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Water Footprint Assessment of Rice Production in Malaysia Using LCA Approach

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Abstract

The demand for rice in year 2030 is projected to be around 533 million ton of milled rice and known to be a high water consuming crop. In Asia alone, irrigated rice consumes as much as 150 billion m^3 of water. With water being the most important component for rice production, yielding more rice with less water is therefore a formidable challenge. The aim of this study is to assess the water footprint of paddy plantation at Muda Rice Granary, Kedah for five consecutive years; 2012 to 2016. By using the life cycle assessment (LCA) approach, the potential environmental impacts due to water consumption in planting and processing rice will be assessed. By integrating water footprint with LCA may assist in analysing environmental impacts associated with direct and indirect water consumption throughout the whole process; starting from raw material extraction, processing or production, distribution, use, and disposal. The methodological framework follows the LCA framework; setting up goal and specifying the scope of study, followed by inventory analysis, water footprint sustainability assessment and finally interpretation or response formulation. The research boundary for this study include the growing phase of paddy; seedling and cultivating of the paddy until the rice milling process. By implementing this water footprint research in paddy field, it will be essential not only in research area but also in agricultural development in Malaysia. Consequently, it will become the baseline for other agricultural in Malaysia in this research area.

Keywords: Water footprints; life cycle assessment (LCA); rice; environmental impacts

1.0 INTRODUCTION

Rice is major crops and also a crucial part of Malaysians diet. Report from Department of Agriculture (DOA) on 2011, stated that 1.66 million metric tons of rice has been produced in Malaysia while statistics shows that 36.3 million metric was worldwide production [1]. This shows that the country's production of rice is only 0.4% of the total world rice production. Up until today, Malaysia only requires 80% of the produce while exporting the rest to neighbouring countries such as Vietnam and Thailand. According to this problem, Malaysian citizen needs 82.3 kilograms of rice annualy and 1 hectare of paddy field to produce such average 3.7 metric ton (MT) of rice [2]. Hence, due to the increasing rise in population has led to initiatives in tackling rice production for consumption purposes. Furthermore, more technologies for fertilizers, pesticides and machineries, have been widely used to increase production of rice, unfortunately these techniques can cause adverse environmental impacts. Food and water are two fundamental necessities of life; moreover water is crucial for food production [3]. Rice has long been distributed to the world population especially countries in South Asia and Africa [4]. To meet the huge water demand in paddy plantation and production of rice, large irrigation projects have always been the key to meet the demand. Hence, it is not wrong to say that rice is amongst the largest water consumers in the world [4]. Increasing water demand mainly for agriculture activity has caused stress which is becoming more prominent especially during dry seasons. As an effort to resolve the water issues, life cycle assessment (LCA) plays an important role to assess the environmental impacts of one system or series of process; cradle-to-grave perspective. LCA has been widely used by European country and applied to agricultural sector, however limited studies has been applied on rice production in Asia, since rice is the staple food in Asia. Lately, there have been an increase in the production of organic rice, hence this may necessitate to assess the environmental impacts to respective sectors [5]. The concept of water footprint has been proposed as a tool to measure water usage and the impacts of the production process to the water system [6]. There are a number of methodologies that have been developed to calculate water usage of a product or service as an example of virtual water assessment and water footprint assessment. The water footprint of a product (good or service) is the volume of fresh water used to produce the product, summed over the various steps of the production chain [7]. Any process, production or activities for any groups such as individual or family, city or village or even at national level, the water footprints are able to be calculated [8]. A water footprint is not limited to the total amount of water used for an activity, but it can also project the types of water used, and when and where the water has been used. Hence, this study will be able to quantify on the total amount of fresh water being used to cultivate paddy in Malaysia until finish (processed rice), by using two sources of water during irrigation: surface water (blue water) and rain water (green water). Moreover, water footprint is also able to assess the environmental impact such as quantifying the total amount of polluted water related to the use of pesticides, fertilizer and weeds killer in paddy plantation (grey water). For such examination, life cycle assessment (LCA) is often implemented to check the impacts of farming on environment (global warming, eutrophication, possible damage to living things) [9, 10]. LCA analyse environmental impacts associated with the whole process of certain product from raw material extraction, processing/production, distribution, use, and disposal. It is a useful tool in identifying an inventory of energy/material inputs and their environmental releases, analysing the potential impacts, and establishing a sustainable system. There have been some LCA studies on rice production conducted by countries in Japan and Thailand. The assessment criteria in these studies often place a strong emphasis on greenhouse gas emission and carbon foot-printing [11]. Thailand and China are popular exporter of rice in the country and they have been very active in studying the impact towards the environment. Meanwhile, countries like Japan, whose national environmental policy places a strong emphasis on curbing greenhouse gases, it is expected that much of the assessment are focused on emission of methane and carbon dioxide at different stages of the life cycle. Studies by [12, 5] were among the LCA studies conducted on rice production in Japan that aimed on identifying the best practices in curbing greenhouse gas emissions. For that reason, this LCA study strives to fill the research gap by providing a genuine attempt to exhaustively assess the impact of pesticides and fertilizers on the environment during rice production by identifying and quantifying the environmental impacts of paddy cultivation on a chosen paddy field in Muda area in Kedah, Malaysia. There are several factors that influence the paddy and rice production such as seed variety and quality, crop management, agronomic practices, pest and disease management, and infrastructure facilities. In addition to this, climate change has become one of the primary determinants of agricultural productivity [13]. Changes in mean climate particularly in the frequency of events such as drought, flood, storm and heat waves may reduce total agricultural output [14]. Therefore, thorough understanding of local climate is crucial especially in the developing countries as the climate change is most likely will affect the availability of water and the precipitation rate (rainfall). The availability of water is regarded as one of the important factor to determine the success or failure in paddy plantation [15]. An adequate supply is critical in various stages of plant growth. Thus, rainfall is often the limiting factor, both when there is insufficiency and when there is surplus. Other climatic factors such as temperature, day length or sunshine and humidity also play important role with respect to crop growth and production [16]. The effect of climate change on agriculture requires impact assessment studies not only for seasonal climate variations but also on the overall long term climate changes.To achieve the objective, information on the used of fertilizer and pesticide as well as the quantities and energy information for all agriculture equipment used will be collected and the environmental impact of rice using LCA method will be calculated starting form the early stage (land preparation) until harvesting stage.Once the LCA is complete, information obtained from the impact assessment phase will then be extrapolated to regional level to estimate the impact from paddy cultivation to the regional environment.

