COLLEGE OF AGRICULTURE ANIMALS SCIENCE AND VETERINARY MEDICINE

SCHOOL OF AGRICULTURE ENGINEERING (SAE)

MASTERS OF SOIL AND WATER ENGINEERING

THE ASSESSMENT OF RICE IRRIGATION WATER USE EFFICIENCY AT RWANGINGO MARSHLAND

THESIS

Submitted by

SURWUMWE Alphonse

FOR THE COMPLETION OF THE REQUIREMENTS FOR THE HONOR DEGREE OF MASTERS OF SCIENCE IN AGRICULTURAL ENGINEERING WITH SPECIALIZATION IN SOIL AND WATER ENGINEERING

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DECLARATION

I, **SURWUMWE Alphonse** declare thesis titled '**'the assessment of rice irrigation water use efficiency at Rwangingo marshland** '' is my personal and original work, I havesubmitted this thesis to the University of Rwanda, in realization of the requirements for the honor of the Degree of Master of Science in agriculture engineering with specialization in Soil and Water Engineering. It has never been presented in any university or, other higher institution of learning for the Award degree of masters of Scienceand that all the sources of information here in contained have been properly acknowledged.

SURWUMWE Alphonse

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Date: 13/08/2022

CERTIFICATE

This is to certify, this thesis title **’’the assessment of rice irrigation water use efficiency at Rwangingo marshland ‘’** it has recorded as research study which have done by Mr. SURWUMWE Alphonse under my supervision and guidance.

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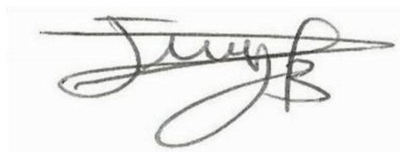

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ABSTRACT

Poor water use management in agricultural sector should cause deep water volume depletion on global world therefore, this thesis is concerned totheassessment of rice irrigation water use efficiency at Rwangingo marshland. The Rwangingo marshland has a bigger dam located at $1^0 35^{'} 34.70''$S and $30^0 17' 26.64''$E, Elevation 1413m with abundant water of 3,751,123 m3 in Gatsibo and Nyagatare, Eastern province of Rwanda.I have chosen to study irrigation water use efficiency because agriculture is the major consumer of water. Worldwide agricultural land might double in subsequently 50 years if trends in foodstuff consumption and existingactivities of production continue. Moreover, the Rwanda water resource board (RWB) together with the World Bank water resources group has performed a hydro-economic analysis in which projections by 2050 shows that irrigation will be the most water consuming sector and the RWB has carried out a study for the inter-catchment water transfer in which the projections by 2040 shows that the eastern province and Amayaga region will be under water deficit.

Therefore Rwangingo marshland is one of the marshland that use more water for agriculture and livestock and this marshland is fencing both anthropogenic and natural problems such as water insufficiency in dry season, flooding during rainy season, undulating topography, competition of water for animal support and poor water use management. After this study, Iwas found that water conveyance efficiency of the primary, secondary, and tertiary channel varies from 40 to 77% and it means that water lost varies between 60 to 23%, the average of sum conveyance efficiency wereestablish to be 59% and average water shrink in conveyance channel was 41%.

Refer to table 2, the accepted conveyance efficiency should not below 65 %, while this study obtained conveyance efficiency of 60%, it means that water in seepage, lack of clearance of canal, canal sedimentation, evaporation of conveyance loss was 41 % through clearing of canal. Rice crop water use efficiency of rice in Rwangingo marshland at whole season is 37 % in 150 day of rice growth stage.Efficient water management of Rwangingo marshland through suitablewater application efficiencies and it wasvery essentialfor understandingof proper decisions concerningthe water use managementunderneath climate variability in the future.

Key words: Irrigation efficiency, Rice water Use Efficiency, Climatic data, Rwangingo Marshland

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LIST OF ACRONYMS AND ABBREVIATIONS

FAO **:** Food agriculture organization

GDP **:** Gross Domestic Product

GIS **:** Geographic information system

GPS **:** Global positioning system

Ha **:** Hectare

IMP **:** Irrigation master plan

Km **:** Kilometer

MINAGRI **:** Ministry of agriculture and animal resource

NAP **:** National Agricultural Policy

PSTA 4 **:** Program for the Transformation of Agriculture

RAB **:** Rwanda Agriculture Board

RSSP **:** Rural Sector Support Project

SST **:** Small Scale Irrigation Technology

UR **:** University of Rwanda

US$ **:** United state dollars

MDGs **:** Millennium Development Goals

NRDS **:**National rice development strategy

NISR : National Institute of Statistics of Rwanda

UNICEF: United Nations International Children's Emergency Fund

WHO: World Health Organization

USGS: United States Geological Survey

IAD: Institutional Analysis and Development

USDA : United States Department of Agriculture

RWB : Rwanda water resources board

SAR : Seasonal agriculture survey report

CHAPTER ONE

INTRODUCTION

1.1. General introduction

The Agriculture sector is the main economic activity in Rwanda where 70% of the working populations are employed in Agriculture(World Bank, 2016). Rwanda have experienced andextremelytough in macroeconomic basically GDP growth averaging 7.4% in 5 years ago, and 8% in the precedent decade, intwo thousand nineteen (2019), the gross domestic productsgrowwith 9.4%, one of the peak rates of growth in Africa along with in the earth(Angela Zeleza (RCO), et al., 2020). Agricultureaccount for a furtherimportantelement of exporttrade ofincomeyieldlike; Coffee, tea, pyrethrum, flowers, and vegetables therefore 75% of Agriculture ofproduction of Rwanda come from local farmers(Angela Zeleza (RCO), et al., 2020). Rwanda cultivate themajor crops compriseof green beans, rice, cassava, banana, tea, pyrethrum, sugar cane and coffee as regards 61% of favorable of cultivated land and suitable for agriculture as the productive soils(Dusabimana, 2012).

Civilizing water use efficiency andsmart agricultural water yield is a important response to grow water shortage, together with the impose to therun off enough water in rivers and lakes, It requireto sustain ecosystems and meet the growth demands of cities and industriesof water use(Sharma et al., 2015). firstly, crop physiologists define water use efficiency as the quantity of carbon assimilate and crop yield per unit of transpiration (Sharma et al., 2015).The seriousactivities of agriculture exist in Rwanda haverequiredhigh demand of water availabilities, about anyapproximation 70% of total water sourcethat are used for agriculture. Amount water use inirrigation need to becarefulof the crop increasewithin Rwanda because rice (Oryza sativa), is presently the $2^{nd}$of allessential cereal require large amount of water .(GSK, 2020),

Water deficiency occurs when water supply is inadequate to meet water use demand.This condition increase as significance of a high rate of cumulative demand from every water use in sectors compared with existingdeliver, beneath the widespread institutional arrangements and infrastructural surroundings. worldwide, freshwater resources are enough for agriculture to meet demand requirements with 2050, given appropriate technologies and investments, exceptsignificant water accessibilityis probablespecial of deviation(Food and Agriculture Organisation, 2017).

Irrigation water use conveyance loss consists mostly of application losses, evaporation and seepage into the soil from the sloping surfaces and bed of the canal, the most important of these is seepage(Jadhav et al., 2014). The seepage loss in the irrigation canals accounts for the major portion of water conveyance loss (98.37%) while approximately 0.3% of the total stream is lost due to evaporation(Jadhav et al., 2014). The lining of an irrigation canal has the advantages of reduction in seepage losses from canals reaching water table and raising it resulting in waterlogging and reduction in yield, reduction in losses thereby making more water available for extension of irrigation to new areas and improvement of irrigation facilities in the areas already under irrigation(Jadhav et al., 2014).

1.2. Problem statement

Eastern province of Rwanda is the province which has great opportunity of agriculture based on irrigation because there are various land agriculture space, swamps, rivers and lakes as major source for irrigation system.Moreover, the Rwanda water resource board (RWB) together with the World Bank water resources group has performed a hydro-economic analysis in which projections by 2050 shows that irrigation will be the most water consuming sector(Sharma et al., 2015) hence it shows that the Eastern Province and Amayaga region will be under water scarcity.

Therefore Rwangingo marshland is the rehabilited marshland located in Gatsibo and Nyagatare district,Eastern province of Rwanda it was developed by the Government of Rwanda at2015-2017 under project of rural Sector Support program III (RSSP),(Hanson et al., 2010).This marshland is fencing both anthropogenic and natural problems such as water insufficiency in dry season, Flooding during rainy season, undulatingtopography, competition of water for animal support and poor water use management.In truth, rainfall is very fragile and inadequate to assure the requirements in livestock, agricultureplus water used in different sectors. Hence the need to conduct a research is predictable.

1.3. Objectives

1.3.1. Overall objectives

The main objective of this study is to assessirrigation rice water use efficiency at Rwangingo marshland.

1.3.2. Specific objectives

Tostudy climaticdata,

To determine cultivating soil texture and soil infiltration rate,

To determine the rice crop water requirement,

To determine water use efficiency and conveyance efficiency.

1.4. Hypothesis

The following hypothesis was made before undertaking the study:

Reliable climatic and soil data are available in Rwangingo marshland for rice crop water requirement calculation.

To assess conveyance efficiency is important forplanning future water use management in Rwangingo marshland.

Calculation of flow discharge will help to know different water los

1.5. Scope of study

The study will investigate the rice water use efficiency at Rwangingo marshland in order to compensate crop water requirement of rice cultivate in thestudy area to sustain production of rice in drought season at Gatsibo district and provide appropriate methods of water use management which can be undertaken.

1.6. Limitations of study

My research project haveassessedthe quantity of rice water use at cultivate land area of 261 ha existing in Gatsibo district and focused on the study of the conveyances efficiency,water use efficiency ,discharge and rice crop irrigation water requirement to satisfy rice wateruse efficiency in the study area.A wide command area and setting of the crop water coefficient of the rice in different season in all the study area and just have named a few; are the limitation of the study.

1.7. Structure of thesis

Thisresearch thesis will start by 1st chapter of beginand comprise of predicament study like water use unequal distribution, research question and specific objectives. 2ndpart consists of reading books which concern with the entirehypothesis of relates specific objective study on irrigation rice water uses efficiency at Rwangingo marshland. 3rdpart is consisting of material; research methods used for achieve objectives and hypothesis. 4^{th} is regardingto discussand data interpretation in the study areas and last chapter was a summary and conclusion.

CHAPTER TWO

LITERATURE REVIEW

2.1. Rice in the world

Rice is a worldwide important cereal crops, it is primary source of food and it account for thirty five to seventy five percent of the calorie eating of extra than three billion of humans. Mostly growth of worldwide people near ten billion in two thousand fifty years, the quantity of rice require by people will be increased highly than other crops because of many people live on world consume rice. Therefore, achievement of high productivities of rice are very challenges (Krishnan et al., 2011). internationally, it lines3rd following a wheat and maize in terms of production food security in the world is challenged by increasing food demand and threatened by declining water availability (Prices, 2021). Rice is second the majority important cereal crop followed by corn. Most Asia country has contributed the bulky rice production on the earth. According to(Prices, 2021) state the production was 209 million metric tons in 2019, China is the first country in the world whichproduce the paddy rice and, followed by India and Indonesia(Prices, 2021).

