



UNIVERSITI PUTRA MALAYSIA

***DETERMINATION OF WATER FOOTPRINT OF OIL PALM FRESH FRUIT
BUNCHES IN MALAYSIA***

SAFWAN MUKMIN BIN MOHAMMAD AMINUDDIN

**Ip
FK 2019 47**

**DETERMINATION OF WATER FOOTPRINT OF OIL PALM FRESH FRUIT
BUNCHES IN MALAYSIA**

SAFWAN MUKMIN BIN MOHAMMAD AMINUDDIN

181700

BACHELOR OF ENGINEERING (AGRICULTURAL & BIOSYSTEMS)

FACULTY OF ENGINEERING

UNIVERSITI PUTRA MALAYSIA

SERDANG, SELANGOR

2018/2019

APPROVAL SHEET

This project report here to entitle “DETERMINATION OF WATER FOOTPRINT OF OIL PALM FRESH FRUIT BUNCHES IN MALAYSIA” was prepared and submitted by SAFWAN MUKMIN BIN MOHAMMAD AMINUDDIN in partial fulfillment of the requirement for the degree of Bachelor of Engineering (Agricultural and Biosystems) is hereby accepted.

Approved by:

.....

Dr. Md Rowshon Kamal

(Project Supervisor)

Date:

Approved by:

.....

Dr. Aimrun Wayayok

(Project Examiner)

Date:

Approved by:

.....

Prof. Madya Dr. Rimfiel Bin Janius

(Project Examiner)

Date:

ACKNOWLEDGEMENT

Alhamdulillah, all praises to Allah S.W.T. the Merciful and the Beneficent for granting the strength, determination, patience, blessing and knowledge in order to complete this research project. Overall, I would like to extend my highest gratitude and appreciation towards everyone who provided me with moral support and encouragement in completing this project whether they are directly and indirectly involved in this project.

Firstly, I would like to take this opportunity to give my highest gratitude and honor to my respectful project supervisor, Dr. Md Rowshon Kamal for his continuous support, guidance, patience, countless advices and also giving me opportunity to learn new knowledge and improve myself throughout this project. I would also like to thank him for all of the comments that greatly improved this project from the beginning.

Besides that, I would like to thank to all of Universiti Putra Malaysia's staffs especially in Department of Engineering Biology and Agriculture which had help me in research funding and also giving the facilities to finish this project.

With a special mention to my best friend, Mrs. Lilis Ayuni Ibrahim for her continuous support, advices, and encouragement from the beginning until the project finished. Also not to forget, Mr. Azzizat Jailani for helping me a lot in data acquisition and lots of explanation which is very important and useful for me.

Last but not least, a special gratitude to my family especially my beloved parents and also to all my friends, especially my housemates and course mates who had supported me both in my life and throughout this project. Thanks for all of your encouragement.

ABSTRACT

Water plan management is very crucial in oil palm sector in order to make sure the oil palm deliver high quality yield. In achieving that, water accounting throughout the production of oil palm fresh fruit bunches (FFB) from the beginning of life cycle of the oil palm must be quantified. This study compiling on quantifying the water footprint (WF) of oil palm FFB production from plantation in selected area in Malaysia. The methodology of this project was based on Hoekstra et al. (2009) in finding the WF of oil palm FFB production. The green and blue WF was calculated by using the rainfall and crop evapotranspiration (ET) data. The result stated that the FFB yield for oil palm crops was averagely $21.51 \text{ t ha}^{-1} \text{ yr}^{-1}$ throughout the 25 years of its economic life. The total WF of oil palm FFB production was $241.69 \text{ m}^3 \text{ t}^{-1}$ FFB which the ratio was $128.88 \text{ m}^3 \text{ t}^{-1}$ FFB green WF, $112.59 \text{ m}^3 \text{ t}^{-1}$ FFB blue WF, and $0.22 \text{ m}^3 \text{ t}^{-1}$ FFB grey WF. The result showed that the most water that had been utilized in oil palm plantation was green WF followed by blue WF and grey WF as the oil palm production depends on rainfall as water supply and without irrigation. In oil palm case, green water which is the rainfall must meet the crop water requirements (CWR). But when the amount of rainfall distribution is lower than the amount of ET, it is crucial to quantify the water deficit of the soil in the oil palm plantation. This step can overcome any water crisis affecting crop's yield that probably occurred in future events due to drought season or water scarcity and irrigation can be applied to the oil palm in maintaining good quality yield.

ABSTRAK

Pelan pengurusan air adalah sangat penting dalam sektor industri kelapa sawit dalam memastikan kelapa sawit tersebut menghasilkan hasil yang berkualiti tinggi. Bagi mencapai tujuan tersebut, pengiraan air bagi keseluruhan produksi tandan buah segar kelapa sawit bermula daripada kitaran hidup kelapa sawit haruslah diambil kira. Kajian ini merumuskan tentang pengiraan jejak air tandan buah segar kelapa sawit daripada ladang kelapa sawit yang terpilih di Malaysia. Metodologi projek ini adalah berdasarkan Hoekstra (2009) dalam mencari jumlah jejak air tandan buah segar kelapa sawit tersebut. Jejak air hijau dan biru telah dikira dengan menggunakan data hujan dan evapotranspirasi tanaman tersebut. Hasil daripada itu menunjukkan bahawa hasil tandan buah segar secara purata adalah sebanyak 21.51 tan untuk setiap hektar setiap tahun sepanjang 25 tahun usia ekonominya. Jumlah jejak air untuk produksi tandan buah segar kelapa sawit adalah sebanyak 241.69 m³ setiap tan tandan buah segar dimana nisbahnya adalah 128.88 m³ setiap tan bagi jejak air hijau, 112.59 m³ setiap tan bagi jejak air biru, dan 0.22 m³ setiap tan bagi jejak air kelabu. Hasil menunjukkan bahawa air yang paling banyak digunakan dalam penanaman kelapa sawit adalah jejak air hijau diikuti oleh jejak air biru dan jejak air kelabu dimana produksi kelapa sawit bergantung kepada hujan sebagai sumber air dan bukanlah melalui pengairan. Dalam konteks kelapa sawit, air hijau atau air hujan mestilah memenuhi keperluan air tanaman. Tetapi apabila jumlah hujan lebih rendah berbanding evapotranspirasi, pengiraan defisit air untuk tanah didalam ladang kelapa sawit tersebut mestilah dilakukan. Langkah ini dapat mengelak sebarang krisis air yang memberi impak kepada hasil tanaman yang mungkin akan berlaku pada masa hadapan yang disebabkan musim kemarau atau kekurangan air dan pengairan boleh disalurkan kepada pokok kelapa sawit dalam mengekalkan hasil tanaman yang berkualiti tinggi.

TABLE OF CONTENT

APPROVAL SHEET	i
ACKNOWLEDGEMENTS	ii
ABSTRACT.....	iii
ABSTRAK	iv
TABLE OF CONTENT	v
LIST OF TABLE.....	vii
LIST OF FIGURES	viii
LIST OF ABBREVIATION	ix
CHAPTER 1	1
1.1 Overview.....	1
1.2 Problem Statement.....	2
1.3 Aim and Objective	3
CHAPTER 2	4
2.1 Introduction.....	4
2.2 Overview of oil palm production in Malaysia	4
2.3 Types of water footprint	6
2.4 Life cycle of oil palm.....	8
2.5 Drought vs oil palm production	11
2.6 Double stage nursery for oil palm.....	13
2.7 Watering.....	14
2.8 Slow release fertilizer for nursery.....	16
2.9 CROPWAT 8.0.....	17
2.10 CLIMWAT 2.0	18
CHAPTER 3	20
3.1 Introduction.....	20
3.2 Study area and site selection	21
3.3 Data Acquisition	21
3.4 Calculation of water footprint.....	22
3.4.1 Water footprint of oil palm seedlings at nursery	23
3.4.2 Water footprint of fresh fruit bunches (FFB) of oil palm at plantation ...	26

3.5 Data analysis on water use management	27
CHAPTER 4	28
4.1 Rainfall Distribution	28
4.2 Components of water footprint at Nursery	31
4.3 Components of water footprint at plantation	32
CHAPTER 5	34
5.1 Conclusion	34
5.2 Recommendations.....	35
REFERENCES.....	36
APPENDICES.....	38



LIST OF TABLE

TABLES

Table 2.1: Advantages and disadvantages of irrigation	14
Table 4.1: Specifications of polybag used in pre-nursery	30
Table 4.2: Total Water Footprint of Fresh Fruit Bunches (FFB) production	31
Table 4.3: Rainfall distribution in year 2009 (mm)	37
Table 4.4: Rainfall distribution in year 2010 (mm)	38
Table 4.5: Rainfall distribution in year 2011 (mm)	39
Table 4.6: Rainfall distribution in year 2012 (mm)	40
Table 4.7: Rainfall distribution in year 2013 (mm)	41
Table 4.8: Rainfall distribution in year 2014 (mm)	42
Table 4.9: Rainfall distribution in year 2015 (mm)	43
Table 4.10: Rainfall distribution in year 2016 (mm)	44
Table 4.11: Rainfall distribution in year 2017 (mm)	45
Table 4.12: Rainfall distribution in year 2018 (mm)	46
Table 4.13: Total rainfall distribution from year 2009 to 2018 (mm)	47
Table 4.14: Classification of dry and wet months from year 2009 to 2018 (mm)	47
Table 4.15: Monthly evapotranspiration (ET) from year 2009 to 2018	48
Table 4.16: Green water footprint (WF) from year 2009 to 2018 (m ³ /ha)	48
Table 4.17: Grey water footprint (WF) from year 2009 to 2018 (m ³ /ha)	49
Table 4.18: Blue water footprint (WF) from year 2009 to 2018 (m ³ /ha)	50

LIST OF FIGURES

FIGURES

Figure 2.1: Water footprint categorization	6
Figure 2.2: System boundary for oil palm fresh fruit bunches (FFB) production	9
Figure 3.1: Flow chart of the methodology	19
Figure 4.1: Rainfall at Kolam Takungan Sg. Merab from 2009 to 2013	27
Figure 4.2: Rainfall at Kolam Takungan Sg. Merab from 2014 to 2018	28
Figure 4.3: Average Monthly Rainfall and Evapotranspiration (mm)	29
Figure 4.3: Total Water Footprint (WF) of Fresh Fruit Bunch (FFB) Production	32

LIST OF ABBREVIATION

WF – Water Footprint

CWR – Crop Water Requirement

FFB – Fresh Fruit Bunches

ET – Evapotranspiration

ENSO – El Nino Southern Oscillation

LCA – Life Cycle Assessment

UNDP – United Nations Development Programme

HDR – Human Development Report

ISO – International Organization for Standardization

MPOB – Malaysian Palm Oil Board

CWU – Crop Water Use

DWU – Degrading Water Use

SRF – Slow Release Fertilizer

FAO – Food and Agriculture Organization

CHAPTER 1

INTRODUCTION

1.1 Overview

Water is the most basic common assets that is imperative to the development of countries, and also an essential natural resources that must be protected to maintain a healthy environment. Nonetheless, water, particularly freshwater is constrained. Just 3% of Earth's water is freshwater, and its over-utilization, driven by an exponential population growth that could trigger a worldwide water shortage crisis if feasible water administration techniques are not applied and practiced.

Oil palm is one of the agricultural products that needs an enough supply of water for it to deliver high quality yields. As the biggest agricultural crop in Malaysia, the oil palm industry needs a reliable water supply to guarantee that it can meet the consistently developing worldwide demand for vegetable oils and fats. A water management plan had to be plan and practiced to make sure this industry can economically utilize the limited freshwater supply so that it will not be overused. One of the devices that are accessible is to direct a water footprint assessment.

1.2 Problem Statement

Water is a very important factor in the oil palm production. With Malaysia situated close to the equator, her atmosphere is classified as equatorial which is being hot and moist consistently. However, palm oil generation is impacted by the climate pattern. The occurrence of El Nino event (prolonged sweltering and dry climate) has demonstrated to altogether influence the oil palm production. Climate change alludes to occasions which occurs over centuries, such as global warming. The year-to-year fluctuation in the atmosphere of the Pacific is affected by El Nino Southern Oscillation (ENSO).

However, the effect of this atmosphere fluctuation on the Malaysian palm oil industry relies upon the intensity of the events. The disturbances that caused from these outrageous climate conditions are significant to the Malaysian palm oil industry.

In this study, we examined and determined the water footprint of oil palm fresh fruit bunch which is the amount of fresh water utilized in the production of these crops. This study also compiles data that can help in maintaining the highest quality of oil palm fresh fruit bunches throughout drought season as they are important for accessing the potential impact and for influencing the potential adaptation strategies to reduce the impact of these phenomena.