2.0 METHODOLOGY

2.1 Study Area

Muda Irrigation Scheme is the largest rice granary in Malaysia. Covering some 191,853 hectare of paddy land, it is situated along the coastal plain in the northern states of Kedah and Perlis in the Peninsular Malaysia. Figure 1 shows the area of paddy in Muda Irrigation Scheme in Kedah.

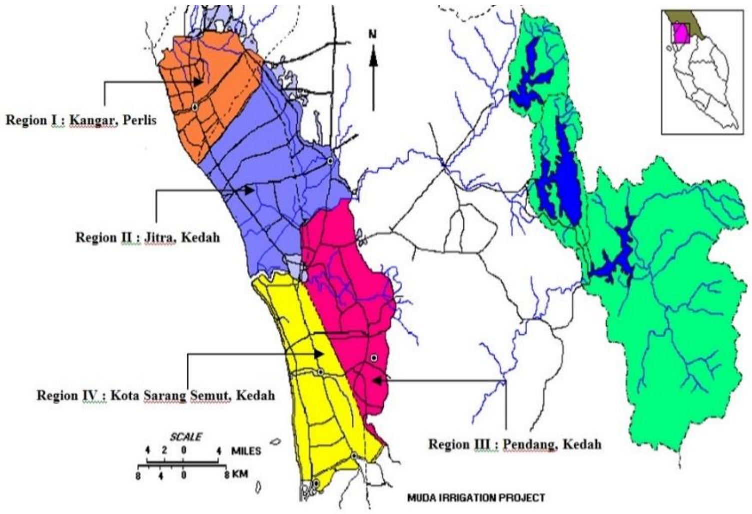

Figure 1. Layout Plan of Muda Area

2.2 Research Design and Procedure

Figure 2 shows the research design and the procedure of the work.