2.2. Rice production in Rwanda

The land areas cultivated paddy rice wetland in 2020 is 21,848 haaverage paddy rice: The cultivated area for paddy rice was estimated to be 15,374 ha, an increase of 5% when compared to 2020 season A. The production was 63,950 MT, an increase of 22% from the 2020 season A, while the average yield was 4.1 tons per hectare(Survey, 2021), according to the updated of SARand(NISR), the rice production area in Rwanda is about 15,000 hectares (Survey, 2021). The national rice development strategy (NRDS) aims to achieve self-sufficiency in rice production by 2018, and to substantially raise the competitiveness of Rwanda rice in local and regional markets. (Agriculture & Resources, 2018).

2.3. Water

Water (H_2O) is important in all living organism which is transparent, tasteless, odorless, and colorless which is the majorcomponent of earth of hydrolosphere(UNICEF & WHO, 2005). the Millennium Development Goals (MDGs) is achieving the target for access and safe drinking water and basic sanitation will bring a benefitsvalue many investorsfor water use demand(UNICEF & WHO, 2005)

2.3. 1. Water as major factor of rice production

Water (H_2O) is essential factor in agriculture of rice production and the increasing of yield production require adequate of water, In continent of Asia and other continents exist on thisplanet, rice crop suffers from both too tiny water (drought) andexcess water (floods). Mainly studies on constrainttowardlofty rice yield show that water is the key factor on yieldsgap and yield unpredictability from research stations to arable farm(Food and Agriculture Organization, 2000). On typical, agriculture book 70 % of global fresh water withdraws. In the previous 30 years, foodstuff production has improved by extra 100 %. FAO predict that 60 % additional food will be needed by 2050 to meet the food demand for growing global population (Food and Agriculture Organisation, 2017).

Irrigation has helped boost agricultural yields and outputs, oflowland rice which requires a lot of water and to produce 1 kg coarse rice the crop need 2.5 kilolitres of water, it plays essentialfunction in the cultivation of rice, This includeeverydeliverareatogether with rainfall and irrigation of all water seasonal used in field of ricevary from 4cm in closed clay soils andgroundwater 'shallow tables to higher than 2dm in textured soil of coarse (sandy) soils bycavernous groundwater table(Food and Agriculture Organisation, 2017).

2.4. Determination of uniformity water use application

2.4.1. Field water use efficiency

This referto the ratio of the amount of monetary crop yield to the quantity of water required for crop growing (Sharma et al., 2015). It is obtained as follows,

$$WUE = Yi \div WR \quad (1)$$

Where, WUE = Field water use efficiency expressed in kilogram of economic yield per hectare-cm or hectare-mm of water:

Yi = monetary crop yield in kg/ha

WR = Water requirement of the crop in ha-cm

2.4.2. Crop water use efficiency

It is the ratio of yield of crop (Yi) to the amount of water depleted by crop in evapotranspiration (ET). It is found out as follows, Source: (Irmak et al., 2011)

Table1. Potential water application efficiency for well designed surface irrigation system

Surface irrigation system	Application potential efficiency %
Furrow (conventional)	45-65
Furrow (surge)	55-75
Furrow (With tail water reuse)	60-80
Basin (paddy)	40-60
Basin (with or without furrow)	60-80
Precision basin level	65-80

Source: (Irmak et al., 2011)

E_{CU} (or WUE) = Yi÷ (Pe+IR+SW)(2)

Where, CWUE= crop Water Use Efficiency, Yi = Crop yields in kg/ha, IR=Irrigation applied, SW= change in soil water content in the root zone during the growing season, Pe=Effective rainfall

2.4.3. Water use efficiency

It is the proportion of water delivered and beneficially used on the project and it can be calculated using the following formula:

WUe= WBe ÷ WD (3)

Where, WUE =Water use efficiency, WBe=Water beneficially use, WD=Water delivery(Sharma et al., 2015)

2.4.4. Water distribution efficiency

Water distribution efficiency dealings the extent to which water is uniformly spread in the effective root zone soil beside the irrigation use(Sharma et al., 2015). It is describe as,

$E_f = (1 - \frac{Z}{Y})$ 100(4)

Where, E_f = Water distribution efficiency in percent

z = Average numerical deviation in depth of water stored in root zone soil along the irrigation run from the average depth of water stored during irrigation

y = Average depth of water stored during irrigation along the water run

2.4.5. Conveyance efficiency

The low pressure buried pipe distribution systems for surface irrigation constitute evaluable alternative to open channel distributors. (Osman et al., 2016) hasconfirmed that the conveyances loss was 2.8 to 9.5% in PVC and HDPE pipewhile in opencanal it varies from 30 to 33% in silts-clay loam soil and conducted field study and confirmed that water savings is 2%,efficiency of conveyanceis 98%, reduction viairrigation interval with 50 to 60% increase in crop yield should be added that total water savings of 10% in summer and 5% in winter were achieve since the discharge of the irrigation development project(Osman et al., 2016). The conveyance efficiency is calculated as follows for the earthen channels.

$$\text{Conveyance Efficiency \%} = \frac{\text{Discharge in outlet end of channel}}{\text{Discharge in inlet end of channel}} \times 100 \qquad (5)$$

Water loss included mainly of water flow in canal though the seepage, deeper percolation, and mostlyessential of these is seepage. Evaporation loss in irrigation networks is normally didn’t take into kindness. The seepage loss in the irrigation canals account for the main portion of water conveyance loss (98.37%) while around 0.3% of the total stream is lost due to evaporation.

Table 2.Comparison of conveyance efficiency in different type of canal

Types of canal	Conveyance efficiency %
Earthen canal	65
Lined canal	92
Buried pipe	98
LSD	5.6

Source: (Osman et al., 2016)

2.4.6. Crop water requirements

Crop water requirement: it means the amount of water required for compensate the evapotranspiration lost from plant. Even if the value evapotranspiration of crop realize condition (ETc) and water crop requirement islike amount of water that needs to be supplied in field,

Evapotranspirationof c**rop**: it is the total water that is elapsed through evapotranspiration. Experimentally can determine the ratio of ETc/ETo, crop coefficient (Kc), are used to the calculation relationship between Etc and ETo which can express in the following formular = Kc * ETo(Food and Agriculture Organisation, 2017).

2.4.7. Irrigation water requirement

Refer to the amount of water applied in filed and addition for cover the crop water requirements. For irrigation scheduling it is computed as the difference between Crop water requirement (CWR) and the actual crop evapotranspiration under rain-fed conditions with periods of water stress (Food and Agriculture Organisation, 2017).

IN = ET crop – Pe (6)

Consequently, the Irrigation Need (IN) is a difference between the crop water need (ETc) and effective rain fall (Pe) which is use with different plants.

2.4.8. Total irrigation requirement

Total irrigation requirement, refer to thesumof water suppliedviairrigation. It has determined by considering the appropriate loss at several stage(Foley et al., 2011).

Gross irrigation requirement= Net irrigation requirement+ water loss (7)

2.4.9. Water flow rate measurement

Flow rate(Q) is the volume of fluidtravelin canal per unit of periode which expressed in m^3/sec. In general, canalflow rate is calculated withmultiplication of area and flow velocityin a canal then time correction factor of 0.85.

Discharge = area x velocity (8)

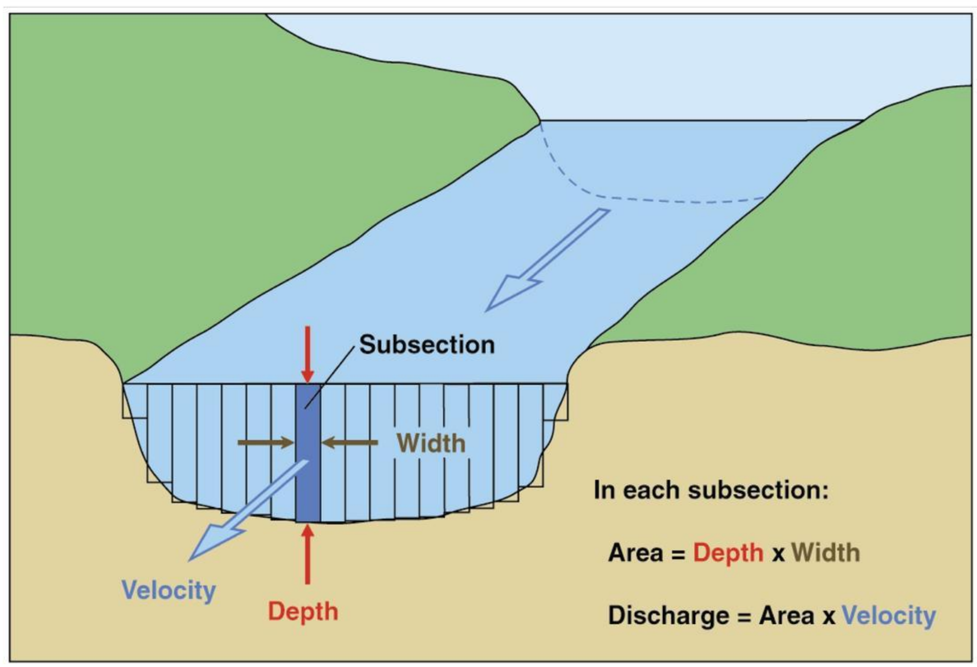

Figure1.Cross section of channel

Source: (Food and Agriculture Organisation, 2017)

The usefully method used for measuring of of flow velocity is current meter and float methods. Nevertheless, a range of high quality material should be used to brainsstep of measuring stream flow rate. These depth and velocity measurement is used to calculate the total volume of water flowing past the line during a specific interval of time.

2.5.Climatology

Climatology is the part of meteorology study that deals with climate configuration, thatcirculation of weather over the earth and the analysis that causes of differentphysical climate characteristics then look its application of data of climatic to the answer of fited design in the operation of problems of different area(Passarella et al., 2005).

The study area hascomprised with 2 main season like the dry season on annual mean temperature change among 15.5 °C and 27.7°C with and without of rainfall. The rainfall is little and negative influence ofaccessibility hydraulic ofagriculture and livestock activity. The wetlandanalysis ofsite project development either dry and wet seasons, which is 15.13% for overall land cover of Rwanda, it means that Rwangingo marshland hasthe average of annual precipitation of 803 mm, briefly it change 827millimeter and 900 millimeterof rainfall. The long rainfall season extend since February upto June with the high peak of rainfall in April which more than120 mm per month. The closest meteorological stations of Rwangingo and Karangazi marsh site are Gabiro, Nyagahanga, Kiziguro, Ngarama and Ngarama.

2.5.1. Precipitation

Precipitation is explaining of depth of fluid water collected during in defined interval period on a flatearea(Passarella et al., 2005). Rainfallshould be determinedto know the annual rainfall, hence the cycle of hydrologyprovide the understandable critical variation ofdeterminingwater supply either agricultural use or domestic(Passarella et al., 2005).

2.5.2. Relative humidity

Relative humidity is the ratio of water vapor pressure present in a gas (Pw) to the saturation vapor pressure of water at that temperature Pws (t), The amount of water vapor present in air (gas) expressed as % of the amount needed for saturation at the same temperature (Alanoly, 2008)

$$RH = 100 \times Pw \div Pws\ (t) \qquad (9)$$

2.5.3. Wind

Wind is the atmospheric air in movement;it is ever-present and single of the basic physical elements of our environment. Depending on the speed of the moving air, wind capacitysuffer lightbeing silent and invisible to the naked eye (Kalmikov, 2017).