1.3 Aim and Objective

The main aim of this study is to determine the water footprint of oil palm fresh fruit bunches in Malaysia.

The specific objectives were:

1. To determine the crop water requirements (CWR) of oil palm
2. To estimate the components of water footprint for oil palm fresh fruit bunches.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter covers several reviews of literature from previous researches and studies on the determination of water footprint of oil palm fresh fruit bunches and topics related. In addition, it also introduces the information and some knowledge and concepts about water footprint and impact of climate to quality of oil palm fresh fruit bunches.

2.2 Overview of oil palm production in Malaysia

Many factors are important for the productivity of the oil palm plantations, including the critical starting point for germinated oil palm seeds resulting from the cross-pollination of selected parents of the palms for seed plantation. The palm oil industry is instrumental in Malaysia's economic development and in improving people's economic well-being. Many factors are important for the productivity of the oil palm plantations, including the critical starting point for germinated oil palm seeds resulting from the cross-pollination of selected parents of the palms for seed plantation. Also depends very much on the good management practices at the seed production unit to produce high-quality germinated oil palm seeds.

Fresh fruit bunches (FFB) are brought from the plantation to the seed production unit, which registers the bunch weight (Basiron et al 2001). The fruit bunch is cut and placed into a tank by an axis to separate the stalk from spikelet after weighing. The fruits are then saved for around 3-5 days in rackets or bags so that they can be detached. The normal or developed fruit is insulated and separated by parthenocarpics after retting.

The normal / developed fruit is depericarpated in order to separate the mesocarp from the seeds usually using depericarp. Depericarpated seeds are soaked to ensure an optimal moisture content of approximately 18 –19 per cent and then washed out with appropriate detergent before being fungicidally treated to avoid fungal inflammation, so that mesocarp oil can be removed from the surface. The seeds are air-dried and defective ones are removed.

The dormancy of oil palm seeds for germination requires heat treatment. An optimum moisture content, temperature and oxygen level are required for germination. The palm oil seeds are then packed and placed at a temperature of 25 ° C to 35 ° C for 14-30 days in polyethylene bags. The seeds are sprayed with distilled water during this time so it is not desiccated. Only regular and undamaged seeds are counted and selected after germination before they are finally packaged and distributed.

The Life Cycle Assessment (LCA) for Malaysian palm oil, including palm biological diesel, has been completed recently by studies by the Malaysian Palm Oil Board (MPOB). Starting from the production of oil palm seedlings through production and use of biodiesel, the researchers conducted a burrow-to-grave analysis. The findings of these studies have shown that upstream operations such

as FFB production have the main environmental effects on the production of palm biodiesel.

Appropriations of subsystems in the supply chain oil palm using the LCA approach were also published, along with case studies of gate-to-gate oil palm seedling by greenhouse gas (GHG). However, the data required for the complete picture in the supply chain for palm oil, namely in relation to LCA for the manufacture of oil palm seed, were divergent. With the completion of this study, data from the gate-to-gate analysis can therefore be associated with the previous LCA study, which began for a complete supply chain, from LCA of oil palm seedlings to palm biodiesel.

2.3 Types of water footprint

A framework for analysis of the relationship between human consumption and global freshwater appropriation is established in the concept of "water footprint" introduced by Hoekstra (2003) and later developed by Hoekstra and Chapagain (2008). In water volumes of each product, the water footprint of the product (alternatively known as the "virtual water content") is the summary of the water footprints of the process steps taken to produce it. The water footprint of a geographic region (e.g. a province, country, catchment area or water basin) corresponds to the total water base of all processes in that region (Hoekstra et al., 2011).

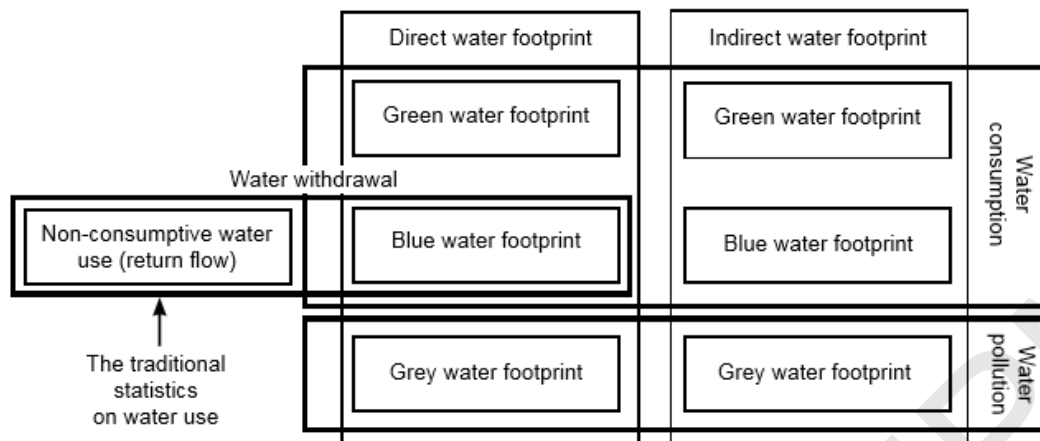


Figure 2.1: Water footprint categorization

The blue water footprint refers to the volume of consumed (evaporated) surface and groundwater from a good production; the green water footprint refers to the rainwater used. The grey water footprint of a product refers to the amount of fresh water required to absorb the pollutant load in accordance with existing environmental standards for quality. The water footprint is an indicator that freshwater resources are directly and indirectly appropriated. The term "freshwater" covers both consumption of water and the water necessary for the treatment of pollution (the green and blue water footprint). For instance: Postel *et al.* (1996) and Chapagain *et al.* (2006) have previously recognized the grey water footprint as the dilution water requirement. The inclusion of grey water in water use studies is relatively new, but justified when the pertinence of pollution to water scarcity is considered.

Water consumption is not the only contributing factor for water scarcity, as was emphasized in UNDP's 2006 Human Development Report (HDR), which also plays a key role (UNDP, 2006). Freshwater pollution not only threatens environmental sustainability and public health, but also increases freshwater

competition. Vorösmarty et al. (2010) argue further, that the global safety of the water and biodiversity of rivers, along with other factors, are at risk.

2.4 Life cycle of oil palm

The palm oil industry plays an important role in the economic development of Malaysia. The efficiency of an oil palm plantation relies on certain variables, including a critical starting stage for the performance of germinating plants used by chosen parent palm pollination in seeding procedures. The development of high-quality germinated oil palm crops also relies on the excellent strategy procedures of the plant manufacturing unit.

The first stage in the oil palm chain is oil palm nursery. From economic standpoint, the main objective of the nursery stage is to minimize the immature period in the sector and to make the early return as high as feasible and keep costs low as necessary. In the nursery, usually the type of nursery that are practice is double stage nursery which are pre-nursery and main nursery. The germinated seeds are first cultivated in tiny polybags of 15 cm x 23 cm to about three to four months. After that, the grown seedlings will be transferred into main nursery where the seedlings will be transplanted in the larger polybags with size 38 cm x 45 cm. During the main nursery, the spacing between the seedlings are 0.9 m x 0.9 m and it will be growth under protective cover for about remaining nine to ten months.

During the nursery stage, the main source of water is supply by irrigation using sprinkler method. In pre-nursery, 0.5 litre per day were been supplied to every plants while 2.0 litre per day were been supplied to seedlings during the main nursery stage. Watering of the seedlings occasionally been given two times in a day which were once before 11.00 am and once after 4.00 pm. Fertilizers and pesticides were been given to ensure the growth and development of the seedlings and also as the protection for the seedlings during the entire nursery stage. In some cases, fertigation which are applying fertilizer containing nutrient through irrigation also been practiced.

After twelve to thirteen months at the nursery, the seedlings then will be transplanted into the field. Before transplanting, holing must first be done at the field. The density of the plant at the plantation is about 136 to 148 plants per hectare. The legume cover will be sown and the soil will be ploughed before planting the seedlings at the field. Purpose of cover crops is to prevent soil erosion and also to fixes Nitrogen from the surrounding and this is important because Nitrogen is a very crucial needs of young oil palm to ensure the growth and development of the seedlings.

Weeding also must be done before transplanting. Usually circle weeding around all of the oil palm seedlings will be made to prevent weed competition and herbicides are being applied in this circle section to make sure the weed will not affect the growth of the seedlings.

After 4-5 years planting, the matured oil palm will start to bear fresh fruit bunches (FFB) and can be readily harvested. This usually continues until the economic life of an oil palm which is 20 to 25 years. Then, the oil palm needs to be replanting due to the lack of yield produced and difficulties of harvesting tall oil palm trees. Usually the harvesting method that was been practiced by manually using sickle that connected with pole. After that the harvested FFB will be transported to the mill by lorries usually 5 -10 tonne lorries.

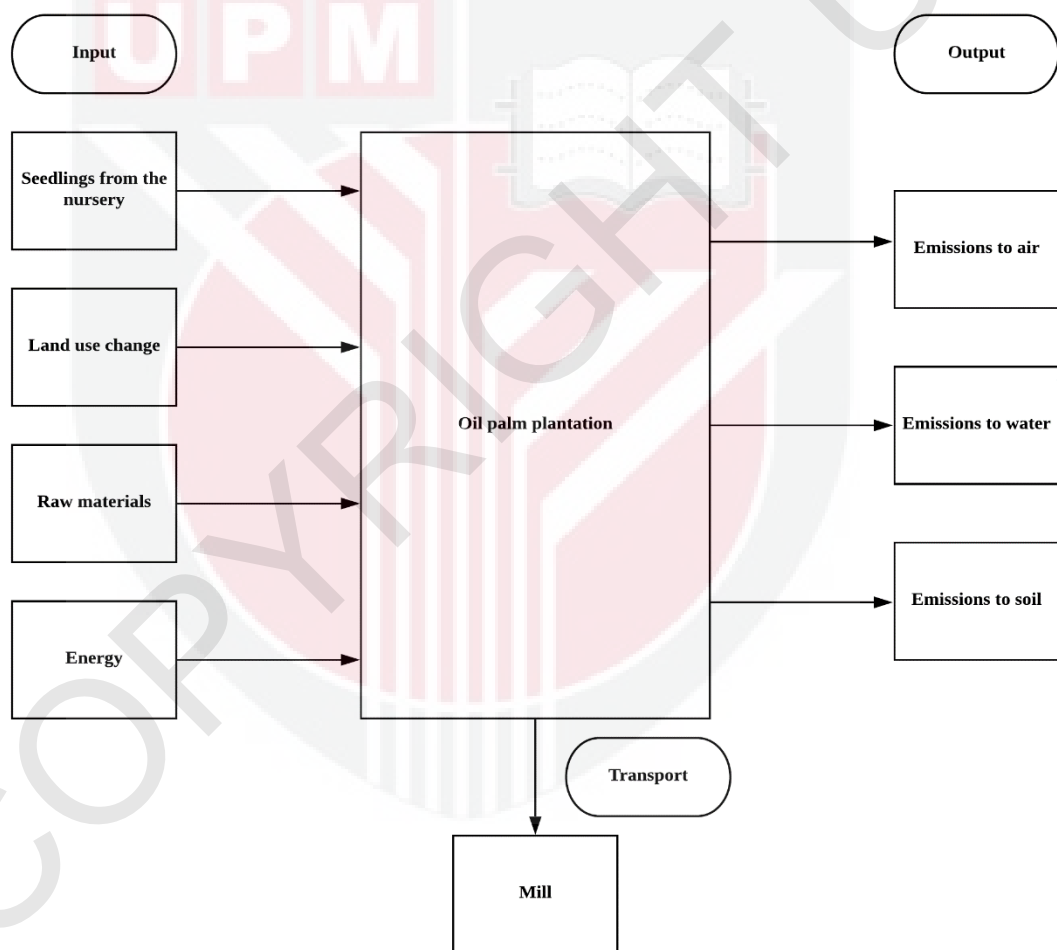


Figure 2.2 System boundary for oil palm fresh fruit bunches (FFB) production

2.5 Drought vs oil palm production

Water is a natural resource of the greatest importance for the development of nations and environmental well-being. Water is, however, limited, particularly fresh water. Only 3% of Earth's water is fresh, and its over-consumption driven by exponential population growth could trigger a global water crisis unless strategies are adopted for sustainable water management.

Oil palm is a farm that requires sufficient water supply to produce high quality yields. The oil palm industry, one of Malaysia's main agricultural commodities, requires a consistent water supply to guarantee the ever increasing global demand for vegetable oils and fats. A water management strategy can be adopted and adapted to ensure that the industry can sustainably take advantage of its limited freshwater supply. A water footprint assessment is one of the tools available in encountering this issue.

