an adequate amount of water is the key for the production of rice; thus, studies on how to increase rice production while reducing the water irrigation are crucial for the coming years (Ragab, 2006). As various sectors are competing for land and water for industry and rural development, increasing rice areas will become even more challenging in the future (Mancosu *et al.,* 2015).

Many methodologies have been proposed and developed to account the water consumption of a service or product. Virtual water concept was originally developed by Allan (1998) and later adopted by Hoekstra and Hung (2002) by introducing a water footprint assessment. Hoekstra *et al.* (2011) considered the total consumptive water usage, Deurer *et al*. (2011) considered the hydrological inflows, outflow and storage changes while there are researchers such as Ridoutt and Pfister who assessed the environmental impacts of water usage in year 2010. In addition, there was research done by Berger and Finkbeiner to discuss water footprint using the Life Cycle Assessment (LCA) approach (Mohammad Sabli *et al.,* 2017). Since there are several methodologies that have been developed to calculate water usage of a product or service, this can confuse the researchers while considering the best method to suit their studies.

There are still some problems in standardising the water footprint report assessment. Therefore, in 2013, the International Standard Organisation (ISO) launched the guideline for reporting water footprint (ISO 14046, 2013). This standard is also known as ISO 14046, where the framework includes four phases: goal and scope definition, water footprint inventory analysis as well as water impact assessment. It can be performed either by itself or as part of the LCA (comprehensive assessment). This present study was done to design the framework for calculating water inventory in paddy fields and quantifying the water footprint of paddy planting activity. The ISO 14046 was chosen as a guideline.

There are three water types: blue, green and grey. Blue water is water from the surface or groundwater supplies that is evaporated, integrated into service/goods or extracted from a water source, which is then transferred to another and returned not at the same time, whereas the fresh water that requires assimilation of contaminants is known as grey water in compliance with established water quality requirements (Mekonnen & Hoekstra, 2011). Green water comes from rainwater, which is suitable for the assessment in the agricultural field (Mekonnen & Hoekstra, 2011).

Agricultural Water Footprint (WF) has been extensively studied on various areas and crops. Many previous studies in agriculture WF only considered freshwater and rainwater, whereas only a few studies discussed the impact driven by the chemicals used during the cultivation. Undeniably, the use of fertilisers in agriculture is unavoidable and may lead to serious pollution to the environment, whereas overdose in fertilisation or excessive use of pesticides/ herbicides may cause severe impact on the water source including eutrophication (Savci, 2012).

By including quantification of water footprint in the research, hotspot can be identified by determining the process that uses a large amount of water. While extensive research on WF of crop yield have been conducted, limited studies have suitably covered the water footprint for paddy cultivation especially in Malaysia. The aim of this study is to develop a framework to quantify WF in paddy cultivation (direct and indirect) on agricultural conditions using actual data. This study began by designing a methodology as a project guideline. Instead of calculating virtual water data proposed by Hoekstra, the idea of this study is to develop a framework that can be used on the actual rice faming process using the actual irrigation data.

A case study has been carried out at Muda Agricultural Development Authority (MADA) Rice Granary, Kedah, Malaysia with the proposed approach. By the end of the case study, the principle and methods developed were considered feasible and through this method, incorporation of field data particularly for important parameters will be a useful addition to other conceptual approaches in water footprint study for paddy cultivation.

Methodology

This study implemented an on-site study. A framework was developed to assess the water footprint and general rice paddy cultivation irrigation profile. A series of calculations on the blue, green and grey water was conducted, developing a systematic framework. The framework of this study started from setting goals and scopes as well as proceed with inventory analysis. Goal and scope definition is aimed at establishing the study objectives, functional unit (FU), and system boundaries and data sources. To conduct a study effectively, some steps will be followed. These steps are presented according to the recommendations provided by the ISO standards.

Goal and Scope

The objectives of developing this approach were to (a) quantify WF of paddy cultivation that comprises blue, grey and green water on a systematic and scientific basis; (b) identify which part of the process that consumes large volume of water (hotspot) of paddy cultivation. In this research study, one hectare of the cultivated area was used as Functional Unit (FU) to compare water footprints of Standard Cultivation Practice (SCP). This unit is applicable to all direct and indirect water inputs and emissions.

System Boundary and Methodology

A perspective of 'cradle-to-gate' assessment was applied in this study. Figure 1, shows the system boundaries of this study. System boundaries represent the agricultural processes within the system such as water input and output, fertilisers and any inputs to the system determined prior to carrying out inventory analysis.

Paddy rice was grown under flooded condition for 95 days and non-flooded condition one week before harvest. As the rice straw was burned on the site after harvesting, it was excluded from the assessment since no distribution metrics are needed in this respect.

To analyse the study precisely, the modelling was carried out based on three phases, which involved a large amount of irrigation of water during the growth of paddy:

(1) Vegetative phase

(2) Reproductive phase

(3) Mature phase

Inventory for Direct Water

In this study, virtual water was not accounted for while water input data (irrigation data) were collected from respective agencies to calculate the total input amount per one hectare of the cultivated area. Irrigation can be intensive. Since irrigation water usually comes from a few sources, this approach has developed a framework to account the water consumed during irrigation and categorised the sources into three classes namely blue water, grey water

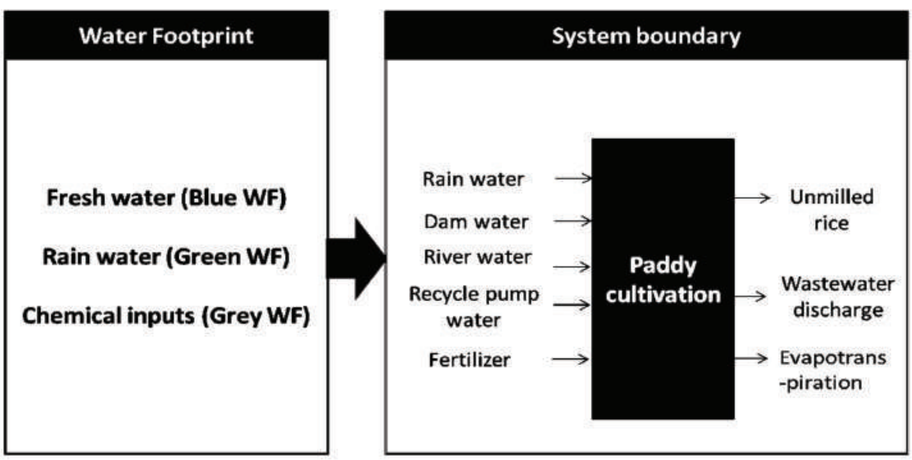

Figure 1: System boundary

and green water. Water from the dam, river water and recycled pump water used in the irrigation were classified as blue water (Fresh water), whereas rainwater was the green water. Rain water has been considered to play a role in the irrigation (Hoekstra, 2019); hence, the amount of water used was accounted using the sum of green water and blue water method.