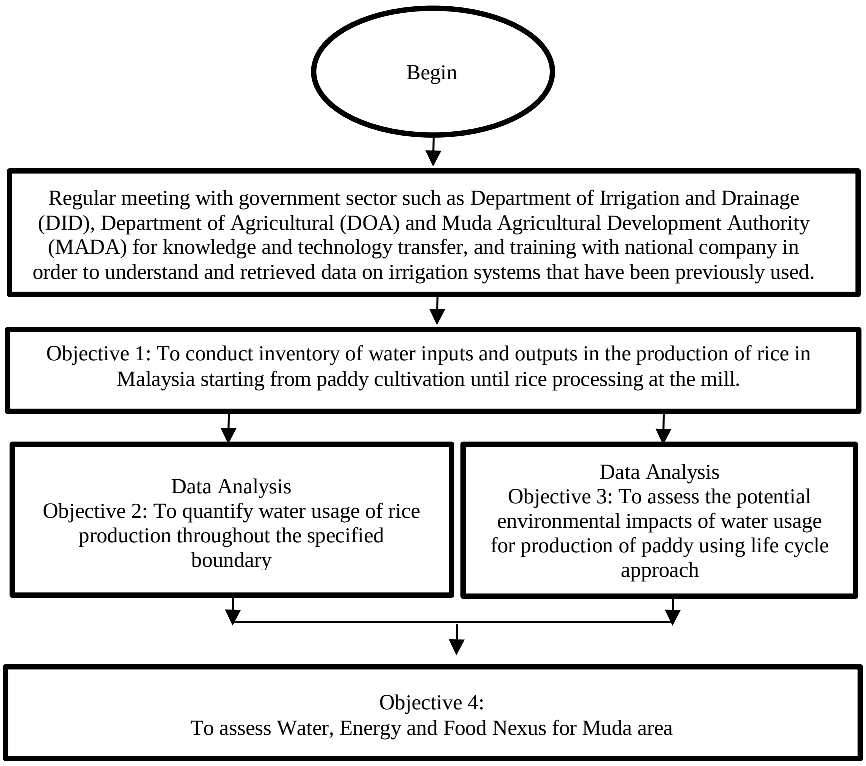

Figure 2. Research Design

2.3 Fieldwork

Data collection was conducted in order to complete the Water Footprint Inventory data set. Thus, it is important to have reliable data. Besides, the data must be relevant to the study and best identified during scope definition. The data collection process was conducted at Muda Agricultural Development Authority (MADA) situated in Alor Setar, Kedah, Malaysia. Thus, it is important to have reliable data. Besides, the data must be relevant to the study and best identified during scope definition. Data collection was tedious and time consuming process but nevertheless crucial in order to gain the most credible and representative data available. Data on rice production outputs, chemical use, size of plantation and information regarding farming machinery, transportation of raw materials to the farm and transportation of products off the farm were available from the year 2011 to 2015. Besides, for irrigation system, all the data and information was given by MADA. Purchase receipts were used to derive information on chemicals while the contract workers who owned the agricultural machineries were interviewed to obtain the energy data. However, these primary data could not be immediately entered into the GaBI software without a series of adjustments. As a result, the raw data had to be transformed to obtain the mass of chemical inputs as well as suitable energy inputs that can be keyed into the software. The alteration of these raw data were made through secondary sources such as scientific journals, material safety data sheet (MSDS) and phone calls to (MADA). Once the data collection is complete, the analysis of the data will be done using the software as an aid tool. The software called GaBi is now being used globally to assess the water footprint. Together with the software, database called EcoInvent were also used to aid the methodology. Thus, the framework for this methodology will be able to be developed. In order to help with this assessment, the software and also the database will be used. After all the data have been calculated by using several methodologies that is most relevant and suitable for crop production, the environmental impact from the water usage will then be carried out using GaBI software. As a result, a link between assessments of environmental damage to the water footprint are shown.

2.4 Methodologies in Calculating Water Footprint

Arjen Hoekstra introduces some water footprints concept that is using an indicator for freshwater appropriation in order to quantify and map indirect water. Also, the relationship of the involvement of consumers and producers from the supply chain in water resources management should be shown as well. Meanwhile, the Life Cycle Assessment (LCA) community have introduced comprehensive methodologies to involve environmental impacts which concern water in LCA studies, hence, in this study, the LCA method will be applied to the research and the focus will be on the assessment of environmental impacts that involves water. The green, blue and grey water footprint calculation uses ISO 14046 framework [17]. This standard can act as a guide in assessing water footprints and environmental impacts by using LCA. As there are numerous methods which arise from different concept are available throughout the world in calculating the water footprints, the ISO 14046 is used to standardize the current water footprints report while the results can be interpreted with the current world's water status. The LCA consists of four steps as shown in Figure 3:

Figure 3. LCA Procedure

LCA were designed to address two categories of impacts which are midpoint and endpoint impact [18]. Midpoint impact are impact which are directed to the characterization factors (CF) and are t able to quantify the environment effects. Whereas endpoint level can be defined as some of the CF that could bring effects on the endpoint level, which might contribute potential damages to human health or causes impacts to the ecosystem and might lead to global warming due to emission of excessive carbon dioxide, CO_2.