In recent years, the importance of the water footprint has increased, particularly as global development threatens to rapidly deplete the natural resources available. Water footprint (WF) is defined as a human measure of fresh water appropriating the volume of water consumed and/or contaminated by the Water Footprint Network.

The concept has now been introduced by Hoekstra in 2002 to measure the sustainability of the uses of water in products production as an environmental indicator for the amount of water consumed. This is an ecologically driven approach (like emissions of greenhouse gas and carbon footprint), but in the course of surplus development there is a threat from freshwater depletion.

Most frequently, case studies for water footprint are conducted in the context of life cycle (LCA), a tool for identifying potential impacts on the environment at any stage of the development of a product. To date, several water footprint studies (M. Mekonnen and Hoesktra 2014, Sabli et al 2017, Gerbens et al 2008, among others) have been conducted on crops. These studies identified the stages (in a crop cultivation and subsequently vegetable oil production) in which large quantities of water could be consumed which could be unsustainable in the long term.

The impacts on water use by oil palm trees, as well as uncertainties on different pathways and allocating types were analyzed using the LCA method in Vijaya Subramaniam's 2018 paper 'Diagramming the water footprint for Malaysian crude palm oil'.

This study focuses on the principles, requirements and guidelines of management of the water footprint, while the system border for the LCA begins from the nursery stage and ends at a milling stage. The methodology chosen was been complied with the ISO 14064: 2014. The LIC data were derived from MPOB's past LCA studies in different oil palm stages. The inventory of LIC data. The total for consumption of the water (CWU / water removal from a body of water) and the degrading use of water (DWU / emissions affecting water quality) were calculated in order to derive water from the oil palm's water footprint.

2.6 Double stage nursery for oil palm

During the pre-nursery, the polybag used was black ultraviolet-stabilised polyethene with minimum gauge of 250 is recommended. The polybags should be filled to capacity. In the filling process, the polybags should be agitated to help consolidate the soil and obviate air entrapment. Polybags should be filled about one week before the seeds are due to arrive.

After filling, the polybags should be transported to marked points in the nursery. If sufficient space is not immediately available, the polybags should instead be placed against each other in beds four polybags wide and of any convenient length, separated by a 0.8 m wide path. Where polybags are placed against each other they should be spaced 0.9 m x 0.9 m triangular before the leaves of adjacent seedlings meet; that is, 4-5 months after planting. There should be no delay in this spacing operation. From filling to the planting of seeds, soil in the polybags would have settled to an appreciate level below the rim of polybags.

Seedlings grown in the small polybags should be completely transplanted into large polybags at 3 months after seed planting without fail. The soil from the center of the large polybag should be scooped out to leave a planting hole with depth equal to that of the small polybag. This planting hole should have a base of at least 10 cm diameter, widening towards the top. The polyethene around the base of the small polybag should be cut and removed. The seedling is then placed into the planting hole within the large polybag and the polybag is removed after slitting the polyethene length-wise.

Soil should be tamped into the planting hole so that the seedling is in a firm, upright position. The collar of the seedling should be about 13 mm below the rim of the large polybag. Deep planting should be avoided.

These are the procedure for transplanting seedlings from pre-nursery to main nursery:

- 1) Pre-nursery seedlings should be transplanted at 3 months. Both polybags should be watered before transplanting.
- 2) A coring tool is used to make a planting hole slightly larger in diameter than pre-nursery soil core and of the same height.
- 3) Cored large polybag ready to receive the pre-nursery seedling.
- 4) Where necessary, the planting hole is dressed with 120 g of Rock Phosphate.
- 5) The small polybag is cut
- 6) Care is taken to ensure that the pre-nursery soil core is not broken.
- 7) Seedling is planted in an upright position, surfaces of core and large polybag soil being flush with each other. Deep planting must be avoided.
- 8) Soil for large polybag is consolidated and must be well watered after transplanting.

2.7 Watering

Depending on the size and duration of the planting programme, hand watering or an irrigation system (overhead or otherwise) should be employed. Generally, the latter is preferred, provided that adequate water is available and the duration and size of the plating programme justify the initial capital cost.

There are few types of irrigation system could be used for nursery irrigation as listed in Table 2.1.

Table 2.1 Advantages and disadvantages of different types of irrigation system

Irrigation Type	Advantages	Disadvantages
Overhead Spray Mist System	<ul style="list-style-type: none"> • The mist distributed in a square. • Delivered in fine mist for better penetration into the soil. • No fertilizers wash off from the bag. • Easy for cleaning. • Can be used on undulating terrain 	<ul style="list-style-type: none"> • Clogging of filter that require frequent cleaning. • Strong wind velocity affects water distribution. • Require more piping. • High initial cost to set up. • Frequent cleaning required if water is dirty.
Irrigation Type	Advantages	Disadvantages
Overhead Sprinkler	<ul style="list-style-type: none"> • Uniform watering • Less blockage • Easy to maintain • Reusable 	<ul style="list-style-type: none"> • High capital cost. • Larger water droplet size. • Require more piping.
Lay Flat Perforated Polythene Tube	<ul style="list-style-type: none"> • Very fine mist droplet. • No “hardcapping” • Low pressure requirement. • Low capital cost. 	<ul style="list-style-type: none"> • Need a level base and free of hard article. • Wind rift and blockages. • Interference by growing fronds. • Require clean water. • Require sufficient pressure. • Regular flushing required.

Small nurseries will generally require only hand watering with a watering-can rose attached to the end of a hose. To ensure that water flows out at constant rate and at sufficient pressure, an overhead tank may be necessary.

Regular and sufficient watering is essential. Under local conditions, if an overhead sprinkler system is used, a minimum water equivalent of 8 mm rainfall is required per day. The use of a suitable water container of the rain gauge diameter, to replace the portable rain gauge to monitor the daily watering is mandatory. If hand watering is done, each seedling should receive at least 0.5 liter of water per day initially increasing to a minimum 2 liters per day by the time it is 11 months old. More water would be required during the dry season. Soil splash during watering should be avoided to prevent exposure. If roots of seedlings are exposed, topping up with soil should be carried out immediately to prevent growth retardation of seedlings.

2.8 Slow release fertilizer for nursery

As encouraging results have been obtained from trials whereby slow release fertilizers (SRF) are used for manuring oil palm seedlings at the nursery and field planting. Among the SRF, Agroblen (17:8:9:3) and Apex Polyon (18:7:9+TE) showed good promise in promoting seedling growth. Nevertheless, due to the high material cost, the use of SRF is limited to large scale nursery that is experiencing acute labor shortage.

For the pre-nursery, SRF is applied at the rate of 5 g per bag during seed planting. The granules should be placed just below the seed. Otherwise at the main nursery, the SRF is applied at the rate of 50 g per bag to the planting hole during transplanting of oil palm seedlings from the pre-nursery to the main nursery. As trial result showed that the residual effect of the slow release fertilizer could normally last no longer than 7 months, application of Compound 25 as per the nursery manuring schedule from week 42 (after seed planting) should be adhered to. Polybag mulching with kernel shell or cyclone fibers or any plant organic matter is recommended.

Pest infestations and disease infections in oil palm nursery can result in total loss or destruction or retard the growth of seedlings. However, the pests and disease incidence are usually sporadic. Therefore, no prophylactic spraying is necessary in a well-managed nursery. All spraying equipment for use in the nursery must be clearly labelled and color coded. Separate equipment should be used for the spraying of herbicides, insecticides or fungicides. Equipment used elsewhere on the estate must also not be used in the nursery.

2.9 CROPWAT 8.0

CROPWAT is a FAO Land and Water Development Division decision support instrument. CROPWAT 8.0 is a soil, climate and crop data-based computer program for calculating crop water requirements and irrigation requirements. The program also enables irrigation schedules to be developed for various management conditions and water supply for different crop patterns. In addition, CROPWAT 8.0 can be used for the assessment and the estimation of crop performance in both irrigated and rain-fed conditions.

The two FAO publications of the Irrigation and Drainage Series which are, No. 56 "Crop Evapotranspiration - Guidelines for computing crop water requirements" and No. 33 titled "Yield response to water" are the basis of all calculation procedures for CROPWAT 8.0

CROPWAT 8.0 includes standard crop and soil data as a starting point and to be used only when local data are not available. These data files can be easily modified or new files can be created when local data is available. Also, if there's no local climatic data, it can be collected from CLIMWAT, the associated climatic database, for over 5,000 stations worldwide. The development of irrigation schedules in CROPWAT 8.0 is based on the daily balance between soil and water with different user-defined ways to supply and manage irrigation conditions. The supply of water is based on the user-defined crop pattern that can include up to 20 crops.

2.10 CLIMWAT 2.0

CLIMWAT is a climate-controlled database for use with the CROPWAT computer program. CLIMWAT 2.0 for CROPWAT is an international joint publication between the Water Development and Management Unit and the Climate Change and Bioenergy Unit of the FAO. CLIMWAT 2.0 is a publication of the FAO Water Development and Management unit.

CLIMWAT 2.0 offers agro-climatic data observed of more than 5,000 distributed stations worldwide. The long-term monthly mean value CLIMWAT provides a number of weather parameters. The data can be extracted in the format appropriate for use in CROPWAT for one or more stations. Each selected station is created with two files.

The first file contains monthly long-term [mm / month] precipitation data. Also calculated and included in the same file are effective precipitation. The second file contains the long-term averages for the seven above-mentioned climate parameters. This file also includes the location's coordinates and height. All station information is taken from the Agromet Group of the FAO database.

All variables are direct observations or conversions of observations, except possible evapotranspiration. Under the terms of CLIMWAT, original data from a large number of meteorological stations could not be uniform. For instance, different variables may be used to express humidity and radiation. Data can be provided as relative moisture, temperature of the point of dew or pressure of water vapour with regard to humidity. If the average temperature is known, these three variables can be converted into one another uniquely. However, the actual numbers would not necessarily be consistent if moisture was measured and given in more than one of these variables. In this case, the variable to use must be decided.

When CLIMWAT was compiled, water vapour pressure was decided on as a core variable and only use the temperature and relative humidity of the dew point if it is unavailable. However, given the average temperature, there is a risk that the value of the vapour pressure is higher than that available. This possible inconsistency was verified in the original databases and one of the other variables was used in few cases.

Thus, although vapour pressure and radiation are observed, the relative humidity, and the hours in the sun are often inferred. However, the procedure ensures consistency of the various expressions.

CHAPTER 3 METHODOLOGY

3.1 Introduction

This chapter basically explains on the research methodology adopted and implementations used in this study covering on how to determine the water footprint of oil palm fresh fruit bunches (FFB) which consist of blue, green and grey water footprint using the procedures and formulas. The work flow shown in Figure 3.1 illustrates the methodology to achieve the objectives of this study.