2.5.4. Solar radiation

Solar radiation is electromagnetic radiation ranging from about 0.25 to 4.5 micrometer(um) in wave length including the near ultra violate, visible light, and near infrared(IR) radiation (Dunlop, 2012). Solar radiation is extremelyconnectedfrom photo synthetically activation of radiation in primary production (Passarella et al., 2005).

2.5.5. Temperature

Temperature is a degree of hotness or coldness measured on a definite scale. The average temperature of the air as indicated by a properly exposed thermometer during a given time period, usually a day, a month, or a year (Tatsumi et al., 2013).

2.5.6. Minimum and maximum temperature

Impacts of climate change may depend more on changes in mean daily minimum temperature (Tmin) or maximum temperature (Tmax) than on average temperature (Tavg), (Krishnan et al., 2011) .

2.5.7. Effects of temperature on rice production

At the end oftransplanting, the upper parts of rice crop has accelerated the proprtional temperaturesince 18 to 33^{0}C is crusial important to decrease eighter above or below. Breaking dormancy of rice require heat of 50 °C in 4-5 days (Krishnan et al., 2011).

2.5.8. Evapotranspiration concepts, ETO and ETc

According to the FAO, the relationship ETo and ETc, is a climatic weather whichexpress the lossatmospeheric power whilecrop evapotranspiration (ETc) is the demand of evaporation from crops that has grown in big scale of the fields under optimum soil water, exceptionalenvironmental and management conditions should completeassemblybeneath the specified climatic conditions.

ETc= Kc x ETo (FAO, 1998) (10)

(Kc=Crop coefficient)

2.5.9. Crop coefficient (Kc)

Crop coefficients means the dimensionless factor that used to determinecop water requirement with respect to the evapotranspiration rate. Kc iscalculated with experimental fact and take leaf surface consideration and physiology of crop shade (Paula P, Geraldo J. Rodrigues et al 2018)

2.6. Relationship between Soil, crops and water

2.6.1. Soil texture

USDA texture triangle indicate the relative content of soil particleat different size, such as sand, silt and clay in the soil. Soil textures influence the straightforwardness with which soil can be worked, the amount of water and air it hold, and the rate which water preserve enter and travelvia the soil. The major soil textural class percentage is sand, silt, and clay(Matthews, 2014).

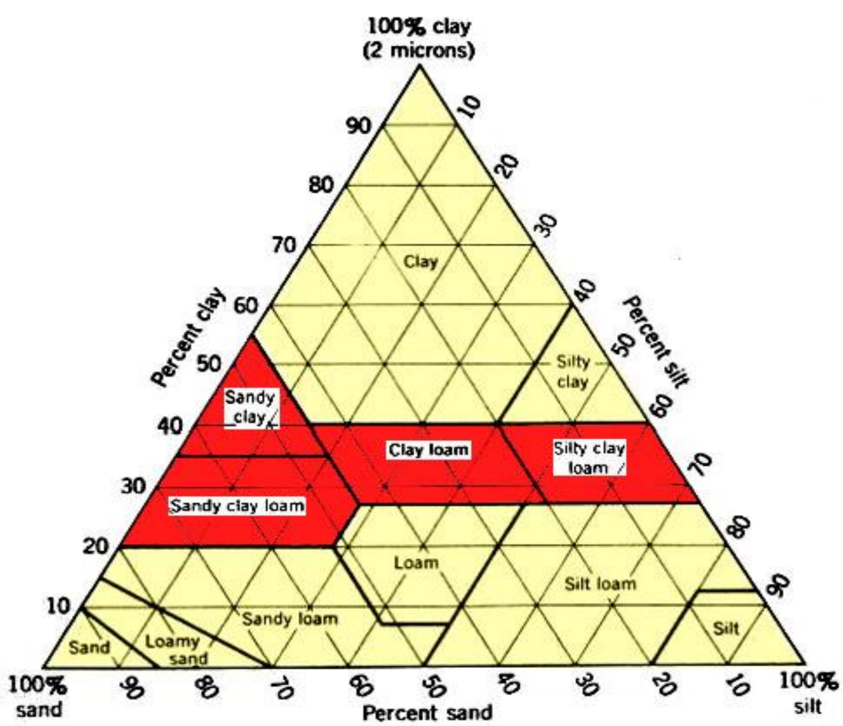

Figure2.USDA triangular of basic soil textural classes

Source:(Matthews, 2014)

2.6.2. Infiltration rate

Infiltration rate is the ability of soil to allow water movement in different soil layer. It provide the soil water to move and making it enough uptaken by soil organisms and vegetation, it express in mm per hour(Soil & Rainfall, 2019).

Table 3.Soil infiltration rate classification in mm/hr

Soil type	Basic infiltration rate (mm/hour)
Sand	Less than 30
sandy loam	20 – 30
Loam	10 – 20
clay loam	5 – 10
Clay	1 – 5

Source:(Soil & Rainfall, 2019).

2.6.3. Bulk density

The bulk density(BP) is one physical characteristic of measurement of soil compaction. BPdesigned as the ratioof dry weight of soil its water volume. The volume of soil particles and the volume of pores among soil particles. BP is calculating in gram/cm^3. The most rocks have a bulk density of 2.65 gram/cm^3, so perfectly, a medium soil textur with 50% pore space that will have a bulk density of 1.33 g/cm3(Arshad et al., 2015).The factors that affect the bulk density is land cover, organic matter, porosity, land management practices and soil structure.

$BP = MS \div VT$ (11)

Where**,** PB= Bulk density, Ms= mass of dry soil, Vt= Volume of soil sample

Table4.Relationship of soil bulk density in different of soil texture

Soil Texture	Best of bulk densities for crop growth, g/cm^3	Bulk densities that restrict root growth, g/cm^3

Sandy	less than1.60	More than 1.80
Clayey	Less than 1.10	More than 1.47
Silty	less than 1.40	More than 1.65

Source: (Arshad et al., 2015)

2.6.4. Rice crop characteristics

The rice plant can grow to 1 to 1.8 m tall, and depending on the type of variety and soil fertility. It has long, slender leaves of 50 to 100 cm long and 2 to 2.5 cm3 in broad.

2.6.5. Root depth system

The effective root zone depth is the depth of soil used by the main body of the plant roots to obtain most of the stored moisture and plant food under proper irrigation. It is not the same as the maximum root zone depth(Lott & Hammond, 2013). About 70% of the moisture extracted by the root is obtained in the top half of the root zone and about 20% from the third quarter and about 10% from the soil in the deepest quarter of the root zone(USDA & Service, 2005).

Root zone depth will vary according to the effective soil depth, fertility management, and the rooting characteristics of the plants, therefore each plant has its own root development characteristics, which vary only slightly under adequate soil moisture conditions in a given soil profile (Lott & Hammond, 2013).

Table 5. Maximun root depth of most cereals crops cultivate in Rwanda

SN	**Type of rice**	**Rooting depth, m**
1	Sorghum	1.0
2	Wheat	1.0
3	Rice	0.5
4	Millet	1.0

5	Maize	0.9

Source: (Lott & Hammond, 2013)

2.7. Irrigation Scheduling

Irrigation scheduling is the process of determining the frequency and constancy ofapplying controlled amounts of water to crops. It considers the crop and the amount ofwater the crop uses via the process of evapotranspiration (Crop Water Use).

2.7.1. Benefits of irrigation scheduling include

It optimizes crop yields.

Ensures best management of water resources.

Significantly decreases soil and nutrient loss due to excessive runoff or leaching.

Helps maintain soil health (aeration, structure, flora and fauna).

2.7.2. Major factors which affect Irrigation Scheduling

Soil Type: Texture and Structure

Crop Type

Climatic Factors, Land Management

CHAPTER THREE

MATERIALS AND METHODS

This chapter deals with different materials used in this research study. It also discusses the methodology adopted to reach different specific objectives.

3.1. Study area description

3.1.1. Location of study

This study is to assess irrigation rice water use efficiency at Rwangingo Marshland located in nearly adjacent sector of Kabarore, Gatsibo and Ngarama. District of Gatsibo is one of seven district consist of Eastern province of republic of Rwanda. It subsdivised within forteen sectors which are Gatsibo, Kageyo, Gasange, Gitoki, Kageyo, Kabarore, Kiramuruzi, Kiziguro, Muhura, Murambi, Ngarama, Nyagihanga, Remera, Rugarama and Rwimbogo. This District delimitedby:

The Akagera national park/ Tanzania country in East,

To the North by Nyagatare district;

To the West by Gicumbi district,

To the South by Rwamagana and Kayonza Districts.

Rwangingo marshland has a bigger dam located at $1^{0}35^{'}34.70''$S and $30^{0}17'26.64''$E, Elevation 1413 m with abundant water of 3,751,123 m3 which used to irrigate at downstream areas, the areas cultivate the rice is 261 ha in side of Gatsibo district, while water used for livestock and irrigation of maize at 639 ha in side of Nyagatare district.The below Figure 4 is only study area of Rwangingo marshland in Gatsibo district. The commend area of marshland is located at the altitude of 1414 meter and 1393 meter, latitude of $1^{0}35'09.74''$S and longitude at $30^{0}17'19.29''$E.

Figure 3. Location of study areas on Google map

3.1.2. Relief

The relief of Rwangingo Marshland is characterized by flat valley andsarrounded by tiny hills which arecharacterize with 2main seasons: plolonged dry season and rain season. The soil type of this marshland is clay loam as determined in Table 12 from chapter four of this study.

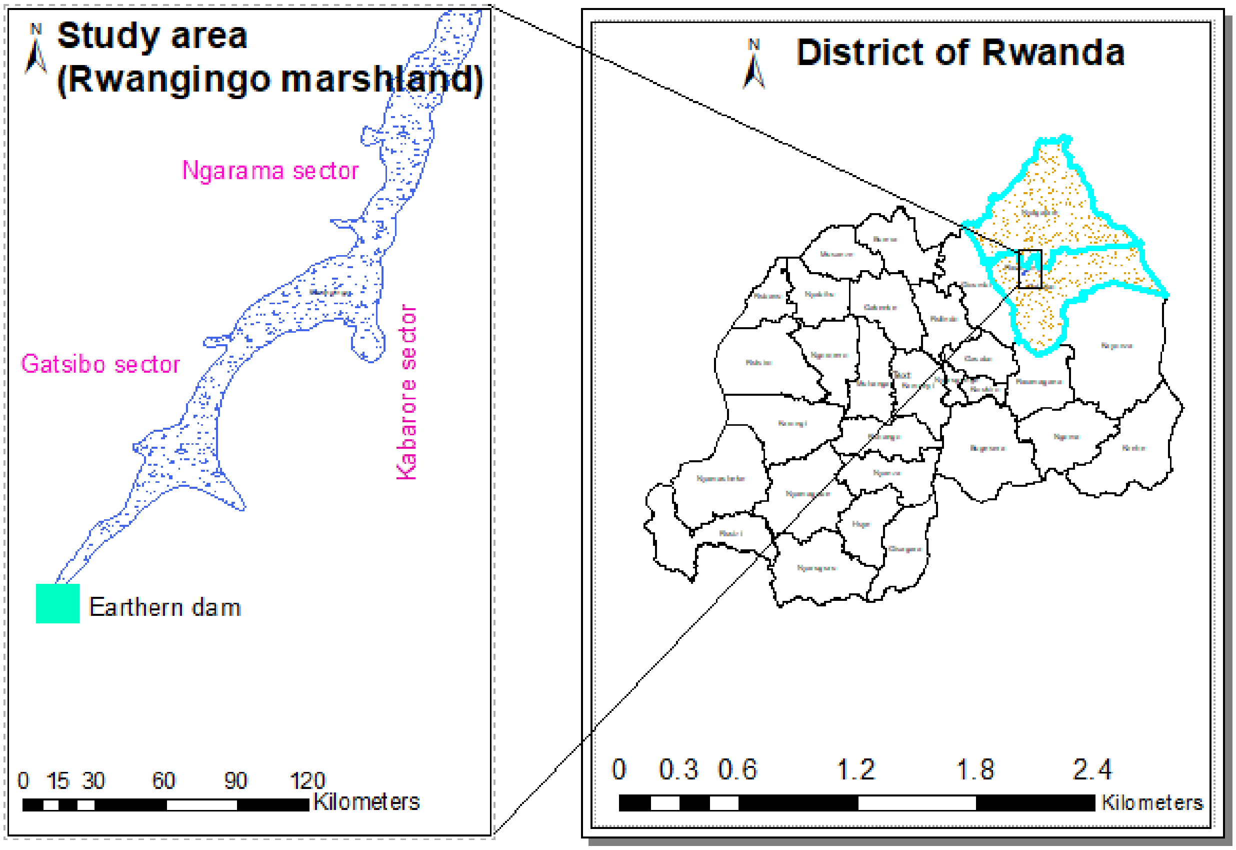

Figure 4. Map of study area location

3.2. Materials

The material that haveused in this research were:Soil sampler, shovel and hoe, Bucket, Jerican,Tape measure, Auger hole, Computer, stop watch,Cropwat 8.0 and double ring inflitrometer.