2.4.1 Goal and Scopes

To investigate the environmental impacts of rice production in Kedah was the main goal of this LCA, focusing on the paddy cultivation stages which include land preparation to harvesting. Moreover, the rice milling stage are also included for this LCA study, for the purpose of quantifying the water usage of rice production throughout the specified boundary. More notice taken to identify the water inventory of this activities as well as the environmental impacts of pesticides, fertilizers and any other chemicals which involved during the nutrition management stage in the cultivation process. The results will then be used to quantify water usage of rice production throughout the specified boundary via life cycle approach. With hope that the farmers will reduce water consumption and use the water wisely for paddy plantation including in rice milling. A countermeasure can also be proposed to minimise the water consumption and the environmental impacts to sustain the rice cultivation system. The functional unit used in the study is 1 metric tonne (MT) of harvested paddy grains. This LCA study is limited from cradle-to-gate only. The research was conducted to compare the environmental impacts and water footprints of rice production for 5 consecutive years. A graphic display of the system boundary is shown in Figure 4. However, the energy input were not limited to the use of agricultural equipment during the land preparation and harvesting stages as well as from the use of transportation in and out of the farm, but were also considered for mill processing in the factory. The chemical input, were found in the sprout planting stage namely the pesticides and fertilizers that have been used. The emissions, in particular to air and water at each stage of the process will also be taken into account. Data such as composition and percentage of chemicals used as ingredients in the production of fertilizers and pesticides are trade secret and this proved to be the main limit. Therefore, the assumptions were made made using secondary data taken from scientific journals, material safety data sheets, etc.

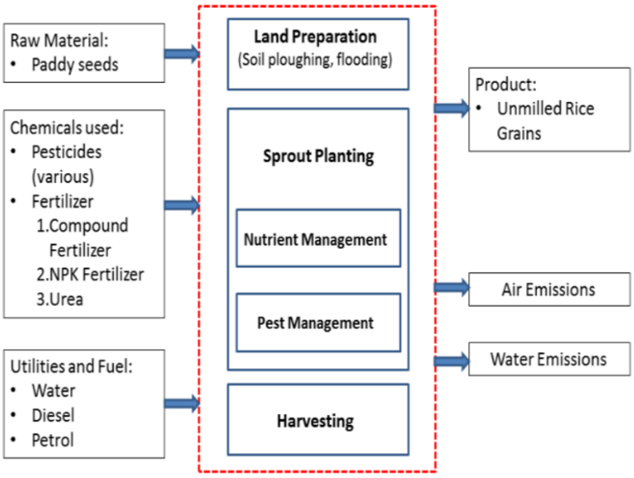

Figure 4. System Boundary for Cradle-to-Gate Rice Production

The key assumptions that need to be highlighted are the assumptions made in cutting criteria.The cut-off criteria chosen in this LCA study are the chemical components that forms less than 5% of the pesticide composition and were assumed to have negligible effect on the environment; hence they are not included in this study. In addition, any ingredients that were not identified from the Safety Data Sheets MSDS were assumed to be lower than 5% in composition or they do not pose any environmental threat. The assumptions made in the critical cut-off rule will be the subject of the sensitivity analysis. This is because numerous reports from the Environment Protection Agency (EPA) states that there are high content of heavy metals and highly toxic organic compounds in pesticides. These components are not included in the label since the pesticide supplier is not required to disclose the material by law. The release of such sensitive information could potentially trigger a public health issue which can be detrimental to the company [19]. Another major assumption is related to the limitation of emission data. The methodology used to formulate the emission components assumes that each chemical constituents of the pesticide were biologically degraded completely into basic chemical components such as CO_2, NOx, SOx, etc. This facilitates the fate and mechanisms of pesticide transportation in various ways. First, there are various pathways for organic matter to degrade, therefore there is potential for pesticides to be converted into something more toxic. Moreover, the rate at which organic material is degraded is not considered as well.