According to MADA irrigation water distribution diagram (Appendix A), the growth of paddy plants was categorised into three phases, while the requirements for the depth of water at the field throughout the process were broken down into four stages. Table 1 illustrates the relationship between the depth of water and growth phases of the paddy plants whereby the percentage of this distribution is illustrated in Figure 2.

Table 1: Irrigation water distribution

Water Distribution in 4 Stages	Paddy Growth in 3 Phases
Stage 1: 0 - 10 (10days) -depth of water- 3 inch	**Vegetative phase:** 0 - 35 (35 days)
Stage 2:11 - 45 (35 days) - depth of water-4 inch	**Reproductive phase:** 36 - 75 (40 days)
Stage 3: 46 - 55 (10 days) - depth of water-2 inch	**Mature/harvest**: 76 - 105 (30 days)
Stage 4: 56 - 95 (40 days) - depth of water-3 inch	76 - 95 (20 days irrigation) 96 - 105 (10 days field drained)

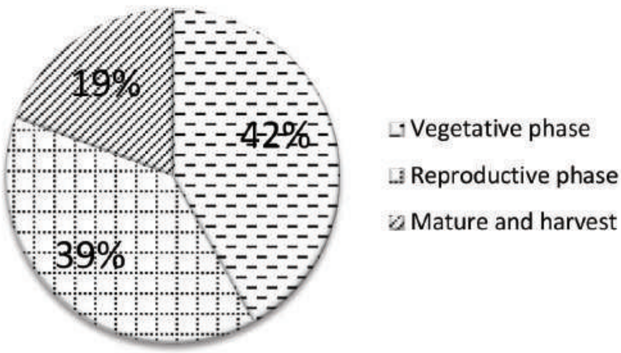

Figure 2: Irrigation water distributions according to phase

Water for irrigation in the four stages was assumed to follow the ratio below (Table 2) based on proportional day to the depth within stages (Refer to appendix A):

Table 2: Stage vs. ratio

Stage	1	2	3	4
Ratio	1.5	7	1	6

Eq. 1 was then used to calculate WF for four different stages

WF for each stage = (A/B)/15.5xC=D **Eq. (1)**

A = Total amount of water used for irrigation
B = Total planted area
C = Ratio
D = Amount of water used in particular stage

Eq. (2) to Eq. (4) were employed to calculate the WF for the growth of paddy in respective phases. The sample of calculation is shown in Appendix B.

E = (D1/10)10+ (D2/35)25 **Eq. (2)**
F = (D2/35)10+ (D3/10)10+ (D4/40)20 **Eq. (3)**
G= (D4/40)20 **Eq. (4)**
D1: Amount of water used in **Stage 1**
D2: Amount of water used in **Stage 2**
D3: Amount of water used in **Stage 3**
D4: Amount of water used in **Stage 4**
E: Amount of water used in **Vegetative phase**

F: Amount of water used in **Reproductive phase**

G: Amount of water used in **Mature/harvest phase**

The total amount of fresh water required to dilute the contaminants load generated by paddy cultivation falls under the definition of grey water. To account the grey water footprint (WF_{GREY}), nitrogen (N) is needed as an element to estimate the amount of contaminated water. In this study, a flat rate of 5% of nitrogen application rate was selected as the application rate for nitrogen (Chapagain & Hoekstra, 2010) while the WF_{GREY} was calculated using **Eq. (5)** (Yoo *et al*., 2014) and to trace the water footprint (WF).

$$WF_{GREY} = (\alpha x\ L_N)/(C_{max}-C_{nat})(Y) \qquad \textbf{Eq. (5)}$$

where LN is the nitrogen application rate determined from the rice check plan with a total of 67.50 kg N/ha used per season while C_{max} is the required limit of 10 mg nitrate-NO_3 per litre as per the National Drinking Water Quality Standard of Malaysia, NDWQS (Alif & Shaharuddin, 2014). C_{max} was then used to measure the required amount of water to assimilate leached nitrogen to the required level. C_{nat} is the nitrate-NO_3 concentration in the receiving waterbody, but since there was a lack of related data, the value was assumed to be 0 while Y is the yield of paddy per hectare (tonne).

In calculating the evapotranspiration, **Eq. (6)** was used incorporating irrigation efficiency factors listed in Table 3.

$$ET_{irr} = I_{withdrawal}\ x\ EF_{irr} \qquad \textbf{Eq. (6)}$$

ET_{irr} = Evapotranspiration from irrigation [m^3/t]

EFi_{rr} = Irrgation efficiency factor [-]

$I_{withdrawal}$ =Water input for irrigation

Method Application

To demonstrate the utilisation of the method, the proposed methodological framework was implemented by conducting a case study at Muda Agricultural Development Authority (MADA) Rice Granary, Kedah, Malaysia (Figure 3). The quantification WF of paddy cultivation study was studied and discussed in the following sections.

Water footprint quantification and direct water inventory

Primary data collection for this stage involved the surveyed MADA area where some of the MADA officers, farmers and service providers were interviewed. The irrigation (from different water sources) data and typical cultivation practices were provided by the MADA authority. Information from farmers served only as a reference due to varied information, individual finances and resources. Some of the literature data were included since some of the secondary data were unable to be obtained due to private and confidential matters.