3.2.1. Shovel and hoe

Refer to the equipment used to manipulate and excavation of soil sample.

3.2.2. Tape measure

It is equipments used to measure crop height, depth of water in canal

3.2.3. Double ring inflitrometer

It will used to determine soil infiltrationrate (Sharma et al., 2015)

3.2.4. Computer

It has used for data entry in excel, word and different software like GIS, Google earth and crop wat 8.

3.2.5. Stop watch

A stopwatch is a chronometer designed to measure the amount of time that elapses between its activation and deactivation(Sharma et al., 2015).

3.3.Methods

In this thesis of assessment of rice irrigation water use efficiency at Rwangingo marshlandwill consist of research methods at different scales that have used to obtain data for answering the research questions and to achieveobjective study. Working together with the national meteorology station, reading different literature, unstructured interviews,surveying and the models were used in this research.

3.3.1. Semi unstructured individual interviews

Semi unstructured interviews have used to get full information of rice crop characteristics and I have worked together with UBUMWE Gatsibo cooperative agronomist, water user association manager (WUas). The field work has used to bedone eight months for arranging and writing of data. Therefore, methodof gathering data it has helped to getobvious image of the daily irrigation practice of rice rehabilitated areas.

3.3.2. Soil sample experimental

Soil samples have collected in three different selected rice plot of the Rwangingo marshland under study. Three plots have picked a sample of soil at depths of 0 to 60 cm only. The soil texture analysis involved with three samples from three different depth for laboratory analysis and use soil texture triangle. To know the soil type from study was help to determine the rice crop water requirement by using cropwat model and help farmers of Rwangingo marshland to know irrigation scheduling in this commend area.

3.3.3. Soil infiltration rateexperiment

Soil infiltration hascollected and determinedto know infiltration rate for help exact water application rate and irrigation interval of rice crop within Rwangingowetland.Infiltration rate trial

Step1. select area and fix doubling inflitrometer

Step1.Hammer the two rings simultaneously at least 15 cm into the soil

Step3.Begin by test filling water into the double rings until the depth is about 17cm

Step5. Followingin one to five minutes, record the depth of water level in the inner ring on the measuring rod and add water to bring the level back

Step6. Continue the test until the drop in water level is the same over the same time interval.

3.3.4.Methods of determination of flow rate in Channel

The velocity of a canalhave determined by use of surface floats body method. To use floats body is a relative straight reach of canal of 10 meter along with a faith uniform cross section along its length of selected. To control wind drift on float body take bottle and fill it water.Then count the time taken by body to move from one point to the end point and record it.Again take leading by using tape measure and record width, depth of cross section area.(Michaud & Wierenga, 2005).

Then calculation of velocity consider distance L divide by time traveled by float body then calculate the cross section areas by using the average of depth and widthand the result multiply by calculated velocity and times correcting factor 0.85(Michaud & Wierenga, 2005).

The formula for calculating the irrigation canalflow rate may be formulate as,

$\mathbf{Q = 0.85 * \left(\frac{a+b}{2}\right) H.V}$ where, Q = flow rate, cm^3/s (12)

a = Width of the channel at flow surface level, cm

b = Bottom width of the channel, cm

H = Flow depth in the channel, cm

V = Flow velocity, cm/s

3.3.5. CROPWAT model

This model should to determinethe crop water requirement which have used the developed software of crowat8.0 entered and compute climatic data of Rwanda Meteological station nearly study area of recorded data (like Rainfall, max and min temperature, relative moisture) has obtained from Headquarter (HQ) of Meteo-Rwanda in period of 20 years ago from 2000-2019 while cropping technical data like Kc factor, planting date, time-span of growth stages, Crop height were obtained from the field and reading books.

3.3.5.1. Meteological data of 20 years

This climate data has collected from branch of meteo-Rwandaha has gave climatic data of Gabiro meteological station which located at elevation of 1507 m, altitude of 1^{0}31’24.69’’S and longitude of 30^{0}24’53.23’’Ethat imported in excel sheet for computing mean and average of daily data collect of minimum, maximum of temperature, rainfall, relative humid, sunshine and wind speed of climate data from 2000 up to 2019.

Table6.Input climate data into CROPWAT 8.0

Month	Max temp (deg.c)	Min temp (deg.c)	Humidity (%)	Wind (spd.km/d)	Sun shine (hours)	Solar rad (Mj/m2/d)	Eto (mm/d)
January	27.51	16.65	76.8	144.1	5.3	17.5	3.78
February	27.67	17.10	75.2	141.7	5.2	17.5	3.92
March	26.21	14.94	78.9	145.7	5.1	14.3	3.70
April	26.84	15.75	82.6	139.2	5.1	14.7	3.50
May	26.77	15.25	79.6	147.7	5.7	18.6	3.50
June	26.51	14.65	68.3	157.3	7.5	12.4	3.98
July	27.08	13.51	59.9	175	8.5	10.3	3.92
August	27.56	14.18	60.1	184.9	6.4	14.5	4.38
September	27.42	15.26	68.3	176.3	6.4	14.5	4.31
October	26.98	16.11	68.3	166.8	6.2	18.7	4.26

November	27.07	15.78	81	153.8	5.6	18.1	3.69
December	27.78	16.78	79.1	148	5.4	18.5	3.70
Total	325.4	186	878.08	1708.2	72.4	189.6	47.04
Average	27.12	15.50	73.17	142.35	6.03	15.80	3.92

From above table7, climate data from 2000 to 2019 has represented 20 years and have collected from Meteo Rwanda at near station of Gabiro and Ngarama station thesignificate of month of data has worked from the daily data gathered in 20 years and includingmean of minimum and maximum temperature, rainfall, relative humidity, wind velocity and sunshine hours.

3.3.5.2. Rain fall data

Table7. Rainfall and effective rainfall from CROPWAT8.0

Month	Rain fall, mm	Effect. Rainfall, mm
January	39.43	36.9
February	87.67	75.4
March	115.62	94.2
April	154	116.1
May	58.33	52.9
June	31.14	29.6
July	7.38	7.3
August	71.67	63.5
September	110.57	91.0
October	109.86	90.0

November	99.86	83.9
December	66.29	59.3
Total	951.82	800.5

3.3.5.3. Crop water requirement

In order to calculate the water requirements for the Rice, the different data have entered in software of FAO model CROPWAT 8.0for analyzing various climate data, the program automatically calculates. The duration of every development stage of Rice is entered: the planting date 23 July, seedling (initial) stage of 25 days, 50 days of vegetative growth (development) stage, reproductive growth (mid-season) stage of 40 days and the maturing growth stage of 35 days. According to (FAO, 1998b) the root depth of rice was taken as 50 cm and the Kc according to the growth stage of 1.00 for the seedling stage 1.2 for growth and flowing stage and 1.00 late stage crop.

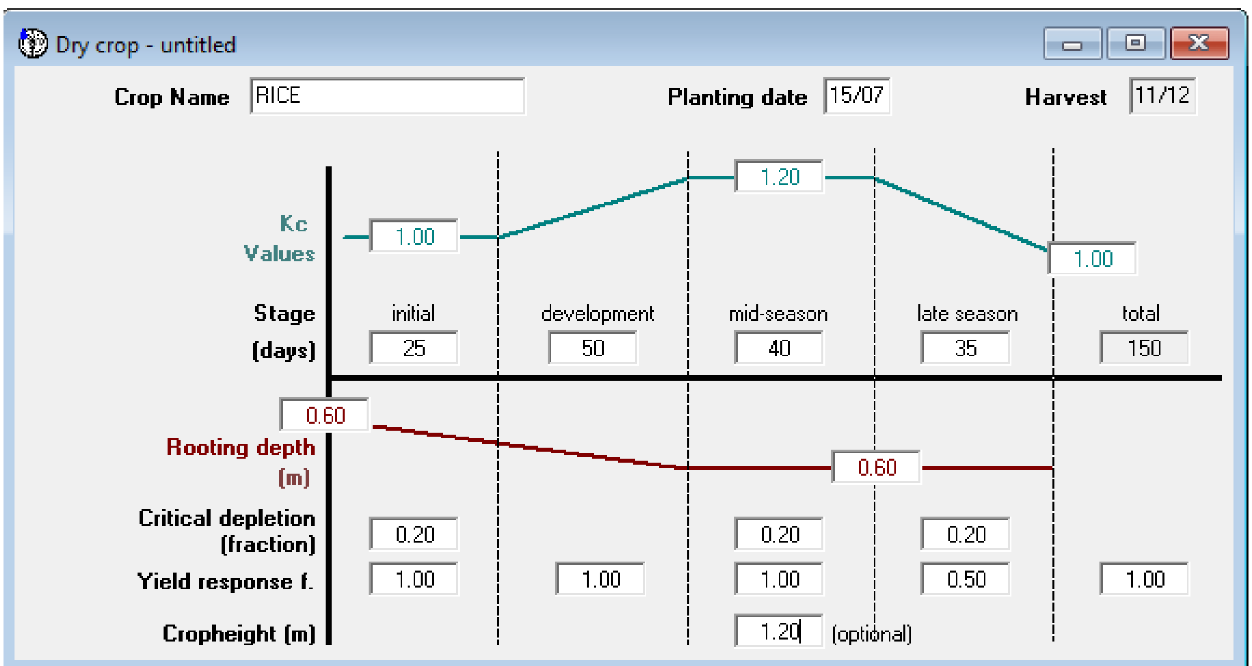

Figure 5. Computed Crop characteristics from CROPWAT 8.0

The program does not take into account the amount of water necessary for the puddling operation for the paddy Rice and the percolation losses, which amount is respectively estimated to 100 mm and 30 mm (Anonymous, 2008). Therefore, this amount of water has added to the crop water requirements for rice during calculations.