2.4.2 Inventory Analysis

Interview session with academic professors, farmers and MADA will be carried out to investigate the activities which has been performed in the boundary system. Data concerning field operations will also be retrieved from interviews with the farmers. The quality of the result from this LCA study may be affected by the quality of the data, which were collected throughout the studies. Data collection is very long and time consuming process but it is also a crucial step to ensure the obtained data is most reliable and can be used to represent the current situation precisely. All the raw data collected from this study were retrieved directly from the farmers; MADA and technician of the paddy plantation study area- Muda Rice Granary. Whereas the data on paddy plantation outputs, chemical use, total area of plantation and information regarding farming machinery from the year 2011 to 2015 will be collected. Farmers and MADA officer who owned the agricultural machineries will be interviewed to obtain the energy data. However, the primary data obtained cannot be immediately use in GaBi software because it requires a series of calculation and adjustment. Consequently, raw data needs to be exchanged to obtain the appropriate mass of chemical inputs and energy inputs that can be included in GaBi. These raw data changes will be made through secondary sources such as scientific journals, material safety data sheets (MSDS) and farmers and interview officers at MADA.

Table 1. Data Collection from respective agency for vary data.

No	Type of Data	Agency
1	System irrigation and types of paddy	MADA
2	Irrigation and water requirement	MADA
3	Technology for paddy irrigation and growth	MARDI
4	Rainfall data	Meteorological Department
5	Process in Rice Mill	Serba Wangi Sdn Bhd

Since different paddy species and different land use for different areas of the farm may produce in different use of fertilizers, pesticides and weed killers, the data to be used in modeling is the data that will be collected through personal communication and questionnaires from farm rice and MADA. Inputs for chemicals and fertilizers are in the form of primary data. The chemical contents from the fertilizers were considered primary data and is required for LCA study as an input, however, during the running of this research, we discovered that different types of rice species were used at different parts of the farm, hence resulting in different use of fertilizers, weed killers and pesticides. The data were retrieved via questionnaires from rice farmers and MADA. The same scientific journals by [20] and [21] were used as a guide. From the delivery receipts provided by MADA, information on the fertilizers, such as the brand name, quantity of bags and the weight of each bag were obtained. With this information, MADA has provided details on the ingredients of each brand fertilizer as well as the chemical components and its percentage composition. These chemical components do not add 100%, therefore the chemical components of these fertilizers that were not identified by MADA were assumed to have negligible effects on the environment. The input is then converted into a functional unit using equation 3 while the output emission data were obtained the same way before it is used for pesticides. However, the release of methane is calculated differently from other output data as methane production is a side effect of rice cultivation process. During rice cultivation, paddy fields are flooded with water, preventing oxygen from entering the soil. As a result, anaerobic conditions will cause methanogens; a process in which the microbial undergoes anaerobic respiration. The formation of methane is a two-step process as shown below:

$$CO_2 + 4\,H_2 \rightarrow CH_4 + 2H_2O \quad CH_3COOH \rightarrow CH_4 + CO_2$$

As mentioned in the study by [21], the concentration of CH_4 and CO_2 are roughly equivalent under Malaysian weather. The release of CO_2 were divided twice and is due to CH_4 release. Various energy data were needed at different levels in the flow of rice cultivation process. For instance, the tractors that were used during land preparation. A harvester was used during the harvesting seasons. Lorries were used to transport seeds, fertilizers, and harvested paddy grains between the farm, the mills, and the suppliers. The raw energy data were mainly collected through business transaction receipts from rice mills and interviews with Serba Wangi Sdn Bhd in Pendang, Kedah. Information for the weight of the cars and trucks were provided by the mills during the delivery of harvested rice. The machine operators provides information on fuel efficiency, fuel type, and operating time for each machine. This raw data will be used to calculate the emissions, which is required through the following steps: i) fuel consumption in one season is calculated by knowing the fuel efficiency and the size of the plant. ii) air pollutants emitted from agricultural machinery has been identified based on the study by [22], iii) The amount of emitted air pollutants calculated by the amount of fuel used in functional units multiplied by the pollutant emitted per liters of fuel used get from this study.