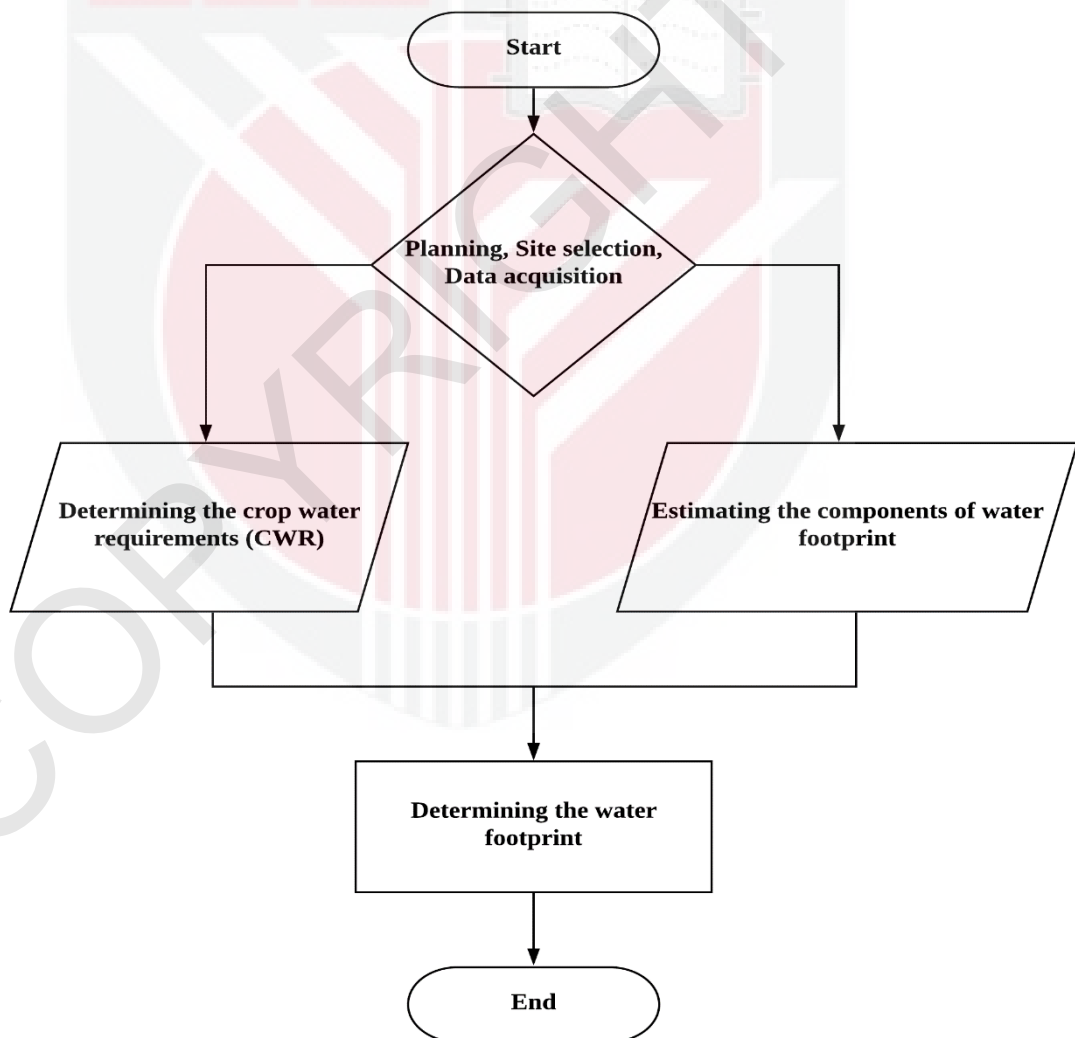


Figure 3.1: Work flow of the method applied.

3.2 Study area and site selection

In this study, there will be one oil palm nursery and plantation area that will be selected around Selangor to be tested and studied which the specific place is currently been discussed. From this study area, all the data about this study which related on oil palm production will be taken for processing in achieving all of the objectives.

3.3 Data Acquisition

Generally, crop productivity during the initial year of planting is low and the best production is usually after some years of planting. These variations were considered in the present study and therefore, the average annual yields were calculated for the selected areas of study. The activities involved foreground and background data collection. Data will be compiled from the field studies and various secondary data sources such as books, publications, reports, Department of Meteorology and Department of Irrigation and Drainage. Relevant data that considered all components and parameters pertinent to water use for oil palm will be identified.

Foreground data collection during site visit will be gathered by communicating with data providers and developing questionnaires. Site visits will then conducted as follow up for data verification. In this study, data on climate, soil, crop and irrigation will be included and these parameters can be calculated based on a decision support system called CROPWAT 8.0 Model developed by the Land and Water Development Division of FAO. This practical tool will be used to carry out standard calculations for evapotranspiration and

crop water use of this study, based on inputs of climatic and crop databases. Evapotranspiration rate will be determined using the Penman-Monteith method.

Parameters that had been used in order to determine the water footprint will be transferred to CROPWAT 8.0 software for other calculation in determining these water footprints. A statistical analysis was also used to estimate the rainfall deficit for irrigation water requirements based on long-term rainfall records. This analysis is important to determine part of the rainfall which effectively contributes to cover crop water requirements (CWR).

3.4 Calculation of water footprint

Calculation of the water footprint will be divided into two section which are water footprint during seedling which is at the nursery and water footprint of fresh fruit bunches of oil palm at plantation or in filed. During the nursery, there will be three different types of water footprint which are blue, green and grey water footprint. Blue water footprint can be divided into two types which are direct blue water footprint and indirect blue water footprint. For the water footprint at oil palm plantation, there are also three different water footprint which are blue, green and grey water footprint.

3.4.1 Water footprint of oil palm seedlings at nursery

This section covered the water footprint of oil palm seedlings beginning from the transportation of germinated seed to the nursery and ending with the transportation of 12-month old seedlings in big polybags to the plantation. The system boundary involving the production of pre-plantation inputs for the cultivation of oil palm seedlings in the nursery.

The total water footprint for production of oil palm seedlings is the sum of the blue, green and grey water footprint. Blue water footprint can be divided into two which are direct and indirect water. The water footprint (WF) of the oil palm seedlings growing process will be calculated by adding the direct water footprint of the individual and its indirect water footprint.

The direct water footprint refers to the water consumption and pollution that is related to water at nursery. The indirect water footprint refers to the water consumption and pollution of the water that can be associated with the production of the oil palm seedlings. Indirect water use will be based on data sourced from the Eco invent database.

The blue component in crop water use will be calculated by accumulation of daily evapotranspiration over the complete growing period. These formula was used to determine the evapotranspiration of the oil palm seedlings which are placed in small size polybag.

$$LPD = ET_{blue} * A_p \quad (1)$$

Where:

LPD = Rate of water volume intake to the polybag per plant per day (mm/day)

ET_{blue} = Blue water evapotranspiration (mm)

A_p = Area of the polybag (m²)

Then, the calculated ET will be multiplied by the total days at the nursery which are pre-nursery and main nursery.

$$CWR_{blue} = ET_{blue} * 10 \quad (2)$$

After that, crop water requirements, CWR blue will be calculated by multiplying ET blue with 10 where ET blue represents blue water evapotranspiration, the factor 10 was meant to convert water depths in millimeters into water volume per land surface stands for length of growing period in days. Later on, the CWR will be divided by Y represents crop yield which is seedlings per hectare to get the exact blue water footprint during nursery.

For achieving the components of green water footprint, accumulation of daily crop water requirements over complete growing period at the nursery will be taken:

$$Total\ CWR_{green} = [(q_{np} * N_d) + (q_{nm} * N_d)] * N_p \quad (3)$$

Where:

q_{np} = Volume of water intake per day per plant at pre-nursery (L)

q_{nm} = Volume of water intake per day per plant at main nursery (L)

N_d = Number of days

N_p = Number of oil palm seedlings per hectare

The total CWR is then divide by 1000 to convert from liter to m³. Then, the total CWR will be multiplied by factor 10 to find the CWR green.

$$CWR_{green} = Total\ CWR * 10 \quad (4)$$

The factor 10 was meant to convert water depth in millimeters into water volumes per land surface. Afterwards, the components of the green water footprint will be divided by total yield to get the green water footprint during nursery including pre-nursery and main nursery.

Grey water footprint will be calculated as the differences of green water footprint at nursery with the blue water footprint at the nursery. In this study, expression of all the processes for water footprint will be expressed in m³ water per ton FFB.

3.4.2 Water footprint of fresh fruit bunches (FFB) of oil palm at plantation

The total water footprint (expressed in m³/ton) of growing oil palm was calculated by summing the green, blue and grey components of water footprint. The green water footprint of growing oil palm refers to the volume of rainwater consumed and was calculated by dividing the green component in crop water use (m³/ha) by the crop yield (Y, ton/ha).

This calculation was also used to derive the blue water footprint (m³/ton) and it refers to the volume of surface water and groundwater consumed which assigned as accumulation of total evapotranspiration for complete growing period. The grey water footprint refers to the volume of freshwater that is required to assimilate the load of pollutants based on natural background concentrations and existing ambient water quality standards. This can be obtained by subtracting green water footprint with the blue water footprint. Components of blue water footprint was calculated by:

$$\sum_{d=1}^{1gp} ET * 10 \quad (5)$$

Where ET is multiplied by the ET_c which is determined by dry months or wet days before multiplied by factor 10 to convert millimeters to m³ per hectares. 1gp is stands for total days to require the fresh fruit bunches of oil palm. The results then will be divided by the total yield of the oil palm fresh fruit bunches (FFB) to get the blue water footprint during at the field.

Components of green water footprint was calculated by:

$$\Sigma \text{Rainfall} * 10$$

(6)

Where the rainfall data was obtained from the Department of Irrigation and Drainage. The result then will be divided by the total yield to get the green water footprint at the plantation. Grey water footprint was calculated by subtracting the green water with the blue water footprint.

3.5 Data analysis on water use management

By using the data that had been collected and calculated, the graph was constructed which shows rainfall distribution and crop water requirement over a period of time. From this graph, an analysis was made to encounter seasons which water supply is lower than the crop water use requirements and the preparation for the best management of water use of oil palm was made. Irrigation and other applications will be applied during the period which the oil palm is in insufficient water condition.

Besides that, graph on amount of three different water footprint which are blue, green and grey water footprint also was constructed. The green water was calculated from the volume of the water evaporated from global green water resources (rainwater stored in the soil as soil moisture). The blue water footprint is the volume of freshwater that evaporated from global blue water resource for example surface water which are from river, ponds and lakes and also ground water which underground water. While the grey water footprint is taken from the volume of polluted water that is associated with the production of all goods and the services. If there is high amount of green water footprint compared to blue and grey water footprint, then it is great for continuing the plantation of this crop in our nation.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Rainfall Distribution

For this study, the hydrological data which is the rainfall was collected from Department of Irrigation and Drainage and I chose the closest rainfall station to my study area which is at Kolam Takungan Sg. Merab. The rainfall data that had been acquired is from year 2009 until 2018. These are the charts on rainfall distribution from 2009 until 2018:

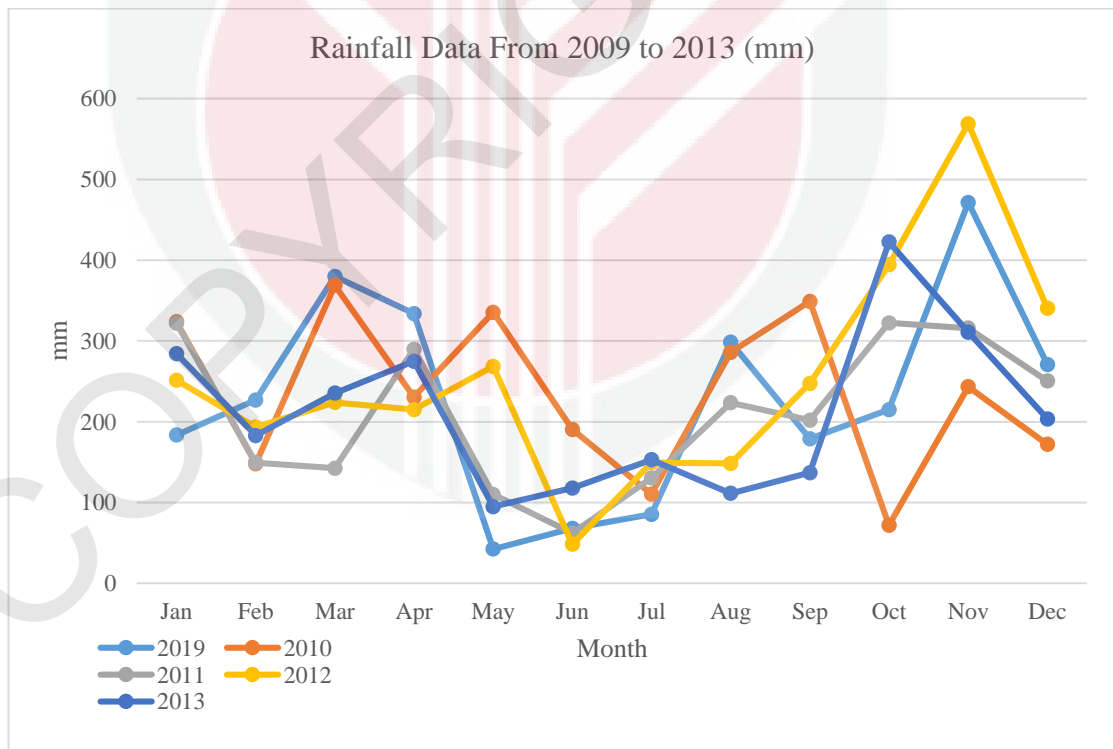


Figure 4.1 Rainfall at Kolam Takungan Sg. Merab from 2009 to 2013

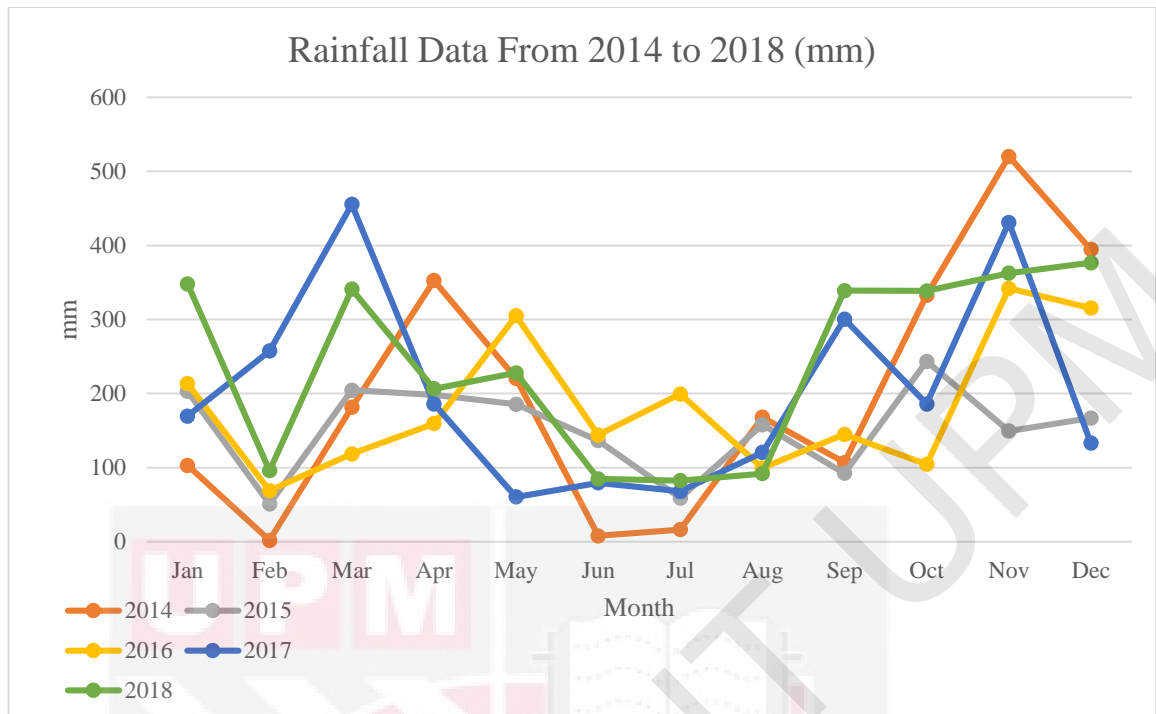


Figure 4.2 Rainfall at Kolam Takungan Sg. Merab from 2014 to 2018

From Figure 4.1, several months that had low rainfall which are below than 200mm and these months are February, May, June and July which can be conclude as dry months. For March, October, November and December, the rainfall is averagely more than 200mm per month and these months can be considered as the wet months.

While from Figure 4.2, the circulation of the rainfall is most likely which stated that on February, June, July and August is averagely below 200mm of rainfall per month. This happen due to the change of monsoon. For the wet months, March, October, November and December was considered as the wet months due to the rainfall which were averagely more than 200mm per month. From these two charts, the rainfall distribution pattern at Kolam Takungan Sg. Merab are in almost constant rate throughout the year.

From Figure 4.3, there are four months which the rainfall is lower than the evapotranspiration and these months are February, June, July and August. There will be water stress for the oil palm during these four months and it will affect the yield of the oil palm itself. This happened because oil palm is one of the agricultural crop that need adequate water supply for delivering high quality yield and high yield. In order to achieve enough water supply for the oil palm in these months, irrigation should be applied to the oil palm to overcome water stress during these months.

Moreover, for the remaining months, the amount of rainfall is higher than the amount of evapotranspiration. So, the water supply is efficient for the oil palm to produce high quality yield and irrigation does not require in these months due to high rainfall and it will not cause problems to the crops.

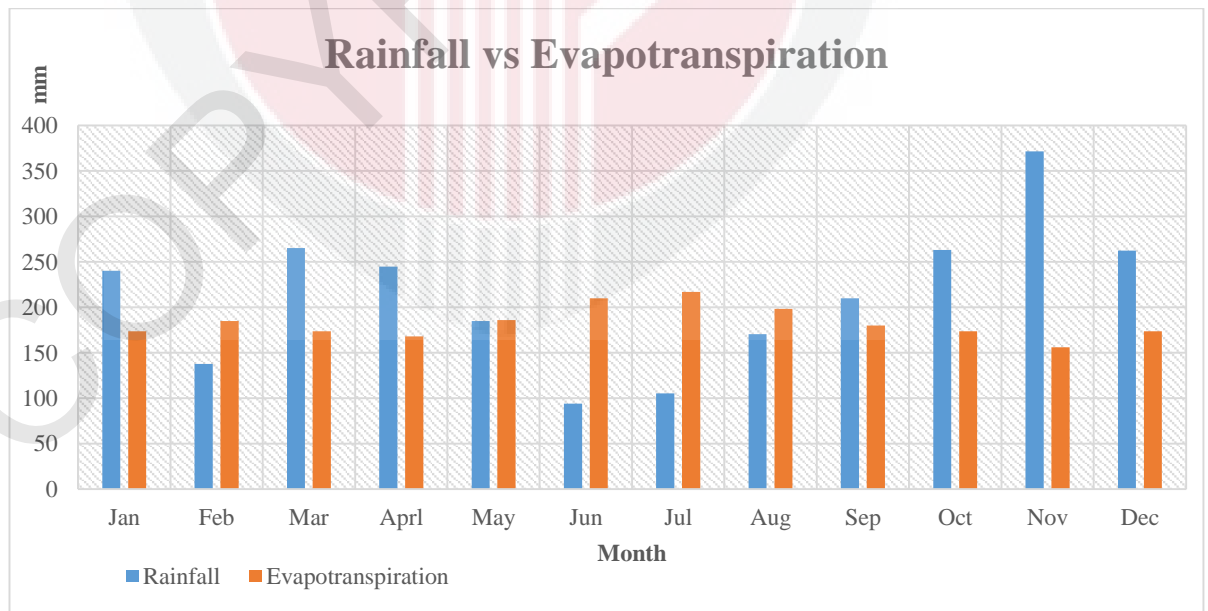


Figure 4.3 Average Monthly Rainfall and Evapotranspiration (mm)

4.2 Components of water footprint at Nursery

In this study, oil palm variety that had been planted is the tenera variety which is the cross hybrid from the dura variety and pisifera variety. The process of oil palm production started from the nursery which is the double stage nursery. Double stage nursery can be divided into two stages which are pre-nursery and main nursery. Duration of pre nursery stage is for three months before continuing the process to main nursery. For the polybag that had been used in the pre-nursery is the black ultraviolet-stabilized polyethene with a minimum of 250 gauge.

Table 4.1 Specifications of polybag used in pre-nursery

Lay flat dimension	15 cm wide, 23 cm deep
Perforations	5 mm at 5 cm interval to allow for drainage

After three months, the seedlings in the small polybags will be transplanting to the main nursery where the seedlings will be transplanted into a larger polybag. Duration for the main nursery took about nine months which completed a year at the nursery stage. The oil palm seedlings will be irrigated by the sprinkler throughout the entire process at the nursery. The volume rate for irrigating a plant at the pre nursery and main nursery are 0.5 liter per plant per day and 2.0 liter per plant per day.

For the components of water footprint at the nursery, the result was being calculated and concluded as below:

Table 4.2 Total Water Footprint (WF) of Fresh Fruit Bunches (FFB) production

Components of WF of FFB production ($\text{m}^3 \text{ ha}^{-1} \text{ FFB}$)			
Blue	Green	Grey	Total
6.93	94.96	88.03	189.919

From this result, we can conclude that components of water footprint of oil palm fresh fruit bunches which are green, grey and blue water footprint were 94.96, 88.03 and 6.9 $\text{m}^3 \text{ ha}^{-1}$. The blue and green components of water footprint were calculated by using the formula from equation 1 and 2.

4.3 Components of water footprint at plantation

After a complete year the oil palm seedlings at the nursery, the fully develop seedlings which are healthy and not damaged will be transferred to field or plantation. From this, it will take about three to four years for the oil palm to start producing yields. From figure 4.3, the total water footprint of oil palm fresh fruit bunches can be arranged in descending order from green water footprint, blue water footprint and grey water footprint which are 128.88, 112.59 and 0.22 m^3 per ton fresh fruit bunches. From this, we can conclude that the most water usage in the production of oil palm fresh fruit bunches is from green water. This happened because the production of oil palm fresh fruit bunches in Malaysia is only depend on rainfall for the oil palm usage. The irrigation method only been applied in the nursery stage which using the sprinkler.

For our country, Malaysia, we are lucky because the rainfall is adequate to act as the water resource to supply for the oil palm production. From this result, we can say that the oil palm plantation in Malaysia is suitable because of high amount of rainfall. For the water wastage which is the grey water, the amount is too little compared with other water footprint. For future, we might want to use this grey water as the water resource to supply the production of the oil palm due to the long drought season perhaps or due to water scarcity. However, the grey water must firstly be treated before been used as water supply. For suggestion, maybe the planters should build a dam or reservoir for grey water storage at the field so that the grey water does not wasted and polluted into the river, ponds and etc.

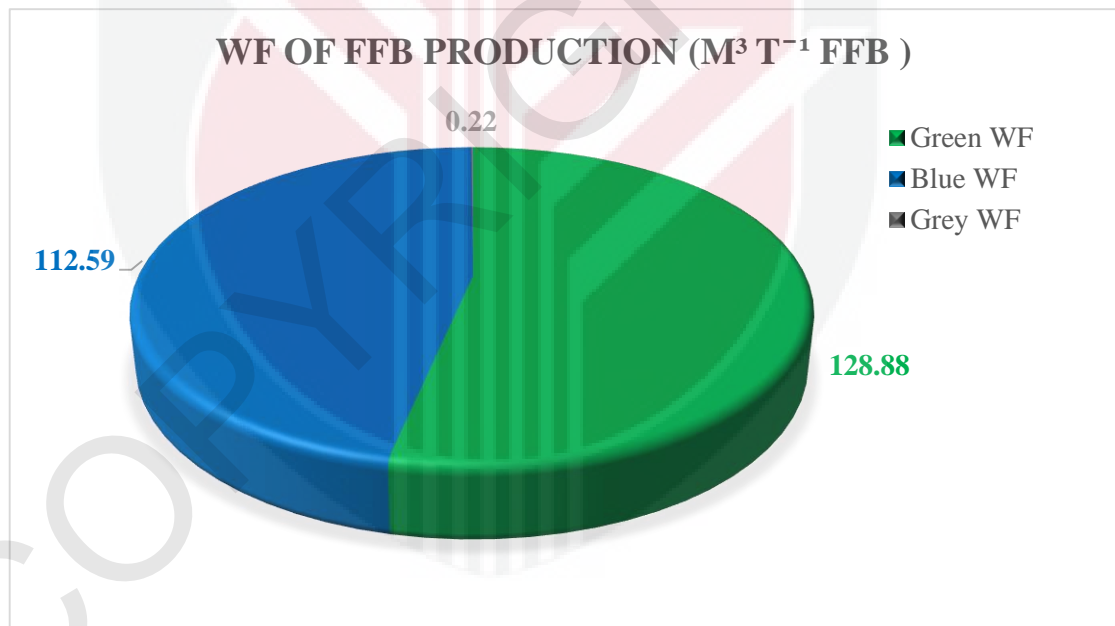


Figure 4.3 Total Water Footprint (WF) of Fresh Fruit Bunch (FFB) Production

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, the amount of water footprint of oil palm fresh fruit bunches that had been obtained in this study are 128.88 m³ t⁻¹ FFB for green WF followed by blue WF which is 112.59 m³ t⁻¹ FFB and 0.22 m³ t⁻¹ FFB for grey WF. Total WF that had been utilized in oil palm production is 241.69 m³ t⁻¹ FFB. The green WF which are the rainfall is the main water resource in the oil palm production. Nowadays water scarcity is the conflicts that happen in worldwide and this happened due to fill the requirement and needs for both biofuel stock and food production. However, in Malaysia, the rainfall is still sufficient to supply as the water resource in oil palm production.

The result and data that had been obtained in this study can slightly provide as a guidance to the other planters and also policy makers in context of planting the oil palm in Malaysia. With these, maybe the water management plan for producing oil palm FFB will be more sustainable in order to get high amount of yield and with quality.

Last but not least, the WF of oil palm FFB are different throughout the countries. This happened due to the variation of climate, weather, agricultural practices and lots of other factors that will affected the total yield of the crops.

5.2 Recommendations

In this section, there are some recommendations and suggestions that will be helpful to improve this study in future research. First of all, the suggestion to improve this study in future research is to widen the area of the site study. For example, in future research maybe the data that will be taken from all of the oil palm plantation throughout Malaysia or maybe throughout the states. This is because the variation of weather for example rainfall, humidity, wind and sunlight radiation is different throughout the country. When the WF of oil palm FFB is carried out for the whole plantations in the country, the result that had been obtained can be used as the references and guidance for all oil palm planters in Malaysia to improve the water management plan.