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter discuses the study of various data gatheredbase on methodology adopt in this chapter III. It deals with the obtaining of the suitable results and provides requiredinterpretation for superior accepting or rejected of hypothesis and execution of this thesis, which deal with to assess irrigation rice water use efficiency at Rwangingo marshland.

4.1. Determination of rice crop water requirement and irrigation requirements in study area

Rice water requirement computed by using CROPWAT 8.0 software engineering by FAO, it has used to determine crop water requirementsand irrigation requirements of rice in Rwangingoswamp using the input data like soil, climate climate and crop data.

4.1.1.ETоat Rwangingo marshland

ET_O is the rate of evapotranspiration from a bulky area, enclosed by green grassland, eight to fifteen centimeter tall, which growenergetically, entirely shades the ground and which is not short of water (Anonymous, 2008). When rainfall, element of the precipitationit infiltrate in the soil, onather runoff, the remaining uptaken by plant root this colled effective .From the appendix1 and table 5; show that the mean ETo for Rwangingo marshland is 3.97 mm/day while minimum and maximum of Eto change from 3.50 to 4.92 mm/day.

The maximum ETo hasestablish in the month July and the minimum has establish in the month of April, May and June. The change between maximum and minimum of ETo hasestablish to be 1.42 mm/day.

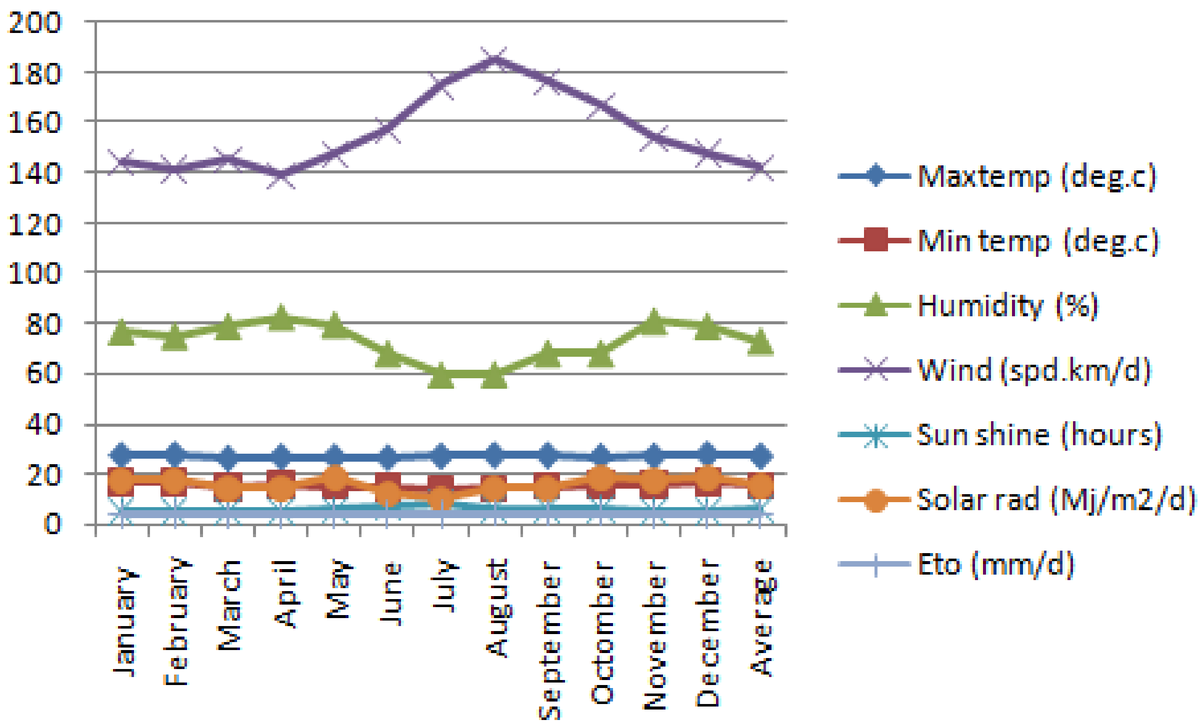

Figure 6.Climatic data analysis

4.1.2. Effective rainfall Rwangingo marshland

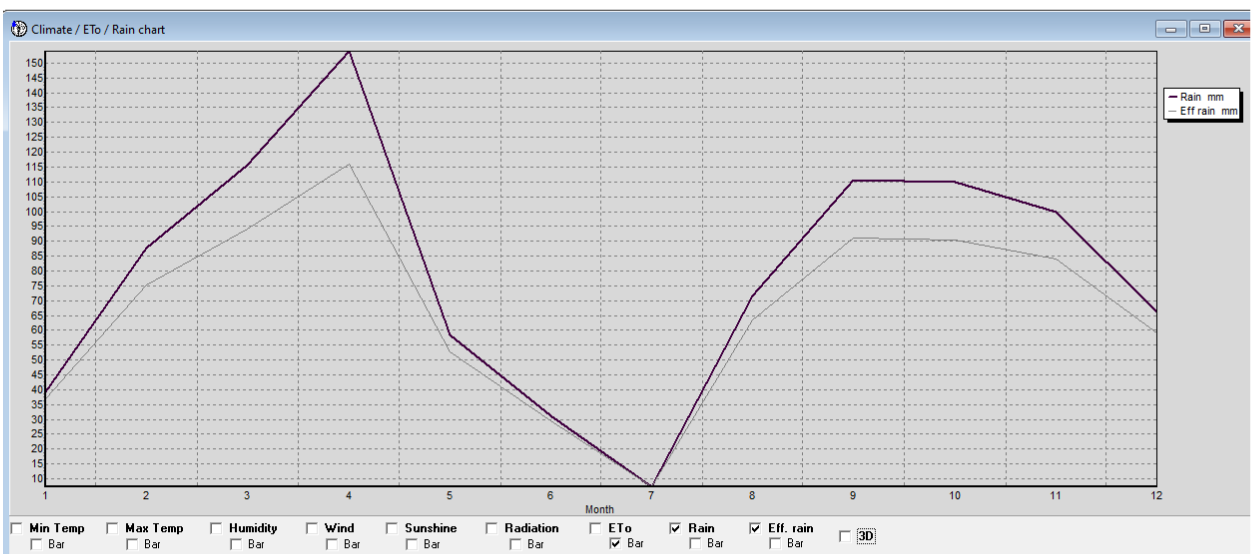

Figure7.Analysis of effective rainfall from CROPWAT 8.0 Model

The mean of data of rainfall has collected in 20 years (2000-2019) from NGARAMA meteology station located at elevation of 1492m,altitude of $1^0$32’43.30’’S and longitude of $30^0$14’23.22’’Eat distance of7 km from study areas of Rwangingo marshland. So, it is extremelyprecise and rain fall data are collected in order to analysis the effective rain fall which help to determine irrigation requirement and water irrigation use effeciency in Rwangingo marshland. The Effective Rainfall was calculated in crop wat 8 by rain data that is presented in appendix 2.

From the above figure 7, it proves that highest rainfall have received in the month respectively of April, March and May such as 154 mm, 115.6 mm and 58.3 mm during long rainy season. The rainfall of 110.5 mm, 109.8 mm and 99.9 mm have received during September, and October respectively during short rainy season. The lowest rainfall is received during the month of July (7.3 mm).

4.1.3. Net Irrigation Requirement at Rwangingo marshland

NIR (Net Irrigation Requirement) is not samewith the crop water requirement(CWR). CWR is the water used by the plant for speed up the growthto compensate water lost through evapotranspiration while NIR is the irrigation water abounding to the field that the crop gets its full CWR and it didn't include any water losses due to the method of irrigation. The Crop Water Requirement of rice has given as output in table 8 which is below.

Table 8.Water Requirement of rice and irrigation requirement

Month	Decade	Stage of crop	Kc	ETc mm/day	ETc mm/dec	Effective Rain mm/dec	Net Irrigation requirement mm/dec
July	2	Initial	1.00	4.45	26.7	0.0	26.7
July	3	Initial	1.00	4.49	49.4	5.1	44.3
Aug	1	Develop	1.00	4.53	45.3	15.8	29.5
Aug	2	Develop	1.03	4.69	46.9	22.5	24.4
Aug	3	Develop	1.06	4.77	52.5	25.1	27.4
Sept	1	Develop	1.10	4.85	48.5	28.1	20.3

Sept	2	Develop	1.14	4.90	49.0	31.6	17.4
Sept	3	Mid	1.17	5.03	50.3	31.1	19.2
Oct	1	Mid	1.18	5.04	50.4	30.4	20.0
Oct	2	Mid	1.18	5.02	50.2	30.4	19.8
Oct	3	Mid	1.18	4.80	52.8	29.6	23.2
Nov	1	Late	1.17	4.56	45.6	29.2	16.3
Nov	2	Late	1.12	4.15	41.5	28.8	12.7
Nov	3	Late	1.06	3.92	39.2	25.8	13.4
Dec	1	Late	1.01	3.69	36.9	22.5	14.4
Dec	2	Late	0.97	3.55	3.6	2.0	3.6
Total irrigation water requirement for rice for the season (July up to December)							332.8

The rainfall in the month of August, September, October and February ranges from 31 mm to 102.9 mm.Total Water Requirements for the Rice growing season = 688.8 mm + 100 mm + 30 mm =**818.8 mm** per 150 days, Crop wat 8.0 has taken 100 mm for puddling and 30 mm for percolation losses. Net Irrigation requirement for the growing season = 332.8 mm per 150 days

Average effective rainfall per month = $\frac{332.8 \text{ mm x } 30 \text{ mm}}{150 \text{ day}}$= 66.56 mm/month

Average Water Requirements per month = $\frac{\mathbf{818.8} \text{ mm x } 30 \text{ mm}}{150 \text{ day}}$= 163.76 mm

The highest net Irrigation Requirements of the crop is during July amounting 44.3 mm/decade or 4.4 mm/day, Hence, considering 50% overall irrigation efficiency, gross irrigation water requirement = 4.4÷0.5= **9 mm**

Therefore, the daily Gross Irrigation Requirements (GIR) for 261 hectares during July;

$$GIR = \frac{\mathbf{9}\ \text{mm x 261 ha x 10000}}{1000} = \mathbf{23{,}490\ m^3/day}\ \text{or}\ \mathbf{272lit/sec}$$