2.4.3 Assessing the Impact

The LCA study will be using GaBi software to assess the water footprint of rice plantation system in Muda Rice Granary. At the same time, comparison for 5 consequent years will be made by studying the impacts from the paddy plantation process. Two modeling methods were selected to study the effects of rice cultivation process. Classification and characterization, as a mandatory element under the ISO 14046 series will be conducted to meet the requirements of the LCA study.

2.4.4 Interpreting results and Identify Environmental Impacts

By the end of the study, the total life cycle impacts and water footprints of MUDA area of paddy harvested area will be obtained from the GaBi analysis. Countermeasures to optimize the reduction of water consumption and the potential impacts should be proposed by the end of the study after interpreting the results and identifying, the environmental impacts.

2.5 Water, Energy and Food (WEF) Nexus Quantification

Recently, the WEFN approach has become an increasingly popular perspective among scholars. A 'nexus' among water-energy- food was conceived by the World Economic Forum to highlight the inseparable linkages between the use of resources and the universal human rights to water, energy, and food security. The WEFN concept is based on systematic analysis of the interactions between the natural environment and human activities in order to better understand and to work towards a more balanced use of natural resources [23].

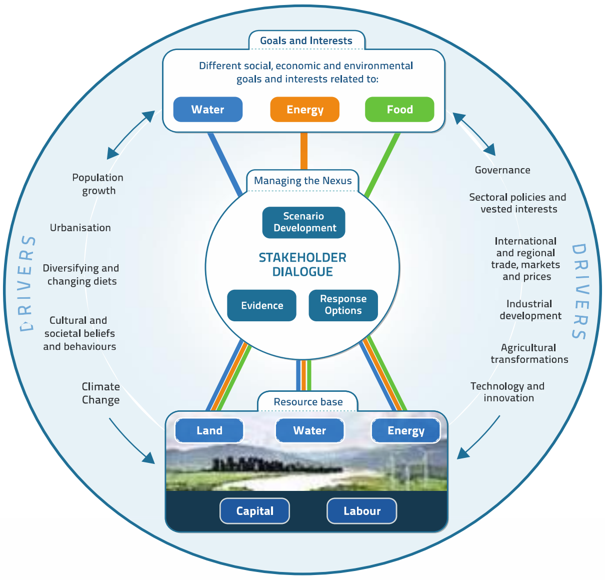

Figure 5. The Food and Agriculture Organization of United Nation (FAO) approach to the Water-Energy-Food Nexus: the management of the nexus helps determine national and local nexus-related goals and ways to achieve them

In this study, the concept of Water-Energy-Food Nexus explicitly addresses interactions and feedback between human and natural systems. It focuses on the resource base, including both biophysical and socio-economic resources, on which we depend to achieve social, environmental and economic goals pertaining to water, energy and food. Interactions take place within the context of external global drivers, such as demographic change, urbanization, industrial development, agricultural modernization, international and regional trade, markets and prices, technological advancements, diversification of diets, and climate change as well as more site-specific internal drivers, like governance structures and processes, vested interests, cultural and societal beliefs and behaviors. Figure 5 illustrates the Food and Agriculture Organization of United Nation (FAO) Approach to the Water-Energy-Food Nexus.

3.0 RESULTS AND DISCUSSION

3.1 Water Usage of Rice Production

Table 2 tabulate the water sources used in paddy plantation from year 2011-2015. In Muda area, the water requirement for the first (off) season crop is 1,300 mm and for the second (main) season crop is 1,100 mm. Hence the total water requirement for double cropping is 2,400 mm. the water requirement is met from four sources, i.e. rainfall (52%), run of the river (10%), dam release (30%) and recycled pump water (8%). Since Muda area is a "water stress" region, every effort is made to improve the water use efficiency so as to reduce the irrigation water consumption. Being the major water user, the irrigation sector consumes some 90% of the total of water supply. Increase in water productivity, therefore, has a great impact in ensuring the sustainability of sufficient water supply for all sectors. There are many factors that influence paddy land productivity. Some of the more significant factors are: soil types; seeds; agronomic practices; harvesting loss; good water management and cropping intensity. Water consumption of paddy in Muda area for 2011-2015 is presented in Table 3. The average water consumption for the last 5 years was 2,600 m^3/ton and it is above the world's average 2,500 m^3/ton. The exceptionally low water consumption of 1,430 m^3/ton was due to severe floods which occurred in December 2014. Since the Muda irrigation Scheme is the country's leading rice granary area as far as paddy production and efficient water management practices are concerned, its water footprint of rice should be adopted as the benchmark for other irrigation schemes. Besides, the water use efficiency (90%) in the scheme is among the highest in the regions. Therefore, the target for water footprint for the granary areas can be reasonably set after the analysis and result of this research.