Result and discussion

Fertiliser inventory

Since rice species and soil used in different farm may result in different usage of fertilisers, the data used in the modelling were those collected through personal communications and questionnaires from rice farms and MADA. The data were adopted from "Rice Check" provided by MADA (Appendix D), which served as a

Table 3: Irrigation efficiency EF_{irr} (source: Nemecek *et al.*, 2014)

Irrigation Technique	Field Application Efficiency (Ea) [-]	Conveyance Efficiency (Ec) [-]	Irrigation Efficiency Factor EFirr [-]
Surface irrigation	0.60	0.75	0.45
Sprinkler irrigation	0.75	1.00	0.75
Drip irrigation	0.90	1.00	0.90

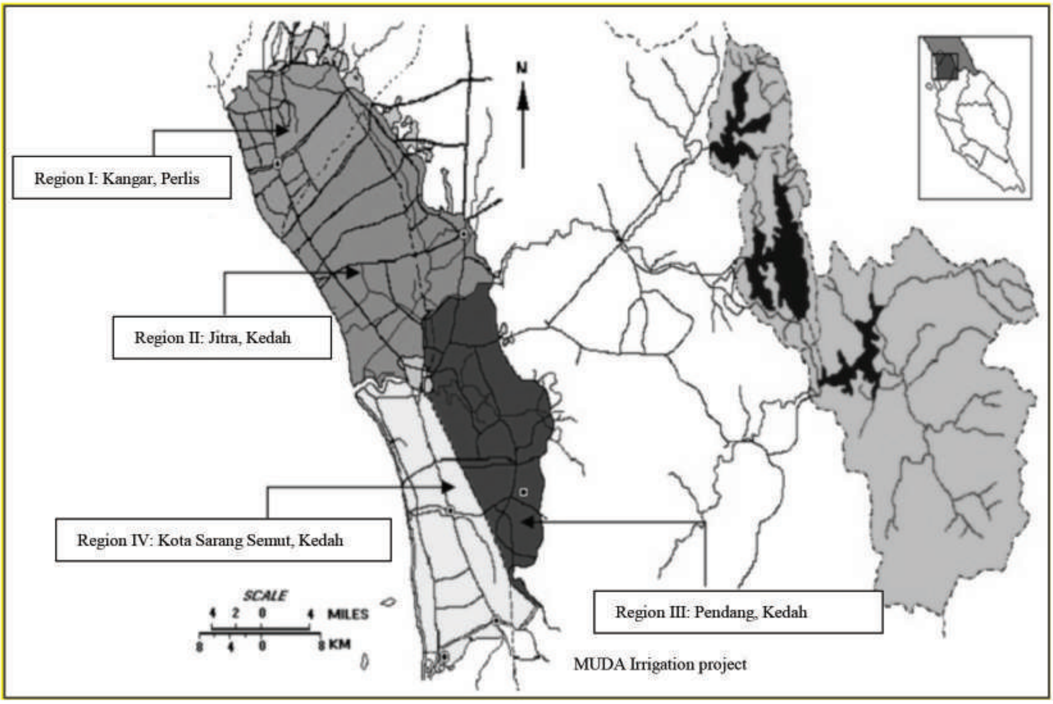

Figure 3: Location of study are

guideline to the farmers to use the chemicals without over using or providing insufficient aid to the paddy plants. Generally, different types and the number of fertilisers used as well as the applications depend on many factors such as soil, paddy species, farmer's self-preferences and region of the paddy field. Hence, "Rice Check" sheet was used to estimate the average application number of fertilisers. When cross checked with personal communication with rice farmers, the data were substantially similar. The variations were not deemed common and therefore, only the generally used quantity was included in this study. Table 4 shows the inventory for fertiliser throughout the three phases; vegetative phase, reproductive phase and mature/harvest phase. Meanwhile, Table 5 tabulates the quantity of nitrate leaching to water.

WF analysis

The irrigation water raw data were collected from MADA (Appendix C) and after a series of calculations, the data were then broken down into three phases and categorised as blue, green and grey water (Table 6). Figure 4 illustrates the water used during irrigation across the three phases while Figure 5 shows the total water consumed during irrigation versus evapotranspiration rate of paddy. Vegetative phase was identified as the hotspot during paddy cultivation as it demonstrated the highest water consumption.

Table 4: Inventory of fertiliser for three phases

Phase	Fertiliser	Total Usage kg/ha	Chemical Content	Data Source	Input kg/ha
Vegetative phase	1st fertiliser application NPK Fertiliser (17.5:15.5:10)	140	Nitrogen	Rice check	24.5
			Phosphate		21.7
			Potassium		14
Reproductive phase	2nd fertiliser application NPK Fertiliser (17.5:15.5:10)	100	Nitrogen	Rice check	17.5
			Phosphate		15.5
			Potassium		10
			Urea (N)		20
	3rd Fertiliser application NPK Fertiliser (17:3:25)	100	Nitrogen	Rice check	17
			Phosphate		3
			Potassium		25
			Urea (N)		40
Mature/harvest phase	4th Fertiliser application NPK Fertiliser (17:3:25)	50	Nitrogen	Rice check	8.5
			Phosphate		1.5
			Potassium		12.5
		20	Urea (N)		20

Table 5: Nitrate leaching to water

Emission	Phase	Quantity kg/Ha
Nitrate leaching	Vegetative phase	1.225
	Reproductive phase	4.725
	Mature/harvest phase	1.425