Therefore main channel capacity should be designed to carry 272 lit/second

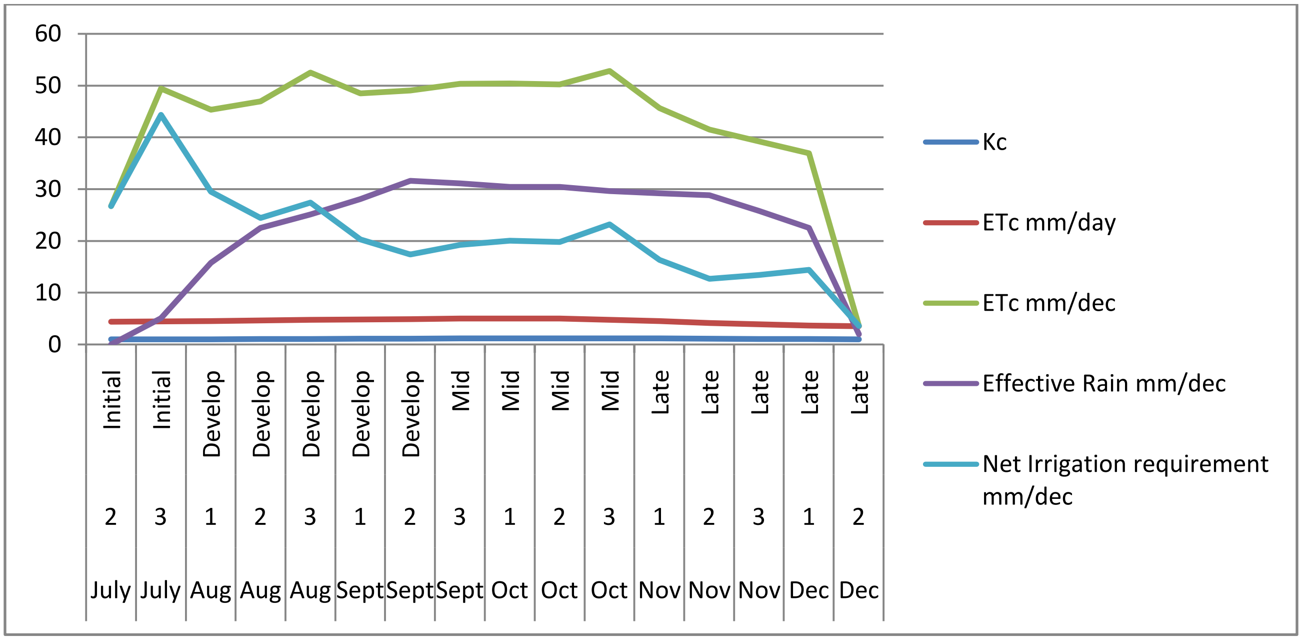

Figure8.Analysis of effective rainfall and water requirement

The net irrigation of rice crop at season would start since July to December equal to 332.8 mm in Rwangingo marshland. The cause of low rice water requirement is caused by high peak of effective rainfalland low evapotranspiration withinstudy areas start Julyup to December. It was also resultof higher irrigation willrequiredsince July up to August because effective rainfall is decreasing during that period.

4.1.4. Irrigation schedule for the site

Irrigation scheduling gives precise periode to do any irrigation practiceand how much water required for supplying on rice crops in order to distribute water equally. The software has performed for computing irrigation schedule by keeping the field irrigation efficiency of 70%.

Table 8 and appendix 4 show the calculation of irrigation and rain efficiency use modelling of cropwat8 software. The planting date of rice is starting on 15July 2021 and rice crop have harvested on 11December 2021 and it carry 150 days to be harvesting. There are three stages of the rice crop development stage include; development stage, mid stage and harvesting stage. The potential rice water use equal to 685.3 mm efficiency of rain is 3.5 % in Rwangingo marshland therefore 96.5% of irrigation water will be required to compensate evapotranspiration of rice crop that is why care of water management need to be taken.

4.2. Measurement water in conveyance system of Rwangingo marshland

4.2.1. Discharge in Primary Channel of Rwangingo

This channel has the total length estimated to 7.9 km, from dam water source which delivery water to cultivatedareas of 261 ha of rice. Measures taken for the first section are:

Procedures:

From (Michaud & Wierenga, 2005) in chapter III state and detail explain well the procedures of discharge measurement. Select two point of canal and measure A up to B which is equal 20 m length, Place float body and start counting time which is equal to 39 min and data taken from five point and different zone such as zone 1, 3, 5,8, 11. Measure bottom of canal: Bx=1.60 m, top of canal: TX=2.8 m and depth: Hx= 0.5m, B=1.70 m, T=2.9 m, H= 0.40 m, Calculate trapezoid area

Figure 9. Discharge experiment

Velocity= 20 m/39 sec=0. 512m/ sec

Area= {(Bx+B)/2} + {(Tx+T)/2} *[{Hx+H}/2]/2

Area= {(1.60+1.70)/2+(2.9+2.8)/2} *[(0.5+0.4)/2]/2=1.575 m^2

Flow rate(Q)=A*V=0.512*1.575=0.806 m3/sec

The answer times the correction factor of 0.85, the flow rate will be equal 0.685m3/sec or 685.44 lit/sec lthis sampled experiment was tested from zone 1.

Table 9.Estimation of velocity and discharge at full length of Primary channel from Dam Rwangingo to the field

Point	Average Depth of water	Average Length	Average Top width	Average Bottom width	Average Time	Velocity	Average cross section areas	Average Discharge
	M	M	M	M	Sec	m/s	m2	m3/sec
P1	0.45	20	2.9	1.6	39	0.512	1.575	0.806
P2	0.395	20	2.7	1.43	47	0.425	0.815	0.346
P3	0.3725	20	2.5	1.25	49	0.408	0.432	0.176
P4	0.355	20	2.45	1.2	60	0.333	0.665	0.221
P5	0.349	20	2.8	1.29	70	0.286	0.713	0.204
Mean	0.3843	20	2.67	1.354	53	0.393	0.84	0.351

From the above data show the average discharge is 0.307 m3/sec or 307.4 litr/sec, and the flow rate decrease as distance flow increased because of water loss though the infiltration rate, seepage, evaporation, percolation, canal roughness and debris of canal. During this study have measured average of discharge at zone 11 was found as 0.109 m3/sec, the water conveyance efficiency in primary channel can be estimated as

Conveyance Efficiency % = $\frac{\text{Discharge in outlet end of channel}}{\text{Discharge in inlet end of channel}}$ x 100= $\frac{0.108 \text{ m3/sec}}{0.351 \text{ m3/sec}}$ x 100%=31%

4.2.2. Discharge of secondary channel Rwangingo marshland

The primary channel is divided into many secondary channels to take the water for irrigation of rice fields.

Table 10.Measurement of discharge as conducted in the secondary channel

Point	Average Depth of water	Average Length	Average Top width	Average Bottom width	Average Time	Velocity	Average cross section areas	Average Discharge
	M	m	M	m	Sec	m/s	m2	m^3/sec
P 1	0.9	20	1.1	0.7	90	0.222	0.81	0. 179
P 2	0.145	20	0.62	0.525	60	0.333	0.083	0.0276
P 3	0.8	20	0.9	0.85	73	0.273	0.7	0.191
P 4	0.455	20	0.6	0.23	53	0.377	0.188	0.377
P 5	0.515	20	0.54	0.34	43	0.465	0.226	0.1053
Mean	0.563	20	0.752	0.529	63.8	0.334	0.4014	0.14018

4.2.3. Discharge of tertiary channel Rwangingo marshland

Measurement of discharge has conducted in the tertiary channel, which takes water to the experimental rice field in which seepage losses was taking place. The discharge measurements were done in the tertiary channel at five different pointsand follow the steps as explained in Chapter 3.

Table 11. Discharge of tertiary channel Rwangingo marshland

Point	Average Depth of water	Average Length	Average Top width	Average Bottom width	Average Time	Velocit y	Average cross section	Average Discharg e

							areas	
	M	M	M	m	Sec	m/s	m2	m^3/sec
P1	0.39	20	0.7	0.6	45	0.444	0.256	0.11366
P 2	0.4	20	0.68	0.5	60	0.333	0.236	0.07859
P 3	0.35	20	0.73	0.41	25	0.8	0.199	0.1592
P4	0.355	20	0.95	0.45	51	0.392	0.248	0.09722
P 5	0.595	20	0.74	0.35	70	0.285	0.324	0.09234
Mean	0.418	20	0.76	0.462	50.2	0.4508	0.2526	0.1082

4.3. Determination of irrigation water use efficiency in Rwangingo marshland

4.3.1. Water conveyance efficiency

The conveyance efficiency is representing the efficiency of water flow in the channel. The water conveyance efficiency is the proportion of water conveyed in one point to another point of the channel. The present study was conducted in the primary, secondary and tertiary channels. The conveyance efficiency is calculated as follows for the earthen channels.

Table 12. Conveyance efficiency of channels at Rwangingo marshland

Type of channels	Discharge in channel m3/sec	Efficiency in conveyance %	Average efficiency %
Primary	0.351	40	59
Secondary	0.1401	77	
Tertiary	0.108		

Table 11, the calculation of the conveyance efficiency of the primary, secondary, and tertiary channel varies from 40 to 77% and it mean that water loosed was varies between 60 to 23%, the average of overallconveyance efficiency is 59%while average water loosed in conveyance channel was 41%. With regard to table 2 of (Osman et al., 2016), the accepted conveyance efficiency should not below 65 %, while this study obtained conveyance efficiency is 59% and it means that water in deep percolation, lack of clearance of canal, canal sedimentation, evaporation of conveyance loss was 40 % through clearing of canal. Rwangingo marshland water loss is 41% it is very heavy, the farmer need to fore seen seepage, debris seepage, deep percolation, canal deterioration by livestock and undesirable vegetation the canals remove it to optimize water use efficiency.

4.3.2. Conveyance loss

Conveyance loss (CL) = $\frac{\text{Qin} - \text{Qout}}{\text{Qin}} * 100$ (14)

$\frac{0.351 - 0.108}{0.351} * 100$=69 %

Qin: discharge inflow (m3/sec)

Out: discharge outflow (m3/sec)

It means that conveyance loss varies is 40% and 69 % are loss in deep percolation, seepage; debris exists in canal and evaporation, this cause famer to use water inefficiently.

4.3.3. Crop water use efficiency

It is the ratio of yield of crop (Y) to the total amount of water used in the field (ETc). It is found out as follows,(Irmak et al., 2011)

E_{CU} (or WUE) = Yi÷ (ETc) =$\frac{4\ 000 \text{ kg/ha}}{72 \frac{\text{mm}}{\text{day}} \text{x } 150 \text{ day}}$=37%

Crop water use efficiency of rice Rwangingo marshland at whole season is 37 % in 150 day of rice growth stage.

4.4. Determination of soil texture properties

Soil texture is the important soilphysical properties studied for assessing the water use efficiency. It describes the proportion of sand, silt and clay particles. Soil sample collected in field of rice under taken study. Three trials have sampled and soil samples collected at three different depthwhich detailed with below: 1) 0 to 20 cm 2) 20 cm to 40 cm 3) 40 to 60 cm because the root depth of rice is 0.5 m and the soil texture can affect root absorption.

4.4.1. Soil texture (at 20 cm depth)

With Auger hole, soil samples have taken from three rice plots at the soil depth of 0 to 20 cm. The soil samples have analyzed using laboratory of CAVM, Busogo campus, the results are exposed table 13

Table 13.Soil texture of the experimental sample at the depth of 0 to 20 cm

Crop	Trial	Soil depth, cm	Clay %	Silt %	Sand%	Soil texture
Rice	Trial1	0-20	32	14	54	Sand clay loam
Rice	Trial 2	0-20	38	22	40	Clay loam
Rice	Trial 3	0-20	49	30	21	Clay
Average		0-20	40	22	38	Clay loam

According to soil textural classes USDA has recorde in the table12, shows thatupper layer of the soil within 20 cm depth is being the types of texture correspondingly of sandy, clay loam and clay.With analysis of soil texture average in USDA triangular of Figure10 in basic of soil texture has confirmed that soil texture in study area is clay loam. The common value of clay, silt and sand from plots sample were 40%, 22% and 38% correspondingly.