Table 2. Result of water source used on paddy plantation from year 2011-2015

Water source	Season 1/2011		Season 2/2011		Year 2011	
	Acre feet	%	Acre feet	%	Acre feet	%
Water from dam	535,884	44.70	357,148	24.00	893,032	33.30
Precipitation rate	348,421	29.10	762,446	51.30	1,110,867	41.40
River flow	213,926	17.80	295,973	19.90	509,899	19.00
Recycle pump water	101,088	8.34	70,805	4.80	171,893	6.40
Total	**1,199,319**	**100**	**1,486,372**	**100**	**2,685,691**	**100**

Water source	Season 1/2012		Season 2/2012		Year 2012	
	Acre feet	%	Acre feet	%	Acre feet	%
Water from dam	426,598	25.80	263,887	25.80	690,485	32.60
Precipitation rate	418,584	39.40	401,750	39.40	820,334	38.70
River flow	173,914	25.40	259,169	25.40	433,083	20.40
Recycle pump water	79,571	9.40	95,979	9.40	175,550	8.30
Total	**1,098,667**	**100**	**1,020,785**	**100**	**2,119,452**	**100**

Water source	Season 1/2013		Season 2/2013		Year 2013	
	Acre feet	%	Acre feet	%	%	Acre feet
Water from dam	418,450	36.30	213,616	22.3	632,066	30.0
Precipitation rate	508,445	44.20	440,809	46.1	949,254	45.0
River flow	84,364	7.30	150,038	15.7	234,402	11.1
Recycle pump water	140,089	12.20	152,742	16.0	292,831	13.9
Total	**1,151,348**	**100**	**957,205**	**100**	**2,108,553**	**100**

Water source	Season 1/2014		Season 2/2014		Year 2014	
	Acre feet	%	Acre feet		Acre feet	%
Water from dam	383,363	31.40	71,958	Water from dam	383,363	31.40
Precipitation rate	557,448	45.60	496,937	Precipitation rate	557,448	45.60
River flow	191,130	15.60	388,957	River flow	191,130	15.60
Recycle pump water	89,743	7.30	54,098	Recycle pump water	89,743	7.30
Total	**1,221,724**	**100**	**1,011,950**	**Total**	**1,221,724**	**100**

Water source	Season 1/2015		Season 2/2015		Year 2015	
	Acre feet	%	Acre feet	%	Acre feet	%
Water from dam	413,023	38.9	295,243	32.9	708,266	36.2
Precipitation rate	461,510	43.5	422,965	47.2	884,475	45.2
River flow	85,059	8.0	101,858	11.4	186,917	9.5
Recycle pump water	102,214	9.6	76,347	8.5	178,561	9.1
Total	**1,061,806**	**100**	**896,413**	**100**	**1,958,219**	**100**

Table 3. Paddy production, average yield and water consumption of Muda Irrigation Scheme Malaysia (2011-2015)

Year	Total Water Sources (acre feet)	Average Net Yield (ton/hectare)	Area (hectare)	Total Revenue (Ton)	Water Consumption (m^3/ton)
2011	2,685,691	4.955	193,020	956,417	3463.70
2012	2,119,452	4.843	191,843	929,070	2813.89
2013	2,108,553	5.026	187,413	941,889	2761.32
2014	1,221,724	5.539	190,127	1,053,116	1430.96
2015	1,958,219	4.884	191,853	936,995	2577.84

To date, data collection have been completed. The data will then be analyse to quantify the Water Footprint of 1ha area of Kedah River Basin. The current and future demand for water resources taking into account population growth and planned agricultural and industrial development will also be quntified. In this project, Muda Irrigation Scheme is the largest rice granary in Malaysia. Covering some 191,853 ha of paddy land, it is situated along the coastal plain in the northern states of Kedah and Perlis in Peninsular Malaysia. Table 4 shows the result for two season of paddy area in Muda Irrigation Scheme in Kedah.