Besides that, the technic of approaching the water footprint also can be improved in further research. In addition, involving the availability of water as well as the pattern of water consumption in order to find the WF. This approach gives a better concept of possible water stress events. The volumes of water used and water availability in the study areas need to be quantified. This can be used to determine the impact of water consumption. Furthermore, the life cycle assessment (LCA), is one of the technique that can be used to link the consumption of water with the availability of water. Apart from that, this technique will provide more information about scarcity of water that could affect the environment and social.

REFERENCES

- Basri, M., 2010. LIFE CYCLE ASSESSMENT FOR OIL PALM FRESH FRUIT BUNCH PRODUCTION FROM CONTINUED LAND USE FOR OIL PALM PLANTED ON MINERAL SOIL (part 2).
- Carr, B.M.K. V, 2014. THE water relations and irrigation requirements of oil palm (Ealey's guineensis): A review THE WATER RELATIONS AND IRRIGATION REQUIREMENTS OF OIL PALM (ELAEIS GUINEENSIS):
- Choy Er, A., Begum, H., A Ferdous Alam, A.S., Er, A.C., 2005. Malaysian oil palm industry: Prospect and problem WFL Publisher Science and Technology Malaysian oil palm industry: Prospect and problem. Agric. Environ. 13, 143–148.
- Deficit, W., 2004. Water Deficit and Irrigation in Oil Palm: A Review of Recent Studies and Findings 49, 1–6.
- Department of Irrigation and Drainage (DID), 2018. Hydrological Standard for Rainfall Station Instrumentation.
- Egeskog, Y., Scheer, J., 2016. Life Cycle and Water Footprint Assessment of Palm Oil Biodiesel Production in Indonesia.
- Haasjes, Edwin, 2014. Sustainable water management on oil palm plantations on tropical peat lands. Comparing regulations with on field practices Water Resources Management group.
- Hasanudin, U., Setiadi, T., 2016. Sustainable Wastewater Management in Palm Oil Mills. Green Technol. Sustain. Water Manag. 955–973.
- Hashim, Z., Muhamad, H., Subramaniam, V., 2014. WATER FOOTPRINT: PART 2 - FFB PRODUCTION FOR OIL PALM PLANTED IN MALAYSIA 26.

- Hoekstra, A.Y., 2008. Water Neutral: Reducing and offsetting the impacts of water footprints. *Water* 117, 22–2
- Kamil, N.N., Omar, S.F., 2016. Climate Variability and its Impact on the Palm Oil Industry 16.
- Marlia, M.H., 2016. Water Footprint Assessment of Oil Palm in Malaysia: A Preliminary Study 803.
- Mekonnen, M.M., Hoekstra, A.Y., 2011. The green, blue and grey water footprint of crops and derived crop products 1577–1600.
- Mungkalasiri, J., Wisansuwannakorn, R., Paengjuntuek, W., 2015. Water Footprint Evaluation of Oil Palm Fresh Fruit Bunches in Pathumthani and Chonburi (Thailand) 6.
- Othman, H., Mohammed, A.T., Harun, M.H., Darus, F.M., Mos, M., 2010. Best management practices for oil palm planting on peat: optimum groundwater table. *MPOB Inf. Ser.*
- Paterson, R.R.M., 2018. Climate change affecting oil palm agronomy, and oil palm cultivation increasing climate change, require amelioration 452–461.
- Sasha, N.I.K., Khairuddin, K., May, C.Y., 2014. WATER FOOTPRINT: PART 1 - PRODUCTION OF OIL PALM SEEDLINGS IN PENINSULAR MALAYSIA 26, 273–281.
- Sigalingging, R., Sumono, Rahmansyah, N., 2018. Evapotranspiration and crop coefficient of oil palm (*Elaeis guineensis* Jacq.) on the main nursery in a greenhouse. *IOP Conf. Ser. Earth Environ. Sci.* 122, 0–4.
- Shiru, M.S., Shahid, S., Alias, N., Chung, E.S., 2018. Trend analysis of droughts during crop growing seasons of Nigeria. *Sustain.* 10, 1–13.
- Subramaniam, V., May, C.Y., Muhammad, H., Hashim, Z., Tan, Y.E.W.A.I., Wei, P.C., 2010. LIFE CYCLE ASSESSMENT OF THE PRODUCTION OF CRUDE PALM OIL (Part 3) 22, 895–903.

APPENDICES

Table 4.3 Rainfall distribution in year 2009 (mm)

Year 2009												
Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	17	16	38.5	10	0	6	0	1.5	46	0	1	1.5
2	4.5	27	0	0.5	1.5	8.5	1.5	0	0.5	0	16.5	1
3	4	25	15	0	0	0.5	0	0	0	0	0.5	17
4	0	0	0	5.5	0	0	0	0	18	0	3.5	3.5
5	0.5	0	4	3.5	0	0	0	32	10	0.5	12	3.5
6	15.5	0	1	33	0	0	0	0.5	0.5	0.5	2.5	2.5
7	1	0	3.5	0	0	0	0.5	0.5	0	20	19.5	0
8	21	0	0	0	0	2	0	2	0	0	0	4
9	14.5	0	1.5	8.5	0	0	0	0	3.5	0	6.5	0.5
10	0	0	0	7.5	0	0	0	41	0	0	18	0
11	0	0	42.5	54	0	0	0	0	9.5	1	0	0
12	0	0	18	56	0	2.5	0	74	4	1.5	8.5	0
13	1	0	14.5	19	26	13	0	12.5	0	9	1	0
14	0	0	89.5	70	0.5	0.5	19.5	0.5	0	0.5	1	15
15	1	0	0.5	0.5	0.5	0	0.5	0	6	0	26	44.5
16	0.5	0	7.5	0	0.5	0	0.5	34.5	0	0	26.5	11
17	0	21.5	9	0	4	0	0	3	17	23	4.5	12
18	0	0	1.5	0	1	0	0	12.5	32.5	0	75	6
19	0	0	1	37	0	0	0	0	3	13.5	0	7
20	0	0	1.5	30	1.5	2	0	34.5	7	44	79.5	3
21	6.5	44.5	0.5	0	0	1.5	30.5	0.5	16.5	0.5	17.5	0
22	0	43	0	0	0	0	1	1.5	0	4	0	0.5
23	0	5	16	0	0.5	0	0	7	0	0	6.5	7.5
24	0	2.5	67	0	1	0	0	0	0	0.5	14.5	1.5
25	6	0.5	1.5	0	0	0	10	0	0	0.5	0	0
26	0	35.5	0	0.5	0	29.5	0.5	10.5	0	0	0	109
27	0	1	0	0	3.5	0	0	29.5	0	0	48.5	4
28	51.5	5.5	20.5	0	0.5	0.5	20.5	0.5	2	5.5	66.5	0
29	3.5		15.5	0.5	0	1.5	0	0	3	11.5	0	7
30	2.5		10	0	0	0	0	0	0	75.5	16	9.5
31	33		0		1.5		0.5	0		3.5		0

Table 4.4 Rainfall distribution in year 2010 (mm)

Year 2010												
Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	18.5	9	0	33	23	5.5	13.5	0.5	8	0.5	0	0.5
2	12	0	0	9.5	0	0	2	0	10	5.5	2	0
3	27	4.5	0	0.5	0	0	0	24.5	0.5	7	0	0
4	0.5	5.5	0	0	1	4	1.5	0	3.5	2.5	0	30
5	6	11	4.5	4.5	1.5	0	0	0	5	17	0	1
6	3.5	1.5	11.5	9	10.5	0	0	0	6	0	1	26.5
7	0.5	0	3.5	0	5.5	3.5	19.5	24	1	0	0	0
8	4	0	44	1	12.5	0	0	7	83	11.5	1.5	31.5
9	1.5	0	25.5	29	64.5	3.5	0.5	0	3.5	0	4	1
10	9	8	5.5	8.5	0	0	1	0	0	0	0	0
11	0	0	0	9.5	25.5	3.5	0	0	0	0	20.5	0
12	9.5	0	0	0	4.5	22.5	0	0	18	0	4	0
13	0	0	43	30	0.5	0.5	0	56	1.5	0	0.5	8.5
14	0.5	0	26.5	0	0	11.5	25	0.5	0	0	5.5	0
15	0	0	3	0	0	0	0.5	3	0	0	13.5	3
16	20.5	0	21.5	6	26	0	2	61.5	0.5	0	0	5
17	0	10.5	0	46	0.5	1.5	0.5	21	22.5	0	0	5
18	2.5	1	0	13	53	0	5.5	70.5	98	0	0	0
19	39.5	0	0	0	0.5	0	0.5	2.5	4	0	31.5	3
20	58	0	0	13	48.5	0	3.5	0	0	0	0	2.5
21	8	6.5	64.5	9	3	0.5	0	0	7.5	0	0	3
22	39	84.5	2.5	0	0	3	0	4	2.5	3	0	43.5
23	7.5	4	0	2	0	0	0	0	2.5	5	0	0
24	0	0	0	0	0	1.5	0	0	44	3.5	0	3
25	0	1.5	13	0	0	16.5	9.5	0	19	7	43.5	1
26	1.5	0.5	6	0	7	32.5	0	0	3.5	0	0	1.5
27	0.5	0	0	3.5	0	0	0	0	4.5	0.5	17	0
28	22.5	0	0	0	16	0	0	5.5	0.5	2	4.5	2
29	1		13	4.5	18.5	4	0	0	0	2.5	54.5	0
30	26		16	0	4	76.5	25.5	0	0	4	40	0.5
31	5		65.5		9.5		0	5.5		0.5		0

Table 4.5 Rainfall distribution in year 2011 (mm)

Year 2011												
Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0.5	1	22	0	0	0	0	0	31.5	5.5
2	1	0	18.5	0.5	4.5	0	1.5	0	0	0	4.5	44.5
3	7.5	0.5	0	5.5	5.5	0	0	8	0	3	15	0
4	112	0	0.5	0	0	0.5	0	20.5	0	7.5	0.5	31.5
5	34.5	16	0	0	0	1.5	0	0.5	0	16.5	0	0
6	2	0	0	0	0	0	0	0	0	0.5	0.5	0
7	0	0	22	6.5	0	0.5	0	3	0.5	5	1.5	8.5
8	0	0	0	0	0	3.5	0	0	0	0	1	2
9	0	0	8	1.5	0	0	0	0	9.5	0	0	0
10	22	0	0	7.5	0	0	0.5	2	43	0	0	0
11	0	0	8.5	2	2	0	0	0	0.5	0.5	0	5
12	1.5	10	4	54	27	0	0	27	0	0	4.5	0
13	22.5	15.5	0	16	3	0	0	10.5	0	0	58.5	12
14	2.5	17	0	0.5	0	0	8.5	2	46.5	0	1.5	0
15	26	6.5	0.5	24	0	0	34	0	5	34.5	6.5	1
16	0	7.5	0	1	13.5	0	0	0	5	17	18	4.5
17	0	0	2.5	1	4	0	0	0	5	0	27	4
18	4.5	0	2.5	0	3.5	0	0	0	19.5	3	0.5	0
19	0	0	3	2.5	6	0	0	3.5	15.5	70	5	27.5
20	0	1.5	10.5	34	4	0	0	5	1	16.5	34	31
21	0	0	10	12	1	0	0.5	1.5	6	27.5	1.5	1
22	0	3.5	7	0	3.5	11.5	0	31.5	0	0	16.5	2.5
23	20.5	0	4	3	0	0	0	21.5	0	0	0	22
24	10.5	2.5	3	18	0	2.5	0.5	10	0	13	0	5.5
25	0	20	0	0	0	2	0	0	0	47	0.5	0
26	1.5	32.5	0	40	0	18	0.5	61.5	45	34.5	17	0
27	0	3	0	5.5	10.5	1	0	0	0	1	22.5	21
28	0.5	13.5	0	54	0	0	77.5	15.5	0	0.5	0.5	15.5
29	10.5		37.5	1.5	0	21	6.5	0	0	0	47	0
30	42		0	0	0	0	0.5	0	0	9	0.5	6
31	0.5		0		0		0	0		16		0

Table 4.6 Rainfall distribution in year 2012 (mm)