4.4.2. Soil texture (Soil texture 20 to 40 cm depth)

Soil sample collected in field of rice under taken three trials at three different soil depth which have sampled at middle core depths of 20 to 40 cm, The results are exposed table 13

Table 14. Soil texture of the experimental sample at the depth of 20 to 40 cm

Crop	Trial	Soil depth, cm	Clay %	Silt %	Sand%	Soil texture
Rice	Trial1	20-40	43	17	40	Clay soil
Rice	Trial 2	20-40	40	25	35	Clay loam soil
Rice	Trial 3	20-40	32	30	38	Clay loam soil
Average		20-40	38	24	38	Clay loam soil

According to soil textural classes USDA has recorded in the table 13, shows that middle layer of the soil within 40 cm depth is being the types of texture correspondingly of sandy, clay loam and clay. With analysis of soil texture average in USDA triangular of Figure11 in basic of soil texture has confirmed that soil texture in study area is clay loam. The mean value of soil texture is clay, silt and sand from plots sample were 38%, 24% and 38% correspondingly.

4.4.3. Soil texture (Soil texture 40 to 60 cm depth)

Soil sample collected in field of rice under taken three trials have sampled and soil samples collected at middle core depths of 40 to 60 cm. The details are given below: With Auger hole, soil samples have taken from three rice plots at the soil depth of 40 to 60 cm. The results are exposed table 14.

Table 15. Soil texture of the experimental sample at the depth of 40 to 60 cm

Crop	Trial	Soil depth, cm	Clay %	Silt %	Sand%	Soil texture
Rice	Trial1	20-40	27	17	56	Sand clay loam soil
Rice	Trial 2	20-40	30	29	41	Clay loam soil
Rice	Trial 3	20-40	35	20	45	Sand clay loam soil
Average		20-40	31	22	47	Sand clay loam soil

According to soil textural classes USDA has recorde in the table 14, shows that middle layer of the soil within 40 cm depth is being the types of texture correspondingly of sandy, clay loam and clay. With analysis of soil texture average in USDA triangular of Figure12 in basic of soil texture has confirmed that soil texture in study area is clay loam. The common value of clay, silt and sand from plots sample were 31%, 22% and 47% correspondingly which is sand clay loam soil.

Brifly, soil texture of top soil and middle soil profile consist of clay loam soil while deeper soil profile consist of sand clay loam soil. FAO (2008) stated that the maximum depth of root of the rice crop varies from 0.5 m to 1.0 m

4.5. Soil infiltration experiment

The infiltration rate defines as the velocity of water enters into the soil. Infiltration is usually calculated in depth either mm or cm while infiltration rate measure millimeter per hour.The table 14, demonstrate the below the results obtained during the trial

Table 16.Infiltration rate of soil in different trialsample

Time(minute)	Experimenttrial plot 1				Experiment trial plot 2				Experiment trial plot 3			
	Water level in cm			Infiltration rate (mm/hr)	Water level in cm			Infiltration rate (mm/hr)	Water level in cm			Infiltration rate (mm/hr)
	Initial filling	Initial filling	Depth of water	mm/hour	Initial filling	Initial filling	Depth of	mm/hour	Initial filling	After filling	Depth of water	mm/hour
10	17	17	0	0	17	17	0	0	17	15	2	60
20	17	14	3	90	17	15	2.0	60	17	15.5	1.5	30
30	17	14.5	2.5	50	17	15.5	1.5	30	17	16	1	15
40	17	15.5	1.5	22	17	16	1	15	17	15.5	1.5	20
45	17	15.5	1.5	20	17	16.7	0.3	4.0	17	15.5	1.5	18

50	17	15.5	1.5	18	17	16.9	0.1	1.2	17	15.5	1.5	15
53	17	15.5	1.5	17	17	16.9	0.1	1.1	17	17	1.5	18
248				22	248			5	255			9
Mean	12 mm/hour											

Infiltration rate in table 14,display that sample1, 2 and 3 are being22mm/hour, 5cm/hr and 9 mm/hr mm/hour respectively. According to table 2, soil infiltration rate with 22 mm/hr is sandy loam soil, 5 mm/hr is classified in clay and 9 mm/hr is clay loam soil.Mean of infiltration rate from the trial sample field of Rwangingo marsh hasbeen 12 mm/hour which given the soil type stated loam soil.

CHAPTER 5

SUMMARY AND CONCLUSIONS

5.1. Conclusion

Rwangingo marshland has rehabilitated in 2016 by MINAGRI to provide different infrastructure manly Earthen canal, lined canal, chute, bridge, culvert and small plot of 40*50 m for facilitating irrigation activities for rice crop. The method of irrigation system in this marshland is surface irrigation systems used different diversions with gravity flowwhich deliver to the downstream via canal network for flooding of rice fields. Good method ofwater application and water use efficiency in Rwangingo marshland will satisfy future foods demands and water needs for different in Rwangingo marshland and whole world. It was mostly focusing on the assessment of irrigation rice water use efficiency at Rwangingo marshland.

General water use in this marshland is highly lost according to the result of chapter fouras summarized below:

The results mean of minimum and maximum temperature varies both 15.5 ºC and 27.1ºC in20 year ago from 2000 up to 2019;it was also found that the highest and lowest month average temperature is February and July respectively such as 27.7^0 C and 13.5^0C.

It was found that total rainfall is 952 mm and monthly with low and high rainfall is July and April respectively of 7.4 mm and 154 mm.

It was found that the peak speed of wind is 7.0 to 7.7 km/hr hasqualifiedsince July to October. Therefore,least speed of wind 5.8 to 6.2 km/hr of both December and April. The common monthly speed of wind is 6.5 km/hr.

The high level of sunshine duration is involving 6.1 to 6.7 hourall through months of July and October while, the lowest sunshine duration of months of January to April is 5.0 to 5.4 hrs.

In study 2, the determination of flow discharges in the irrigation channels and water losses in field applications, water use efficiency and conveyance efficiency in irrigation channel in the marshland was conducted and the conclusions are summarized below.

It was found that the average discharge in the primary channel is 0.351 m^3/sec. According to CIMA International (2008) the designed discharge rate of primary channel was recommended to be 2.8 m^3/sec. The farmers in the marshland widen the primary channel and remove the sediments to get more discharge. This is the reason the calculated discharge was less than the actual flow rate in the channel. It was found that the average discharge in the secondary channel was 0.108m^3/sec. It was also found that the average dischargein the tertiary channel is 0.140m^3/sec. The discharge is varying from time to time depending upon the number of secondary channels used for irrigation and also varies according the discharge rate of the primary channel supplying water to tertiary channels.

In study-3,to resolve the irrigation requirement and rice crop water requirementfrom FAO CROPWAT8.0 which are summarized below;

Reference crop evapotranspiration (ETo) of Rwangingo marsh is 3.92 millimeter per day. The maximum ETo is in the month of August is 4.57 mm/day and the least month is both May and April is 3.5 mm/day.

The analysis has shown the high peak of effective rainfallin study area is116.1 mm essentially month of April and least of 7.3 mm of July characterized with driest month, that requireadditional irrigation.

Computation of FAO cropwat 8.0 provides the result of totalirrigation water requirement of rice crop with season from July to December was established to be 332.8 mm, this period needlittle irrigation application on rice because of high peak of rain fall in Rwangingo site while Julyhas need the highest irrigation because effective rainfall is lesser during that period.

In study-4,to determine the rice water use and irrigation which are summarized below:

Crop water use efficiency of rice Rwangingo marshland at whole season is 37 % in 150 day of rice growth stage.

It means that conveyance loss varies is 40% and 69 % are loss in deep percolation, seepage; debris exists in canal and evaporation, this cause famer to use water inefficiently.

Study obtained conveyance efficiency of 60% and it means that water in deep percolation, lack of clearance of canal, canal sedimentation, evaporation of conveyance loss was 40 % through clearing of canal.

In study-5,to determine same soil physical properties which are summarized below:

With analysis of soil texture average in USDA triangular of Figure13 in basic of soil texture has confirmed that soil texture in study area is clay loam. The common value of clay, silt and sand from plots sample were 40%, 22% and 38% correspondingly.

The average infiltration rate of the experimental field at Rwangingo marsh established of 12 mm/hr of loam soil.

5.2. Recommendation for future studies

The currently Studies of theassessment of rice irrigation water use efficiency at Rwangingo marshland**.** It has high importance for water use management to compensate future water demand in Rwanda, Africa and general the world. The different recommendations which should be taken into consideration for the success of the similar projects are listed below:

The University of Government of Rwanda and other private institutions mayafford the monetarysupportto different scholars in order to increase the research innovation about irrigation water use management, it will provide strategical plan to save water.

The government of Rwanda provides financial needs for irrigation engineers in order to access knowledge, equipments and skills used to determine water conveyance in irrigation commend area which help irrigation engineer in plan of water use management.

The researcher motivate other fellow to carry out like initiatives for adding new ideas which should bring a best methods that solve the trouble of poor water use management.

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APPENDICES

Appendix1. Reference evapotranspiration calculated by Cropwat 8.0

Monthly ETo Penman-Monteith - untitled

Country RWANDA Station GABIRO

Altitude 1743 m. Latitude 1.55 °S Longitude 57.84 °E

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	16.6	27.5	76	144	5.3	17.3	3.77
February	17.1	27.7	75	141	5.2	17.6	3.92
March	14.9	26.2	78	145	5.1	17.5	3.70
April	15.8	26.8	82	139	5.1	16.9	3.50
May	15.3	26.8	79	147	5.7	16.7	3.50
June	14.7	26.5	68	157	6.5	17.2	3.76
July	13.5	27.1	59	175	8.5	20.3	4.45
August	14.2	27.6	60	184	7.5	19.9	4.57
September	15.3	27.4	68	176	6.4	19.2	4.31
October	16.1	27.0	68	166	6.2	19.1	4.26
November	15.8	27.1	81	153	5.6	17.8	3.70
December	16.8	27.1	79	148	5.4	17.2	3.65
Average	15.5	27.1	73	156	6.0	18.0	3.92

Appendix2. Average Rainfall data and effective rainfall of Rwangingo Marshland

Monthly rain - untitled

Station NGARAMA

Eff. rain method USDA S.C. Method

	Rain	Eff rain
	mm	mm
January	39.4	36.9
February	87.7	75.4
March	115.6	94.2
April	154.0	116.1
May	58.3	52.9
June	31.1	29.6
July	7.4	7.3
August	71.7	63.5
September	110.5	91.0
October	109.8	90.5
November	99.9	83.9
December	66.3	59.3
Total	**951.7**	**800.5**

Appendix3. Net irrigation water requirement for rice crop from CROPWAT 8.0

Crop Water Requirements

ETo station: GABIRO

Crop: RICE

Rain station: NGARAMA

Planting date: 15/07

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jul	2	Init	1.00	4.45	26.7	0.0	26.7
Jul	3	Init	1.00	4.49	49.4	5.1	44.3
Aug	1	Deve	1.00	4.53	45.3	15.8	29.5
Aug	2	Deve	1.03	4.69	46.9	22.5	24.4
Aug	3	Deve	1.06	4.77	52.5	25.1	27.4
Sep	1	Deve	1.10	4.85	48.5	28.1	20.3
Sep	2	Deve	1.14	4.90	49.0	31.6	17.4
Sep	3	Mid	1.17	5.03	50.3	31.1	19.2
Oct	1	Mid	1.18	5.04	50.4	30.4	20.0
Oct	2	Mid	1.18	5.02	50.2	30.4	19.8
Oct	3	Mid	1.18	4.80	52.8	29.6	23.2
Nov	1	Late	1.17	4.56	45.6	29.2	16.3
Nov	2	Late	1.12	4.15	41.5	28.8	12.7
Nov	3	Late	1.06	3.92	39.2	25.8	13.4
Dec	1	Late	1.01	3.69	36.9	22.5	14.4
Dec	2	Late	0.97	3.55	3.6	2.0	3.6
					688.8	**358.0**	**332.8**