Table 6: Water Footprint of paddy cultivation based on three phases

Year/ Season	Phase	Blue Water (m^3/ha)	Green Water (m^3/ha)	Grey Water (m^3/ha)
2012/1	Vegetative phase	3668.50	2257.92	19.40
	Reproductive phase	3386.31	2084.24	27.32
	Mature and harvest	1693.15	1042.12	6.74
2012/2	Vegetative phase	3478.72	2257.67	23.26
	Reproductive phase	3211.13	2084.00	32.76
	Mature and harvest	1605.56	1042.00	8.08
2013/1	Vegetative phase	3487.11	2757.81	18.58
	Reproductive phase	3218.87	2545.67	26.16
	Mature and harvest	1609.44	1272.83	6.44
2013/2	Vegetative phase	2818.28	2405.76	18.98
	Reproductive phase	2601.49	2220.70	26.74
	Mature and harvest	1300.75	1110.35	6.58
2014/1	Vegetative phase	3625.13	3042.55	18.74
	Reproductive phase	3346.28	2808.50	26.40
	Mature and harvest	1673.14	1404.25	6.5
2014/2	Vegetative phase	2936.00	2832.95	23.74
	Reproductive phase	2540.77	2451.59	33.42
	Mature and harvest	1185.69	1144.08	8.24
2015/1	Vegetative phase	3477.51	2213.82	19.50
	Reproductive phase	3210.01	2043.53	27.46
	Mature and harvest	1605.00	1021.76	6.76
2015/2	Vegetative phase	3222.30	1582.52	19.94
	Reproductive phase	2974.43	1460.78	28.08
	Mature and harvest	1487.21	19.35	6.92

According to the result (refer Figure 6**)**, it can be stated that the amount of water consumed for paddy cultivation was not directly proportional to the rice yield. In 2014, season one produced a large amount of water footprint of 15925.67 m^3/ha with rice yield of 6535 kg, whereas in 2013, season one, the rice yield was 6452 kg, which was almost similar to that of the year 2013/1 although lesser amount of water was used during paddy cultivation. Hence, it is important to improve the irrigation efficiency in line with other factors. On average, to produce 1 kg of paddy, 2500 litres of water are needed (rainfall and/or irrigation) for a rice field. These 2,500 litres of water are equivalent to all the outflows of water through percolation, evapotranspiration and seepage (Bouman e*t al.,* 2009). An average amount of 2500 litres of water are based on a wide range of experimental data across Asia at individual field level. There is a wide variability of water consumption during irrigation, ranging from 800 litres to more than 5000 litres (Bouman *et al.,* 2009). This variability is contributed by different methods of rice farm management such as fertilisation, planted variety, pest management, water inputs,