Year 2012												
Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0	11	53	0	0	0	0	0	29	3.5
2	0	3.5	10	1.5	91.5	0	8.5	0.5	1	0	16.5	2.5
3	0	14.5	4	30	0	0	48.5	0.5	0	0	47.5	59
4	0	0	0	0	36.5	0	3.5	0	21.5	1	22	1
5	0	0	0	0	2.5	17	1	0	1	0	27	1
6	0.5	5.5	0.5	0	24	0	0	0	0	1.5	4	5.5
7	0	36.5	104.5	0	0.5	1	0	0	0	3	0	32
8	0	1	10.5	54	0	0.5	0	0	1	0.5	26.5	0
9	0	0	0	6.5	0	1	0.5	0	19	0	70.5	102.5
10	6.5	0	0.5	0	0.5	0	0.5	0	0	21.5	48	12.5
11	27	0	1	0	0.5	0	0	0	23	1	2	2.5
12	0.5	5.5	0.5	0	0	0	11.5	3.5	2	69	24	7
13	37	1.5	0.5	0	0	0	0	0.5	2	26.5	21.5	2.5
14	0	0	0.5	0.5	0	0	0	0	0	0	2.5	0
15	0	5.5	8	36	0	0	0	0.5	55.5	0.5	0	0
16	0	0	5.5	0	5	0	0	17.5	5	29	6.5	31.5
17	0	0	0	0	0	1.5	2.5	2	0	7	5	12
18	8	21.5	0	24	0	0	12	0	0	27.5	12.5	19.5
19	17	0	8	4.5	0	0	10	18.5	0.5	47.5	2.5	0.5
20	2.5	12	0	18	2.5	0	0.5	9	0	0	0	4.5
21	26	32.5	0	0	2.5	10.5	0	0.5	58.5	29.5	0	5.5
22	1	0	0	0	27	0	0	0	0	0	26	0
23	54	0	3	0.5	1	0	30.5	0	16	1.5	13	0
24	29	5	0	1	7	0.5	0	34	0	0	2.5	0.5
25	15	0	0	0	0	0	0	0.5	21.5	47	2	0
26	0	32.5	6	29	0	7	0	36.5	8.5	0.5	12.5	0
27	0	0	5.5	0	0	9.5	0	9.5	0	13	12	1.5
28	26	15.5	0.5	0	0	0	0	15	0	0	121.5	28.5
29	0.5	1	53	0	0	0	0	0	11.5	0	1	5
30	3		1	0	12.5	0	12	0	0	17.5	11	0
31	0		1		2		8	0		50		0

Table 4.7 Rainfall distribution in year 2013 (mm)

Year 2013												
Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.5	1	0	0	1	0	0	0.5	3	0	7	1
2	47.5	0	0	4.5	0	0	14	0	2.5	0	1.5	19.5
3	0	1.5	2	0.5	0	0	0	0	19.5	2	6	8.5
4	51	13.5	0	0	0	23.5	21.5	0	1	21.5	0	0
5	2	0.5	0	0.5	2	70	0	0	0	14.5	1	4.5
6	0	45	0	3.5	7	2	0	0	0	1	0	3.5
7	1.5	29	0.5	0	59	3	0	31	35	0	1.5	0.5
8	0	0.5	3.5	0	0.5	0	0	0	11.5	20.5	30	0
9	0.5	0	0.5	3.5	0	0.5	11.5	0	4	0	0.5	0
10	0	0	9	47	0	0	13	0	0	121	15.5	20
11	12	0	37.5	24	0	0	1.5	0.5	41.5	0	0	2.5
12	2.5	0	10.5	0	0	0	2	16.5	0	10	11	1.5
13	16	1	18	0.5	0	0	17.5	0.5	0	0	3.5	0
14	0	4	13.5	0	0	0	0	0	2.5	0	63	14
15	5.5	0	0	0	1.5	0	0	1	0	0	0.5	0
16	0.5	0	23.5	0	0	0	15.5	0.5	0	0	64	0
17	0	0	0.5	0	1	0	5	0.5	9.5	0	0	0
18	14	17.5	0.5	0	0	0	0	0.5	0.5	74	4	0
19	0	0.5	0	10	0	0	0	19	0	1	20	36.5
20	25.5	0	0	13	0	0	0	0	0	11.5	2	7
21	1	3	6	1	0	0	0	1.5	0	8	0.5	0.5
22	0	0.5	19	11	0	0	0	5	0	1	1	0
23	51	3	0	4	0	0	0	0	6	18.5	0	69.5
24	44	8	0.5	48	15.5	0	9.5	0	0.5	0	0	1.5
25	7.5	1	51	35	0	18.5	0	0	0	0	12.5	0
26	0	38.5	0	11	0	0.5	41.5	0	0	0	0	9
27	0.5	12.5	2.5	32	1	0	0	0	0	23	55	3.5
28	1.5	2.5	4.5	0	1	0	0	0	0	8.5	4.5	0
29	0		12.5	27	4	0	0.5	0	0	0	4.5	0.5
30	0		17.5	1	1.5	0	0	10.5	0	45.5	2	0
31	0		2.5		0		0	24		41		0

Table 4.8 Rainfall distribution in year 20014 (mm)

Year 2014												
Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0	0	0	0	0	0	0	0	7.5	0
2	0	0	2	10	0	1.5	0	0	0	20	5	0
3	53	0	8.5	28	0	0	0	0	1.5	2	0	13.5
4	2.5	0	0	33	0	5.5	4	0	0	23.5	0	0.5
5	11.5	0	0	3.5	17	0.5	0	0	1.5	0	83	0
6	12.5	0	0	0	0	0	0	0.5	0	0.5	48.5	4
7	12	0	0	1.5	36.5	0	4	0	0	0	8	1
8	2	0	0	4	36.5	0	0	2	0	0	8.5	8.5
9	3	0	0	37	0	0	1	0	9.5	0	0	0.5
10	0	1	0	7.5	6	0	0.5	19.5	0	0	24.5	31.5
11	0	0	0	19	1.5	0	4	3	0	0	1	57.5
12	5	0	1	0	6.5	0	0	8	3	24	5	0.5
13	1	1	0	0	0	0	0	5	0.5	15.5	8.5	0.5
14	0.5	0	0	8	9.5	0	0	2	15.5	4.5	34	3
15	0	0	0.5	15	5.5	0	0	0	0	1	23.5	3.5
16	0	0	12.5	0.5	0	0	0	0	0	1	6	0
17	0	0	2	0	0	0	0	0	0	3	0	10
18	0	0	20.5	0.5	0	0	0	0	0.5	43.5	0	0
19	0	0	1.5	9	8	0	0	52.5	0.5	0	0	0
20	0	0	49	11	30	0	0	4.5	37	0	0	50
21	0	0	0	21	20	0	0	0	0	18.5	16	57
22	0	0	0	49	2.5	0	0	0	0	33.5	11.5	51
23	0	0	0	59	0.5	0	0	60.5	0	0	41.5	28.5
24	0	0	0	12	12.5	0	1	0	0	10.5	34	1.5
25	0	0	0	0	0.5	0	0	9	2.5	0	35	1
26	0	0	4.5	7	10	0	0	0	0.5	10.5	28	10
27	0	0	0	16	4	0	0	0	31.5	62	33	11.5
28	0	0	67.5	4	0	0.5	0	1.5	0	9	41.5	36
29	0		1.5	0	1.5	0	2	0	0	46	12	12.5
30	0		0	0.5	11.5	0	0	0	3	2.5	4.5	0
31	0		10.5		0.5		0	0		2		1

Table 4.9 Rainfall distribution in year 2015 (mm)

Year 2015												
Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0.5	17	2	44	0	19	0	10.5	40	0.5
2	9	0	0	3	6.5	34	0	1	0	0	17.5	0
3	3	0	0.5	3	12.5	0	14	6	0	0	55.5	1
4	0	0	0	3	29	1.5	0	0	1.5	0	0	0.5
5	0	0	48	2.5	15.5	0	0	0	2	0	0	1
6	22.5	0	0.5	7.5	0.5	0	0.5	27.5	0.5	33.5	0.5	0.5
7	30.5	0	53.5	6.5	0	9.5	0	3.5	2	48.5	15.5	1
8	18.5	0	35	0.5	25	0.5	0	0	9.5	0	1.5	0
9	0.5	2	28	0	0	0	0	0	0.5	0	1	38
10	0	0	5	0	0	6.5	1.5	4	0.5	2	1	0
11	6	0	0	41	0	5.5	0	78	0	0	1	9
12	0	0	0	2	79.5	13.5	0	0.5	0	51.5	1	7.5
13	0	43	0	0	0.5	2	0	0.5	0	0	1	65.5
14	0	0	0	0	1	5	0	0	0	0	1.5	2
15	0	0	0	0	0	1.5	0	5.5	2.5	0	1	1
16	0	0	0	0	0	0	8.5	1.5	0.5	0	1.5	0.5
17	1.5	0	0	2.5	4	0.5	0	0.5	6	0	1	0
18	0	3	0	0	0	0	0.5	0	0	0	1	0
19	0	0.5	3	0	0	0	4	0	2.5	0	1	17.5
20	0	0	0	0	0	0	0	0	1	0	1	0
21	20.5	0	6	5	5	0	0.5	0	14	0	1	0
22	4	0	1.5	25	0	9	0.5	0	40.5	0	1	3.5
23	1	0	0	5	0	0	0	0	0	0	0.5	0.5
24	0	0	0	12	0	0	4	3	4.5	0	1	0.5
25	0	1	0	1.5	1.5	3.5	15.5	0	0	6.5	0.5	11.5
26	20	1	0	20	0	0	0	0.5	0	10.5	0.5	0
27	14.5	0.5	0	34	0.5	0	9	0	0	17	0.5	4.5
28	6.5	0	23	6.5	2.5	0	0	0	0.5	1.5	0.5	0.5
29	0	0	0	0	0	0	0	0	2.5	27.5	0	0
30	34	0	0	2.5	0	0	0	5.5	1.5	8	0.5	0
31	11	0	0	0	0	0	0.5	1.5	0	26.5	0	0.5

Table 4.10 Rainfall distribution in year 2016 (mm)

Year 2016												
Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.5	0	0	0	2	0.5	0	0	14.5	0	0	66
2	0	0	0	0	27.5	0.5	0	0	0	0	1	40.5
3	13.5	8	0	0	0	0	0	0	1	0	0	1.5
4	3.5	4.5	1.5	27	5.5	0.5	0	2.5	0	0	0	0
5	4	4.5	0.5	1	12	0	1	0	0	10.5	0.5	0
6	6.5	20.5	0.5	0	4.5	0	0	0	24	13.5	0.5	0
7	0	2	0.5	0	96.5	0	1.5	0	4.5	11.5	9	0
8	0	0	0	0	3	0.5	0	0	19.5	0	0.5	12
9	0	0	0.5	0	7.5	0	0	0	4.5	4.5	40.5	1
10	0	0	17.5	6	49	0.5	0	0	9.5	1	8.5	18
11	0	1.5	1	2.5	31.5	0	0	1.5	13.5	0	13.5	21
12	6.5	0	0	0	3.5	0	0	4	10.5	0	5.5	2
13	1	0	36.5	0	0	0.5	0	0	0	0	57.5	0.5
14	3	0	0	0	18	10	0.5	0	0.5	10	0.5	11
15	11	0	18.5	0	24.5	0.5	20.5	0	13.5	0	0	0
16	0	0	0	1	1	47.5	20.5	0	2	14	2.5	0
17	36	0	0	1.5	0	3.5	30	3.5	0	0	22.5	1
18	14.5	0	1	0	0	0	12	1	1	0.5	53.5	0
19	0	0.5	0	0	0	79.5	0	14	0	0.5	0	10
20	0	18.5	36.5	0	10.5	0	5.5	0	3	0	0	8.5
21	0	0	0	0	5.5	0	38.5	0.5	6.5	0	0	0
22	0.5	0	1	0.5	0.5	0	1	0	0	0	12	59.5
23	35.5	0.5	0	0	0.5	0	35.5	42.5	0	0	0	0
24	0	0	3	58	0.5	0	12	0	0	0	1	1
25	0	0	0	1	0	0	0	0	0	7.5	0.5	2.5
26	0	0	0	1.5	0.5	0	0.5	0	0	0.5	29.5	30
27	0	0	0	1	0	0	0	0	4.5	6.5	14.5	21.5
28	46.5	7.5	0	8.5	0.5	0	0	0	11.5	4	68.5	0
29	2	1	0	23	0	0	0	8.5	0	4	0	0
30	0.5		0	29	0.5	0	17.5	19	1	14.5	0	0
31	28.5		0		0		3	2.5		1.5		8

Table 4.11 Rainfall distribution in year 2017 (mm)