Table 4. Water Footprints (WF) of paddy plantation based on MUDA Irrigation Scheme System (2011-2015)

Year	Season	Green WF (m^3)	Blue WF (m^3)	Overall WF (m^3/ha)
2011	**Season 1**	4454.76	10877.90	15332.66
	Season 2	9801.58	9306.39	19107.97
2012	**Season 1**	5384.28	8747.97	14132.25
	Season 2	5383.67	8295.41	13679.08
2013	**Season 1**	6576.31	8315.42	14891.73
	Season 2	5736.81	6720.52	12457.33
2014	**Season 1**	7255.30	8644.55	15899.85
	Season 2	6428.61	6662.45	13091.07
2015	**Season 1**	5279.11	8292.51	13571.63
	Season 2	3773.69	7683.94	11457.63

Rainwater is necessary for rice growth in order to maintain soil moisture and to maintain the standing layer of water over the paddy field. In major rice producing regions across the world, rice is grown during the wet (monsoon) season, which reduces the irrigation demand by effectively using rainwater. Rice is one of the major crops feeding the world population and is the most important crop in Malaysia. Mainly, rice cultivation uses water from precipitation. In the period of 2000-2004, the global average water footprint (WF) of paddy rice was 1,325 m3 /ton, which is much lower than previous estimates. The global water footprint of rice production were estimated to be 784 billion M^3 /yr. The ratio of green to blue water varies greatly, both over time and space. In countries like India, Indonesia, Vietnam, Thailand, Myanmar and the Philippines, the green water fraction is substantially larger than the blue water fraction [4]. The WF is the value of water that is used to produce everything, such as crops, products, etc. Sometimes, WF reference is used as a direct or indirect indicator that comes from the process of production or crops [24, 25]. This study of paddy production took into consideration the rainfall because the study was carried out forthe two main seasons. The WF was studied to evaluate rainfall water used in the green WF, to raise awareness in the use of resources and the environment that affect the ecosystems as well as management to achieve the most effective solution. The WF can be used to compare water use efficiency of each product particularly during the water shortage period so that the policy can be decided on what plant to be promoted taking into consideration net profit of product, market requirement, labour requirement, etc. In Muda area, the water requirement for the first (off) season crop is higher than second (main) season because during the main season, the paddy usually received heavy rainfall which is in August to January. The water requirement is met from four sources, i.e. rainfall (52%), run of the river (10%), dam release (30%) and recycled pump water (8%).

4.0 CONCLUSION

The methodologies, approaches and indicators for assessing the impacts of freshwater usage are still evolving. However, the concept of water footprint is an important step in this direction. By implementing water footprint research in paddy field, it will be essential not only in research area but also in agricultural development in Malaysia. Consequently, it will become the baseline for other agricultural activities in Malaysia. Since Muda area is a "water stress" region, every effort is made to improve the water use efficiency so as to reduce the irrigation water consumption. Being the major water user, the irrigation sector consumes some 90% of the total of water supply. Increase in water productivity, therefore, has a great impact in ensuring the sustainability of sufficient water supply for all sectors. There are many factors that influence paddy land productivity. Some of the more significant factors are: soil types; seeds; agronomic practices; harvesting loss; good water management and cropping intensity. The average water consumption for the last 5 years was 28,724 M^3 /ha. Since the Muda irrigation Scheme is the country's leading rice granary area as far as paddy production and efficient water management practices are concerned, its water footprint of paddy should be adopted as the benchmark for other irrigation schemes to emulate. Besides, the water use efficiency (90%) in the scheme is among the highest in the regions. Therefore, the target for water footprint for the granary areas can be reasonably set after the analysis and result of this research. Besides the amount of Water footprint, there are few factors might affect the yield of paddy plantation.

a) Climatic factor such as less rainfall might causes the crop to have a higher crop evapotranspiration.
b) The types of paddy are another factor which affects the yield. Rice is grown in Malaysia mainly under flood irrigation and there are few varieties of rice grown currently with their maturity days ranging between 105 and 120 days [26].

Farmers may consider dry cultivation or aerobic rice (IRR) method for seedling to reduce the amount of irrigation water. They may also consider planting the paddy which is able to grow with less water supply or shorter maturity days. Excess / limited / no water leads to reduction in yield, the study on the WF of paddy plantation should be able to give an idea to the authority as to consider what is the appropriate amount of irrigation water should be used in the field as to avoid excess or limited condition and causes impact to the rice yield.

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