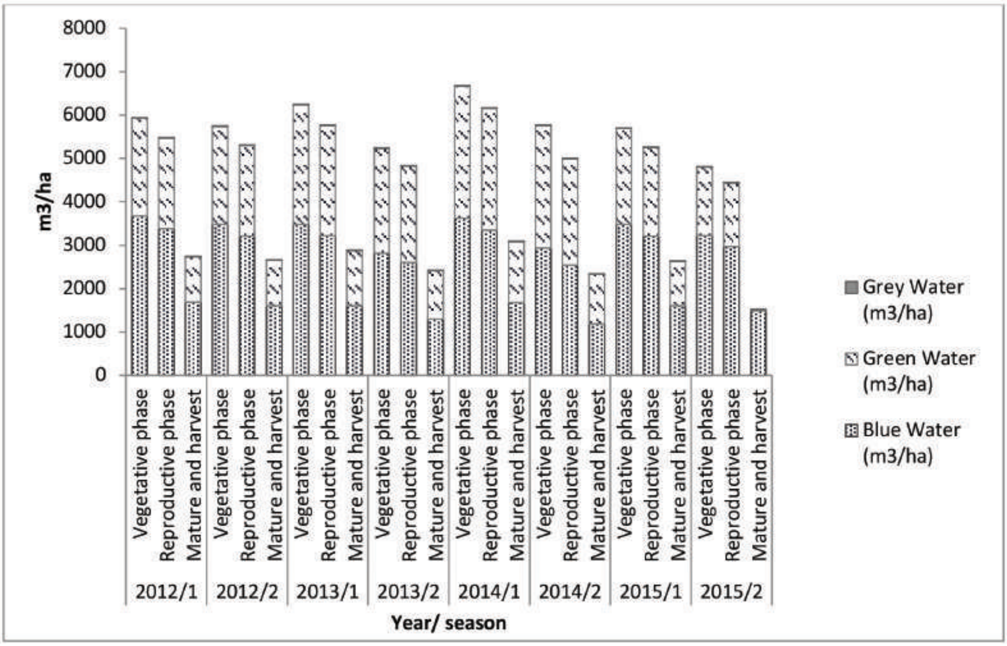

Figure 4: Water consumption at different phases

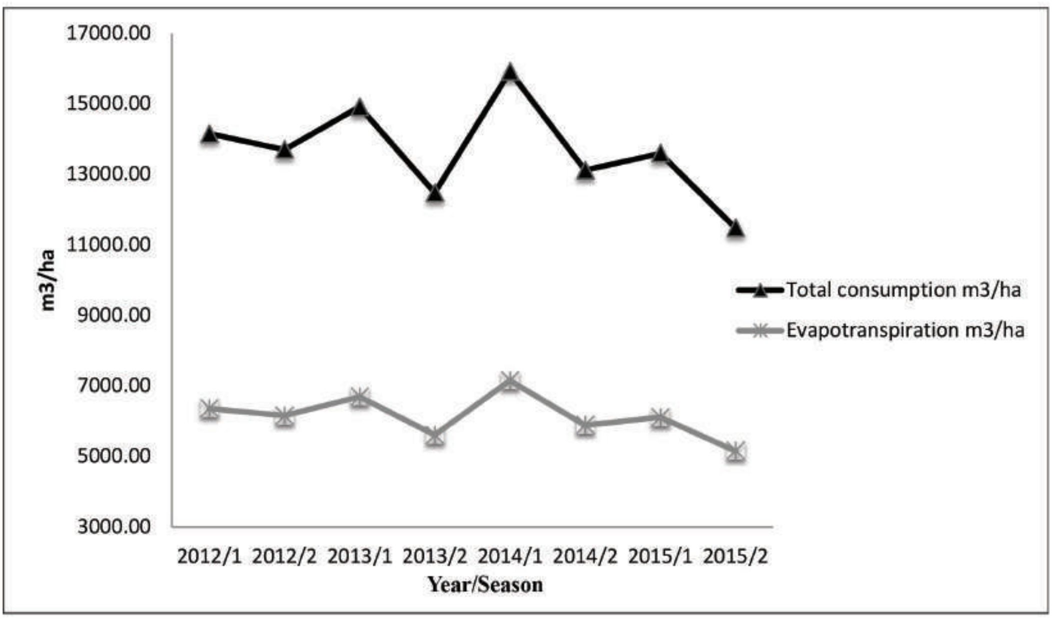

Figure 5: Total water consumption of paddy fields vs. evapotranspiration

weather and soil properties (Bouman *et al.,* 2009). As indicated in Figure 7, water footprint of rice planted in MADA Rice Granary was seen ranging from 1800-2600 litres/kg paddy, which is in agreement with the finding by Bouman (2009), mentioning the range of 800 and 5000 litres of water/kg of paddy. Year 2012/2 demonstrated the highest water footprint value at 2597.77L of water to produce 1 kg of paddy while a significant decrease was observed in the year 2015/2 at the value of 1865.89 litres/kg of paddy.

Figure 8 illustrates the water footprints of paddy cultivation segregated into season one and season two. Looking at the graph, season one showed more water consumption for irrigation than that of season two. Season one tended to use more green water source ranging from 5384.28 m^3/ha to 7255.30 m^3/ha, while season two showed less consumption of green water ranging from 3773.69 m^3/ha to 6428.61 m^3/ha. The rice yield obtained during season 1 demonstrated a consistent trend of 6000 kg/ha while season two illustrated an inconsistent trend of rice yield, which was less than 6000 kg/ha in the year 2012 and 2014.

Judging from the relationship between the consumption of water and yield of paddy, the amount of water was not directly proportional to the yield. Also, it was apparent that a large volume of water has been consumed for the overall rice plantation process. From the calculation and illustrated graph of paddy cultivation, it can be concluded that a very large amount of freshwater (around 2500 L/kg) has been used in paddy cultivation. Therefore, the most ideal way is to increase water-use efficiency in rice fields; this may further trigger the expansion of agriculture (under suitable condition) since water is less available for stressed river systems. The efficiency gain is to be targeted towards consumptive (evaporative) use rather than total use. For paddy cultivation, farmers should adopt a suitable fertiliser application strategy for a full recovery of the crop. Thus, farmers may consider altering the seedling method to adapt to the weather.