Appendix4. Irrigation scheduling and effective rainfall

Date	Days	Stage	Rain	Ks	Eta %	Depl %	Net Irr, mm	Deficit, mm	Loss, mm	Gr. Irr, mm	Flow l/s/ha
14July	1	Initi	0.0	0.63	63	60	16.3	0.0	0.0	23.3	2.69
17July	3	Initi	0.0	1.00	100	33	8.9	0.0	0.0	12.7	0.74
19July	5	Initi	0.0	1.00	100	33	8.9	0.0	0.0	12.7	0.74
21July	7	Initi	0.0	1.00	100	24	8.9	0.0	0.0	12.8	0.74
23July	9	Initi	2.6	1.00	100	33	6.4	0.0	0.0	9.1	0.53
25July	11	Initi	0.0	1.00	100	24	9.0	0.0	0.0	12.8	0.74
27July	13	Initi	0.0	1.00	100	33	6.4	0.0	0.0	12.8	0.53
29July	15	Initi	0.0	1.00	100	33	9.0	0.0	0.0	9.1	0.74
31July	17	init	0.0	1.0	100	33	9.0	0.0	0.0	12.8	0.74
2Aug	19	init	0.0	1.0	100	34	9.1	0.0	0.0	13.0	0.75
4Aug	21	init	0.0	1.0	100	34	9.1	0.0	0.0	13.0	0.75
6Aug	23	init	0.0	1.0	100	34	9.1	0.0	0.0	13.0	0.75
8Aug	25	init	0.0	1.0	100	34	9.1	0.0	0.0	13.0	0.75
10Aug	27	Dev	0.0	1.0	100	34	9.1	0.0	0.0	13.0	0.75
12Aug	29	Dev	0.0	1.0	100	34	9.1	0.0	0.0	13.0	0.75
14Sept	62	Dev	0.0	1.0	100	36	9.8	0.0	0.0	14.0	0.81
16Sept	64	Dev	0.0	1.0	100	36	9.8	0.0	0.0	14.0	0.81

18Sept	66	Dev	0.0	1.0	100	36	9.8	0.0	0.0	14.0	0.81
20Sept	68	Dev	0.0	1.0	100	36	9.8	0.0	0.0	14.0	0.81
22Sept	70	Dev	0.0	1.0	100	37	10.1	0.0	0.0	14.4	0.83
24Sept	72	Dev	0.0	1.0	100	37	10.1	0.0	0.0	14.4	0.83
26Sept	74	Dev	0.0	1.0	100	37	10.1	0.0	0.0	14.4	0.83
28Sept	76	Mid	0.0	1.0	100	37	10.1	0.0	0.0	14.4	0.83
30Sept	78	Mid	0.0	1.0	100	37	10.1	0.0	0.0	14.4	0.83
4 Oct	80	Mid	0.0	1.0	100	37	10.1	0.0	0.0	14.4	0.83
4 Oct	82	Mid	0.0	1.0	100	37	10.1	0.0	0.0	14.4	0.83
4 Oct	84	Mid	0.0	1.0	100	37	10.1	0.0	0.0	14.4	0.83
4 Oct	86	Mid	0.0	1.0	100	37	10.1	0.0	0.0	14.4	0.83
4 Oct	88	Mid	0.0	1.0	100	37	10.1	0.0	0.0	14.4	0.83
4 Oct	90	Mid	0.0	1.0	100	37	10.0	0.0	0.0	14.4	0.83
14Oct	92	Mid	0.0	1.0	100	37	10.0	0.0	0.0	14.4	0.83
16Oct	94	Mid	0.0	1.0	100	37	10.0	0.0	0.0	14.4	0.83
18Oct	96	Mid	0.0	1.0	100	37	10.0	0.0	0.0	14.4	0.83
20Oct	98	Mid	0.0	1.0	100	37	10.0	0.0	0.0	14.4	0.83
22Oct	100	Mid	0.0	1.0	100	36	9.6	0.0	0.0	13.7	0.79
24Oct	102	Mid	0.0	1.0	100	36	9.6	0.0	0.0	13.7	0.79
26Oct	104	Mid	0.0	1.0	100	36	9.6	0.0	0.0	13.7	0.79

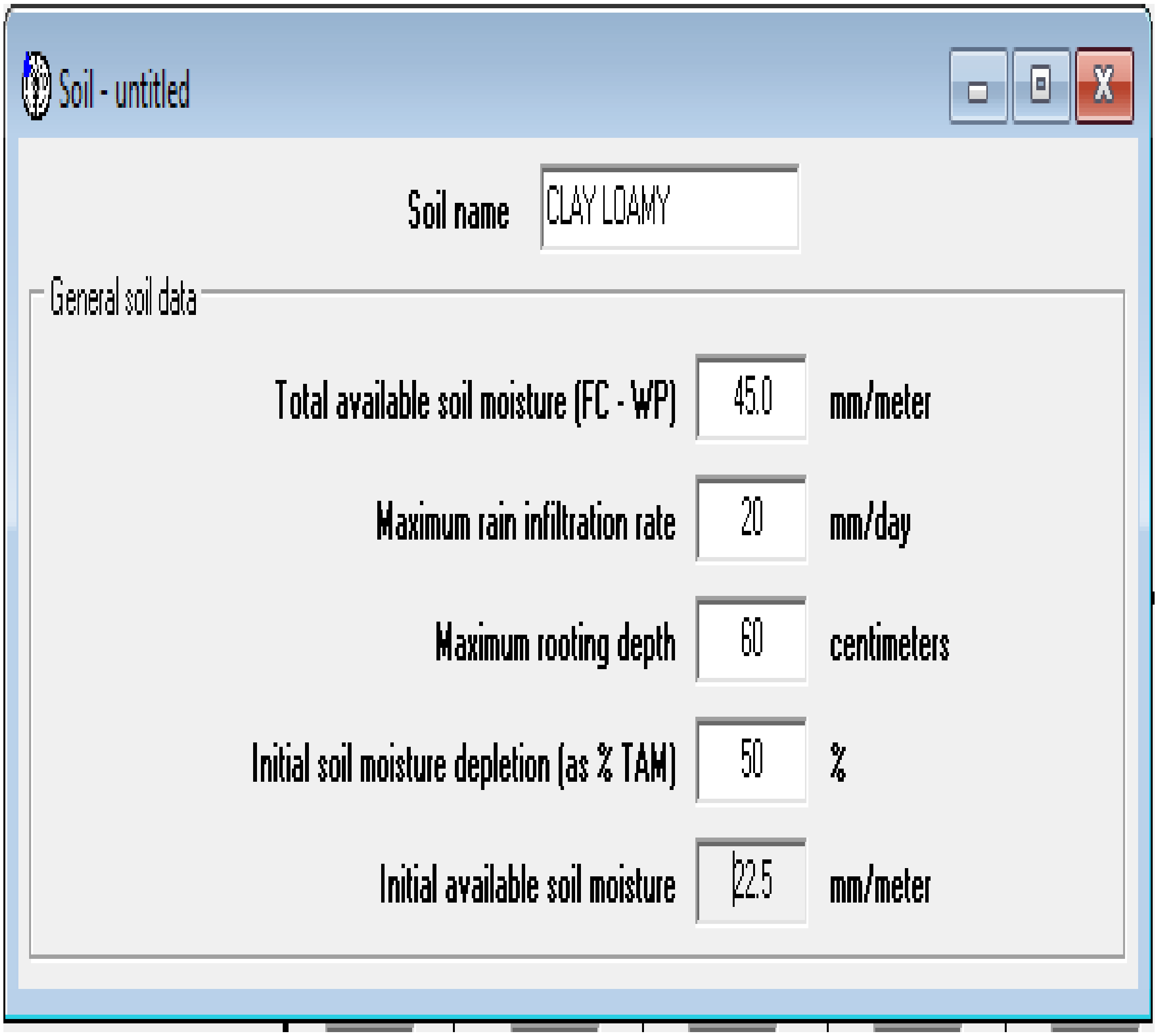
28Oct	106	Mid	0.0	1.0	100	36	9.6	0.0	0.0	13.4	0.79
30Oct	108	Mid	0.0	1.0	100	36	9.6	0.0	0.0	13.0	0.79
1Nov	110	Mid	0.0	1.0	100	35	9.4	0.0	0.0	13.0	0.77
4Nov	113	Mid	0.0	1.0	100	34	9.1	0.0	0.0	13.0	0.50
6Nov	115	Mid	0.0	1.0	100	34	9.1	0.0	0.0	13.0	0.75
8Nov	117	End	0.0	1.0	100	34	9.1	0.0	0.0	13.0	0.75
10Nov	119	End	0.0	1.0	100	34	9.1	0.0	0.0	13.0	0.75
12Nov	121	End	0.0	1.0	100	31	8.3	0.0	0.0	11.9	0.69
14Nov	123	End	0.0	1.0	100	65	11.3	0.0	0.0	11.9	0.69
16Nov	125	End	0.0	1.0	100	59	12.1	0.0	0.0	11.9	0.69
18Nov	127	End	0.0	1.0	100	31	8.3	0.0	0.0	11.9	0.69
20Nov	129	End	0.0	1.0	100	31	8.3	0.0	0.0	11.9	0.69
22Nov	131	End	0.0	1.0	100	31	8.3	0.0	0.0	11.2	0.65
24Nov	133	End	0.0	1.0	100	31	8.3	0.0	0.0	11.2	0.65
26Nov	135	End	0.0	1.0	100	29	7.8	0.0	0.0	11.2	0.65
28Nov	137	End	0.0	1.0	100	29	7.8	0.0	0.0	11.2	0.65
30Nov	139	End	0.0	1.0	100	29	7.8	0.0	0.0	11.2	0.65
2Dec	141	End	0.0	1.0	100	29	7.8	0.0	0.0	10.5	0.61
4Dec	143	End	0.0	1.0	100	29	7.8	0.0	0.0	10.5	0.61
6Dec	145	End	0.0	1.0	100	27	7.4	0.0	0.0	10.5	0.61

8Dec	147	End	0.0	1.0	100	27	7.4	0.0	0.0	10.5	0.61
10Dec	149	End	0.0	1.0	100	27	7.4	0.0	0.0	10.5	0.61
11Dec	End	End	0.0	1.0	100	0					

IRRIGATION SCHEDULE AND RAINFALL

Total gross irrigation	974.9	Mm	Total rainfall	422.4	Mm
Total net irrigation	682.5	mm	Effective rainfall	14.7	Mm
Total irrigation losses	0.0	Mm	Total rain loss	407.8	Mm
Actual water use by crop	683.6	mm	Moisture deficit at harvest	0.0	Mm
Potential water use by crop	685.3	mm	Actual irrigation requirement	670.6	Mm
			Efficiency of rain	3.5	%
Efficiency of irrigation schedule	100	%			
Deficiency of irrigation schedule	0.0	%			

Appendix5. Computed physical soil properties in Cropwat 8.0



Appendix6. Canal layout of Rwangingo marshland