Year 2017												
Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	16.5	0	0.5	16	1	19	0.5	13.5	0	0	3	1
2	8	0	4	2.5	1	0.5	0	4	99.5	0	2	0
3	15	0	2	3.5	1.5	0.5	1	0.5	4.5	0	7	12.5
4	0	0	0	7	0	0	1	41	0	2	8.5	0
5	0	3.5	16	0	0	0	0	0.5	21.5	0	6	0
6	2.5	0	54	0	0	0	0.5	0	0.5	19.5	36.5	0
7	0	44.5	5.5	3	10	0.5	0.5	0	0	16.5	1	4
8	0	0	18.5	40	4.5	10	0	1	0	0	3.5	0
9	0	0	19.5	8	0	0	0	1.5	13.5	0	31.5	0
10	0	27	0	0	3	0	0	0	0	0	45	1.5
11	0	0	0	0	7	0	33	12.5	8.5	0	0.5	0.5
12	0	0	21.5	0	0	0	0	4	0	27.5	0	0
13	0	4	1.5	0	1.5	4.5	15.5	0	2.5	25	3	0.5
14	0	0	0.5	20	1	0	15.5	6.5	12	8	13.5	0
15	8.5	4.5	0	32	0	22.5	0	5.5	4	0	62.5	0
16	2	0	0.5	1.5	0	1	0	0	0	0	93	0
17	9	0	3.5	0	0	5	0	0.5	18	0	0	0
18	0.5	0	68.5	0	4	0	0	0	11.5	12	13.5	44
19	4	6	17	38	2.5	1.5	0	3.5	63	0	0.5	0
20	0	2	14.5	2.5	0	0	0	0	29.5	0	0.5	1
21	0	21.5	0.5	2	0	0	0	0	0	0	2	10
22	0.5	0	13	2	0	0.5	0	0	0	0	2.5	6
23	20.5	38	34.5	1.5	0	0	0.5	0	0	0	17	0.5
24	25.5	75	18.5	1.5	0	1	0	0	0	0	11	0
25	10	23	53	1	0	6	0	1.5	0.5	0	1	20.5
26	4.5	0	6.5	1.5	0	1.5	0	15	0	0.5	34.5	0
27	4	4.5	2	1	18.5	2	0	0	0	31	14	0
28	1	4	73	1	2.5	1.5	0	2	11	0.5	0.5	25.5
29	0		6.5	1	1.5	1.5	0	7	0	20.5	17	3
30	37.5		0.5	1	1	0.5	0	0	0.5	21.5	0.5	2.5
31	0		0		0		0	0.5		1.5		0

Table 4.12 Rainfall distribution in year 2018 (mm)

Year 2018												
Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	27.5	1.5	6	0	1.5	4	39.5	1.5	49	19.5	3	12.5
2	0.5	0	0	1	0	0	0	0	0.5	35	34	7
3	0	0	32	0.5	11.5	0	0	0	6.5	12.5	21.5	4.5
4	1.5	0	39	0	24	0	0	0	0	37.5	37	12.5
5	1.5	0	1	0	1.5	0	0.5	0	26.5	0	2.5	0
6	0	0	4	31	0	1	0	0	18.5	7.5	0	7.5
7	1	4	0	0.5	0	0	0	0	28.5	18	85	12
8	5.5	0	3	0	0	0	0.5	0	13.5	33.5	3.5	0.5
9	5	0	0.5	0	0	0	13.5	0	7.5	9.5	2.5	42
10	15	0	0	0	3	0	0	0	1	11	0	1
11	17	0	0	0	0	0	0	0	6.5	42.5	9.5	60
12	4.5	0	45.5	0.5	21.5	0	0	0	6	2.5	10	3
13	0.5	0	0	7.5	0.5	17.5	0	1	0	7	60	0
14	0	0	2.5	0	5.5	0	0	0	7.5	1	11.5	17.5
15	3.5	0	0	31	1.5	0	0	0	1.5	0	0	48.5
16	0	0	0	19	2	0	0	0	9	0.5	0	24
17	3	11	0	1	0	11.5	5	4.5	20	0	0	7
18	44.5	0	4	33	2.5	7	0.5	0	2	3.5	0.5	30
19	79	0	38.5	31	21.5	0	0	0	15.5	0	1	0
20	0.5	0	38	3.5	0	0	0	0	8	0	7.5	0
21	6	3	0	19	0	0.5	0	0	63.5	0	0.5	12
22	0	0	0	9	59	11	0	8	3.5	9	2.5	20
23	6	68	0	0	1.5	13	0	0	8	23	5	12
24	31.5	0	0	0	0	1	0	11	0	0.5	0	0
25	27.5	0	0	6	5.5	3	0	0	0	0	0	11.5
26	12	0	91.5	0	18	0	0	0.5	3	2.5	15	17.5
27	0	0	8.5	10	0	0	0	1	33	21	1	0.5
28	8	8.5	0	0	0.5	9	2	61.5	0.5	0	42.5	0
29	3.5		0	4	40	3	10.5	3	0	0.5	7	0
30	0.5		27	0	3	3.5	4.5	0	0	3	0	0
31	43		0		4		6	0		38		13.5

Table 4.13 Total rainfall distribution from year 2009 to 2018 (mm)

RF (mm)											
Month	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	AVG
Jan	183.5	324	322	251.5	284.5	103	203	213.5	169.5	348	240.25
Feb	227	148	149.5	193.5	183	2	51	69	257.5	96	137.65
Mar	380	369	142.5	224	235.5	181.5	204.5	118.5	455.5	341	265.2
April	334	230.5	290	215	275	352.5	198	159.5	186	206.5	244.7
May	42.5	335.5	110	268.5	95	220.5	185.5	305	60.5	228	185.1
Jun	68	190.5	62	48.5	118	8	136.5	144	79.5	85	94
Jul	85.5	110.5	130.5	149.5	153	16.5	59	199.5	68	82.5	105.45
Aug	298.5	286	223.5	148.5	111.5	168	158	99.5	120.5	92	170.6
Sep	179	349	202	247.5	137	107	92.5	145	300.5	339	209.85
Oct	215	72	322.5	394.5	422.5	333	243.5	104.5	186	338.5	263.2
Nov	471.5	243.5	316	569	311	520	149.5	342	431	362.5	371.6
Dec	271	172	250.5	340.5	203.5	394.5	167	315.5	133	376.5	262.4

Table 4.14 Classification of dry and wet months from year 2009 to 2018 (mm)

Month	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Jan	Dry	Wet	Wet	Wet	Wet	Dry	Wet	Wet	Dry	Wet
Feb	Wet	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Wet	Dry
Mar	Wet	Wet	Dry	Wet	Wet	Dry	Wet	Dry	Wet	Wet
April	Wet	Wet	Wet	Wet	Wet	Wet	Dry	Dry	Dry	Wet
May	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Jun	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
Jul	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
Aug	Wet	Wet	Wet	Dry	Dry	Dry	Dry	Dry	Dry	Dry
Sep	Dry	Wet	Wet	Wet	Dry	Dry	Dry	Dry	Wet	Wet
Oct	Wet	Dry	Wet	Wet	Wet	Wet	Wet	Dry	Dry	Wet
Nov	Wet	Wet	Wet	Wet	Wet	Wet	Dry	Wet	Wet	Wet
Dec	Wet	Dry	Wet	Wet	Wet	Wet	Dry	Wet	Dry	Wet

Table 4.15 Monthly evapotranspiration (ET) from year 2009 to 2018

ET (mm)											
Month	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	AVG
Jan	217	155	155	155	155	217	155	155	217	155	173.6
Feb	140	196	196	196	196	196	196	196	140	196	184.8
Mar	155	155	217	155	155	217	155	217	155	155	173.6
April	150	150	150	150	150	150	210	210	210	150	168
May	217	155	217	155	217	155	217	155	217	155	186
Jun	210	210	210	210	210	210	210	210	210	210	210
Jul	217	217	217	217	217	217	217	217	217	217	217
Aug	155	155	155	217	217	217	217	217	217	217	198.4
Sep	210	150	150	150	210	210	210	210	150	150	180
Oct	155	217	155	155	155	155	155	217	217	155	173.6
Nov	150	150	150	150	150	150	210	150	150	150	156
Dec	155	217	155	155	155	155	217	155	217	155	173.6

Table 4.16 Green water footprint (WF) from year 2009 to 2018 (m³/ha)

Green WF (m ³ /ha)											
Month	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	AVG
Jan	1835	3240	3220	2515	2845	1030	2030	2135	1695	2200	2274.5
Feb	2270	1480	1495	1935	1830	20	510	690	2575	960	1376.5
Mar	3800	3690	1425	2240	2355	1815	2045	1185	4555	3410	2652
April	3340	2305	2900	2150	2750	3525	1980	1595	1860	2065	2447
May	425	3355	1100	2685	950	2205	1855	3050	605	2280	1851
Jun	680	1905	620	485	1180	80	1365	1440	795	850	940
Jul	855	1105	1305	1495	1530	165	590	1995	680	825	1054.5
Aug	2985	2860	2235	1485	1115	1680	1580	995	1205	920	1706
Sep	1790	3490	2020	2475	1370	1070	925	1450	3005	3390	2098.5
Oct	2150	720	3225	3945	4225	3330	2435	1045	1860	3385	2632
Nov	4715	2435	3160	5690	3110	5200	1495	3420	4310	3625	3716
Dec	2710	1720	2505	3405	2035	3945	1670	3155	1330	3765	2624
Sum	27555	28305	25210	30505	25295	24065	18480	22155	24475	27675	25372
Yield	0	0	0	14.9	15.3	16.3	16.9	16.3	16.5	16.9	16.15714
WFgreen				2047.315	1653.268	1476.38	1093.491	1359.202	1483.333	1637.574	1535.795

Table 4.17 Grey water footprint (WF) from year 2009 to 2018 (m³/ha)

Grey WF											
Month	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	AVG
Jan	-335	1690	1670	965	1295	-1140	480	585	-475	650	538.5
Feb	870	-480	-465	-25	-130	-1940	-1450	-1270	1175	-1000	-471.5
Mar	2250	2140	-745	690	805	-355	495	-985	3005	1860	916
April	1840	805	1400	650	1250	2025	-120	-505	-240	565	767
May	-1745	1805	-1070	1135	-1220	655	-315	1500	-1565	730	-9
Jun	-1420	-195	-1480	-1615	-920	-2020	-735	-660	-1305	-1250	-1160
Jul	-1315	-1065	-865	-675	-640	-2005	-1580	-175	-1490	-1345	-1115.5
Aug	1435	1310	685	-685	-1055	-490	-590	-1175	-965	-1250	-278
Sep	-310	1990	520	975	-730	-1030	-1175	-650	1505	1890	298.5
Oct	600	-1450	1675	2395	2675	1780	885	-1125	-310	1835	896
Nov	3215	935	1660	4190	1610	3700	-605	1920	2810	2125	2156
Dec	1160	-450	955	1855	485	2395	-500	1605	-840	2215	888
Sum	6245	7035	3940	9855	3425	1575	-5210	-935	1305	7025	3426
Yield	0	0	0	14.9	15.3	16.3	16.9	16.3	16.5	16.9	16.15714
WFgrey				661.4094	223.8562	96.62577	-308.284	-57.362	79.09091	415.6805	158.7167

Table 4.18 Blue water footprint (WF) from year 2009 to 2018 (m³/ha)

Blue WF											
ET (m ³ /ha)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Average
Jan	2170	1550	1550	1550	1550	2170	1550	1550	2170	1550	1736
Feb	1400	1960	1960	1960	1960	1960	1960	1960	1400	1960	1848
Mar	1550	1550	2170	1550	1550	2170	1550	2170	1550	1550	1736
April	1500	1500	1500	1500	1500	1500	2100	2100	2100	1500	1680
May	2170	1550	2170	1550	2170	1550	2170	1550	2170	1550	1860
Jun	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100
Jul	2170	2170	2170	2170	2170	2170	2170	2170	2170	2170	2170
Aug	1550	1550	1550	2170	2170	2170	2170	2170	2170	2170	1984
Sep	2100	1500	1500	1500	2100	2100	2100	2100	1500	1500	1800
Oct	1550	2170	1550	1550	1550	1550	1550	2170	2170	1550	1736
Nov	1500	1500	1500	1500	1500	1500	2100	1500	1500	1500	1560
Dec	1550	2170	1550	1550	1550	1550	2170	1550	2170	1550	1736
Sum	21310	21270	21270	20650	21870	25000	23690	23090	23170	20650	22197
Yield	0	0	0	14.9	15.3	16.3	16.9	16.3	16.5	16.9	11.31
WF_{blue}				1385.906	1429.412	1533.742	1401.775	1416.564	1404.242	1221.893	1399.077