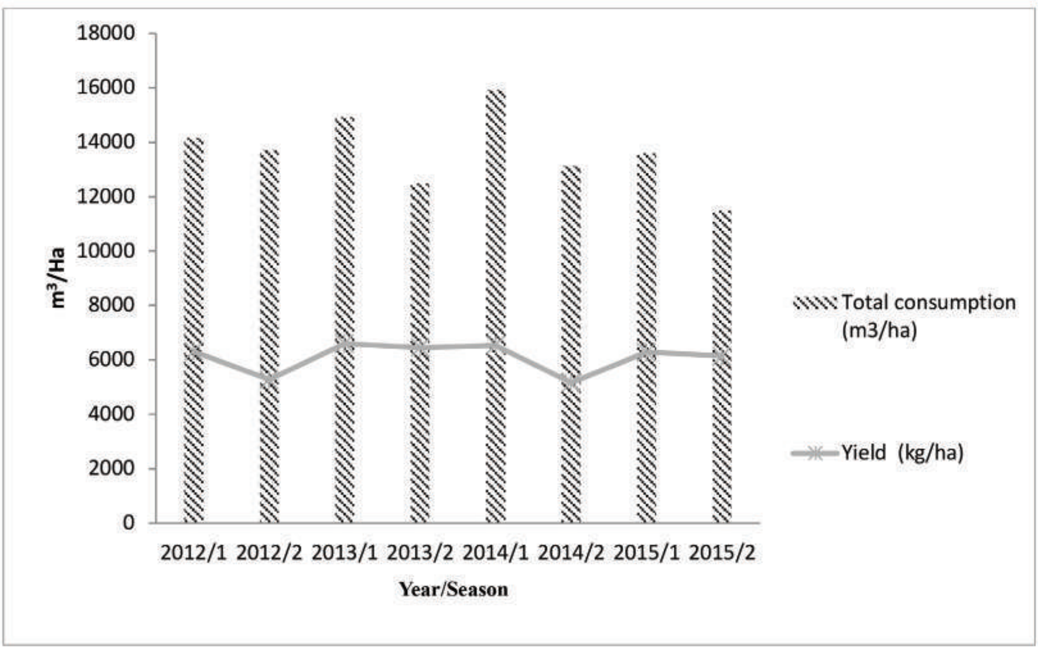

Figure 6: Total water consumption vs. yield

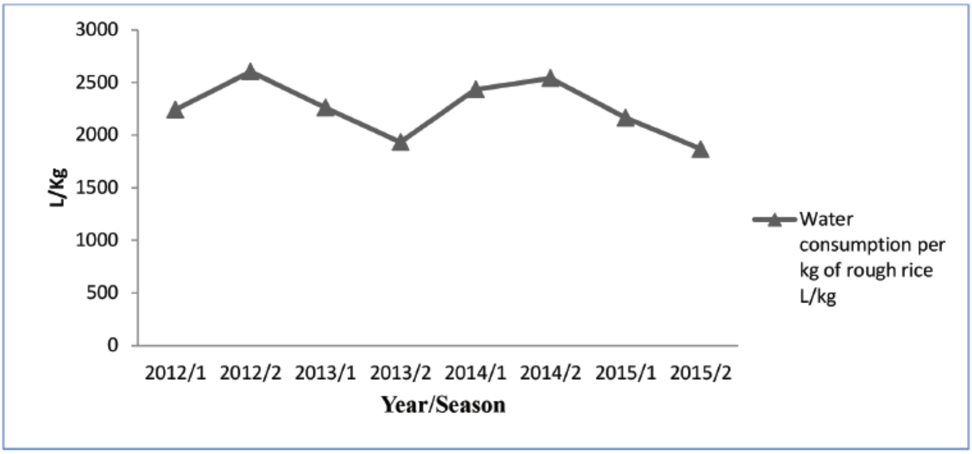

Figure 7: Water footprints vs. rice yield, L/kg

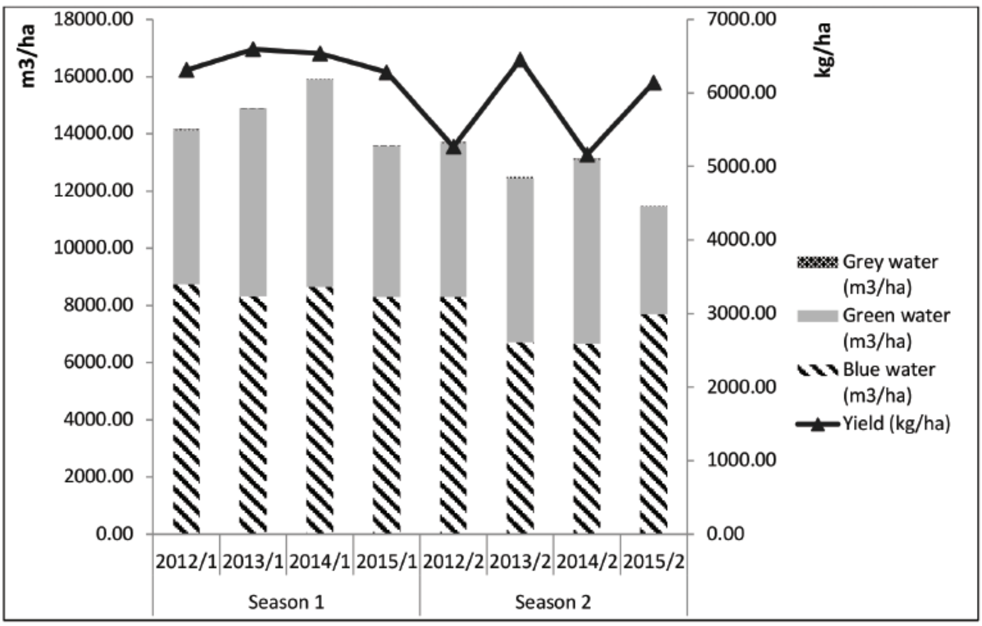

Figure 8: Water footprints vs. yield for season 1 and season 2

Irrigation efficiency has to be increased to optimise the depletion of water for paddy cultivation since the direct use of fresh water seemed to be intense. The water used to irrigate paddy fields during the growing period normally exceeded the actual field demand. This resulted in half to 4/5 of the total water input, which represents a large volume of surface runoff, seepage and percolation into the field (Akinbile *et al*., 2011). Since the direct use of water appeared to be particularly intense, irrigation efficiency needs to be increased to optimise the depletion of water for paddy cultivation. Most of the irrigation practices in Malaysia today are done by flooding the paddy field with efficiency factor of only 0.45 (Nemecek *et al*., 2014). So, to suggest increasing the efficiency factor of irrigation, drip channelling or sprinkle irrigation system can be considered as one of the methods to irrigate the paddy plants. In addition, using new seedling method with a well-planned irrigation system has been assumed to reduce the use of direct water.

Nevertheless, with the current state of affairs, the main challenge on water crisis today is the improper water resource management especially in agriculture, despite having insufficient daily water needs; countermeasures should be taken against the water resource management since it helps to determine future irrigation expectations (Akinbile *et al.,* 2011). Farmers may also consider having Alternate Wetting and Drying method (AWD) for irrigation to reduce the amount of irrigation water. AWD is a technology that helps in water-saving and can be used without decreasing the yield to reduce irrigation water consumption. The field is irrigated several days after the ponded water has drained and it is alternately flooded and not flooded during the cultivation stage. The number of days of non-flooded soil between irrigations may range from one to more than 10 days depending on several factors such as type of soil, condition of weather and plant growth level. Research has shown that "Safe" AWD did not reduce yield (FAO, 2013). Thus, they may consider planting the paddy that can grow with less water supply or shorter maturity days. Excess/limited/no water leads to reduction in yield; thus, the study on the WF of paddy cultivation can provide an approach to the authority to assess a more accurate amount of irrigation water that should be used in the field to avoid excess or limited condition and bring positive impact to the rice yield.

Limitations in Conducting WF of Paddy Cultivation in MADA Rice Granary

There were limitations on the data obtained for chemical inventory due to the confidentiality issues including fertiliser ingredients; thus, estimations need to be done and may affect the quantification of grey water. Various types of rice planting methods have been observed due to the location of each paddy field; hence, Rice Check was used as a standard practice in the modelling, whereas an average area of total MADA area was used to estimate the resources used per hectare.

Through this approach, accuracy and precision of the study can be more efficient if the relative real-time measurement or parameters are implemented in the present method. Since real time data will be practically used instead of assumptions, the limitation of the quantification of WF can be eliminated, thus improving the precision of the approach.

Conclusion

As indicated in water footprint finding, water footprint of rice planted on Muda Rice Granary ranged from 1800 - 2600 litres/kg paddy, which is in agreement with the finding by Mahmod *et al*. (2014) that stated the ranges of 800 and 5000 litres of water/kg of paddy. Farmers in MADA applied similar amount of water in their fields as in the theory. Water management scheme could become important and the present research has supplied quantitative result and information that might be useful for future investigations. The water inventory that has been done in this study is crucial for water impact assessment

Figure 9: WF approach

and researchers may further the research by investigating environmental impact contributed by paddy plantation using ISO14046 as guideline.

This WF quantification approach can be summarised as the steps illustrated in Figure 9. By setting a clear goal and scope and define the system boundary, it will be a good start for data collection and data analysis. More WF are expected to be quantified in the agricultural field using our proposed method; this developed approach can be used as a guideline and indicator of water status as it is consequently able to achieve sustainability in paddy farming. Using this framework practically, the producers and government will have a clear picture of actual field irrigation condition and able to minimise the impact on the environment related to water, optimise the yield and increase irrigation efficiency. The results of the transition can enhance food safety, increase public awareness on agricultural water management and inspire farmers to adopt environmentally friendly practice and management in the industries.

Through this holistic framework, plantation sector can move towards more efficient water use, which leads to greener and sustainable cultivation.

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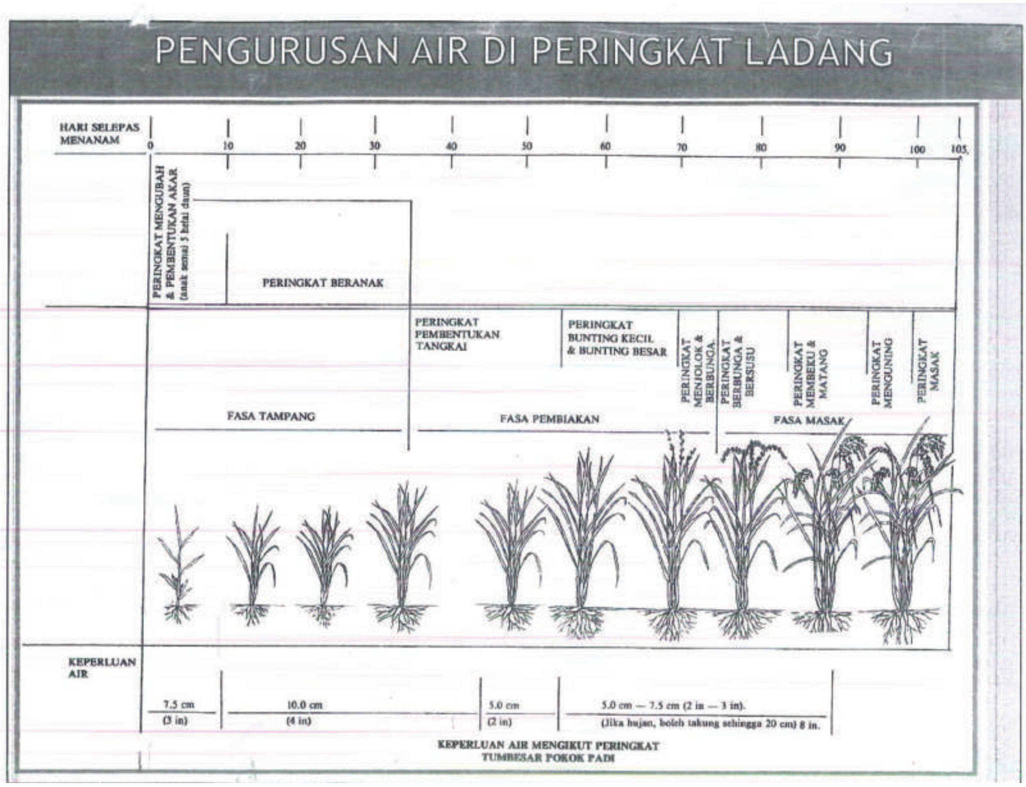
Appendix A- Irrigation Distribution Illustration Diagram and Plant Growth Phase Provided by MADA



Appendix B -WF for the Growth of Paddy in Respective Phases

F = (D2/35)10+ (D3/10)10+ (D4/30)20 **Eq. 3**

G= (D4/30)10 **Eq. 4**

D1: Amount of water used in **Stage 1**

D2: Amount of water used in **Stage 2**

D3: Amount of water used in **Stage 3**

D4: Amount of water used in **Stage 4**

E: Amount of water used in **Vegetative phase**

F: Amount of water used in **Reproductive phase**

G: Amount of water used in **Mature/harvest phase**

Example:

Total area : 95893(B)

Water source	Season 1/2012		Usage/Ha(**A**)	Stage 1	Stage 2	Stage 3	Stage 4
	Cubic Metre	Percentage					
Water from dam	526200101.04	38.8	5487.37	531.04	2478.17	354.02	2124.14
Rain fall (Precipitation)	516314992.32	38.1	5384.28	521.06	2431.61	347.37	2084.24
Uncontrolled flow	214519440.72	15.8	2237.07	216.49	1010.29	144.33	865.96
Recycle pump water	98149237.08	7.3	1023.53	99.05	462.24	66.03	396.20
Total	1355183771.16	100	14132.25	1367.64	6382.31	911.76	5470.55

Water source	Stage 1(**D1**)	1-10 days (per day usage)	Stage 2(**D2**)	11-45 days (per day usage)	Stage 3(**D3**)	46-55 days (per day usage)	Stage 4(**D4**)	56-95 days (per day usage)
Water from dam	531.04	53.10	2478.17	70.80	354.02	35.40	2124.14	53.10
Rain fall (Precipitation)	521.06	52.11	2431.61	69.47	347.37	34.74	2084.24	52.11
Uncontrolled flow	216.49	21.65	1010.29	28.87	144.33	14.43	865.96	21.65
Recycle pump water	99.05	9.91	462.24	13.21	66.03	6.60	396.20	9.91
Total	1367.64	136.76	6382.31	182.35	911.76	91.18	5470.55	136.76
Water source	Water from dam	Rainfall (Precipitation)	Uncontrolled flow	Recycle pump water				
Vegetative phase (0-35)(**E**)	2301.15	2257.92	938.13	429.22	5926.43			
Reproductive phase (36-75)(**F**)	2124.14	2084.24	865.96	396.20	5470.55			
Mature phase (76-105)(**G**)	1062.07	1042.12	432.98	198.10	2735.27			
	5487.37	5384.28	2237.07	1023.53				

Appendix C - Raw Data Provided by MADA

Irrigation data collected from MADA

Total Area: 95893			**Total Area: 92047**		
Water Source	**Season 1/2012**		**Water Source**	**Season 2/2012**	
	Cubic Metre	Percentage		Cubic Metre	Percentage
Water from dam	526200101	38.8	Water from dam	325499336.8	25.8
Rain fall (Precipitation)	516314992.3	38.1	Rain fall (Precipitation)	495550590	39.4
River water	214519440.7	15.8	River water	319679778.1	25.4
Recycle pump water	98149237.08	7.3	Recycle pump water	118388176.9	9.4
Total	1355183771	100	Total	1259117882	100

Total Area: 95366			**Total Area: 94779**		
Water Source	**Season 1/2013**		**Water Source**	**Season 2/2013**	
	Cubic Metre	Percentage		Cubic Metre	Percentage
Water from dam	516149706	36.3	Water from dam	263491063.7	22.3
Rain fall (Precipitation)	627156738.6	44.2	Rain fall (Precipitation)	543729085.3	46
River water	104061306.7	7.3	River water	185068872.2	15.7
Recycle pump water	172796979.7	12.2	Recycle pump water	188404202.2	16
Total	1420164731	100	Total	1180693223	100

Total Area: 94779			**Total Area: 95349**		
Water Source	**Season 1/2014**		**Water Source**	**Season 2/2014**	
	Cubic Metre	Percentage		Cubic Metre	Percentage
Water from dam	472870593.2	31.4	Water from dam	88758753.84	7.1
Rain fall (Precipitation)	687650298.2	45.6	Rain fall (Precipitation)	612961850.8	49.1
River water	235755032.4	15.6	River water	479770680.4	38.4
Recycle pump water	110696195.6	7.4	Recycle pump water	66728801.04	5.4
Total	1506972120	100	Total	1248220086	100

Total Area: 96504			**Total Area: 100636**		
Water Source	**Season 1/2015**		**Water Source**	**Season 2/2015**	
	Cubic Metre	Percentage		Cubic Metre	Percentage
Water from dam	569263354.8	43.5	Water from dam	521718868.2	47.1841662
Rain fall (Precipitation)	509455610	38.9	Rain fall (Precipitation)	364176335.6	32.9360462
River water	104918575.3	8	River water	125639805.8	11.3628428
Recycle pump water	126078924.7	9.6	Recycle pump water	94172497.56	8.51694476
Total	1309716465	100	Total	1105707507	100

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Paddy yield from year 2012-2015

Year/Season	**Yield kg/ha (Paddy before deduction)**	**Yield kg/ha (Paddy after deduction)**
2012/1	6312	5296
2012/2	5266	4466
2013/1	6595	5566
2013/2	6452	5536
2014/1	6535	5542
2014/2	5161	4480
2015/1	6282	5283
2015/2	6141	5307

Appendix D Rice Check Provided by MADA

JADUAL PAKEJ PENINGKATAN HASIL PADI MUSIM 1 DAN 2
VARIETI PADI MATANG 105-110 HLT (MR 219, 220, 253, 263, 269)

Bil Hari	Musim		Aktiviti
0 - 5 hari lepas penuaian	1		Potong tunggul jerami
		2	Biar padi batat tumbuh 7 - 10 hari
2 hari lepas potong tunggul jerami	1	2	Bakar jerami (kawasan yang terkena jangkitan)
6 hari lepas bakar jerami	1		Menabur kapur jenis debu
7 hari lepas bakar jerami	1		Putaran 1 - Keadaan kering dan Biar padi batat tumbuh 7 - 10 hari
7 - 10 hari lepas padi batat tumbuh	1	2	Meracun sebelum tanam dengan glifosat atau glufosinate-ammonium
7 hari lepas meracun	1	2	Masuk air
7 hari lepas masuk air	1		Putaran 2 - Keadaan basah
		2	Putaran 1 - Keadaan basah
1 -2 hari lepas putaran basah	1	2	Menyembur racun pretilachlor atas air dan takung air selama 10 hari
10 hari lepas sembur racun	1		Putaran 3 - membadai dan membuat lorong kerja
		2	Putaran 2 - membadai dan membuat lorong kerja
2 hari sebelum tabur benih	1	2	Kawalan tikus 1 Menyejat dan peram benih selama 12 - 24 jam Merendam benih sah dengan penggalak percambahan selama 24 jam Menyembur kapur cecair (jika tidak menggunakan kapur debu)
1 hari lepas badai	1	2	Menabur benih (kadar 140kg/ha)
0 - 4 HLT	1	2	Kawalan rumpai 1
4 HLT	1	2	Kawalan tikus 2
11 HLT	1	2	Kawalan tikus 3
10 - 15 HLT	1	2	Kawalan rumpai 2
11 - 15 HLT	1	2	Masukkan air ke petak
14 HLT	1	2	Kawalan tikus 4
15 HLT	1	2	Menyulam (jika perlu) Membaja 1 dengan 7 beg (20 kg/beg) baja sebatian NPK 17.5:15.5:10 / hektar Membuat kawalan ulat batang / ulat gulung daun
21 HLT	1	2	Kawalan tikus 5
21 - 30 HLT	1	2	Menebas batas, meninjau musuh dan penyakit serta menyulam (jika perlu)
28 HLT	1	2	Kawalan tikus 6
35 HLT	1	2	Membaja 2 dengan urea 1 beg (20 kg/beg)/ hektar dan 5 beg baja sebatian NPK 17.5:15.5:10 (20 kg/beg) /hektar
40 HLT	1	2	Kawalan penyakit hawar seludang Menyembur baja foliar
45 HLT	1	2	Kawalan bena perang / ulat batang
50 - 55 HLT	1	2	Membaja 3 dengan 4 beg (25 kg/beg) baja sebatian NPK 17:3:25 / hektar dan urea 2 beg (20 kg/beg) / hektar
55 HLT	1	2	Kawalan penyakit hawar seludang
60 HLT	1	2	Kawalan tikus 7 Kawalan penyakit dan serangga
65 HLT (MR 253, 263, 269)	1	2	Menakai padi angin Menyembur baja foliar
75 HLT	1	2	Membaja 4 dengan 2 beg (25 kg/beg) baja sebatian NPK 17:3:25 / hektar + urea 1 beg (20 kg/beg) /hektar
80 HLT (MR 219, 220)	1	2	Menakai padi angin Menyembur baja foliar
95 HLT (MR 253, 263, 269) / 103 HLT (MR 219, 220)	1	2	Mengering Air Sawah
105 HLT (MR 253, 263, 269) / 110 HLT (MR 219, 220)	1	2	Menuai