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Brendaline Shieke NKENEN

RICE PRODUCTION IN CAMEROON: RISKS AND OPPORTUNITIES

Defended on 17/11/2021 Before the Following Committee:

Chair	Ziani Cherif Houcine	Prof	University of Tlemcen, Algeria
Supervisor	Khaldoon A. Mourad	Dr	Swedish National Road and Transport Research Institute, Sweden,
External Examiner	Sheona Shakelton	Prof	University of Capetown, South Africa
Internal Examiner	Abderezzak Bouanani	Prof	University of Tlemcen, Algeria

PAN-AFRICAN UNIVERSITY
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(Including CLIMATE CHANGE)

RICE PRODUCTION IN CAMEROON: RISKS AND OPPORTUNITIES

WATER ENGINEERING

NKENEN BRENDALINE SHIEKE

BSc (Agricultural and Environmental Engineering)

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DEDICATION

This work is dedicated to the NKENEN’s family.

THESIS AND DISSERTATION APPROVAL PAGE

Submitted by

NKENEN BRENDALINE SHIEKE		____________________
Name of Student	Signature	Date

Approved by Examining Board

____________________	____________________	____________________
Name of Examiner	Signature	Date

Thesis/ Dissertation Advisors

____________________	____________________	____________________
Name of Advisor	Signature	Date
____________________	____________________	____________________
Name of Co-Advisor	Signature	Date

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Certified by

Dr. Khaldoon A. Mourad (Supervisor)

Signature Date : 18.10.2021

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ABBREVIATION

CARD	Coalition for African Rice Development
CWR	Crop Water Requirements
DESA	Department of Agricultural Surveys and Statistics
FAO	Food and Agricultural Organization
GBWP	Gross Biomass Water Productivity
GCWP	Gross Crop water productivity
GP-DERUDEP	Grass field Participatory and Decentralized Rural Development
GP-IRDP	Grass field Participatory and Integrated Rural Development
GRFC	Global Report on Food Crises
IRRI	International Rice Research Institute
JICA	Japan International Cooperation Agency
MINADER	Ministry of Agriculture and Rural Development
NCWP	Net Crop water Productivity
NGO	Non-Governmental Organization
NRDS	National Rice Development strategy
PADFA	Agricultural Sector Development Support Project
PRODERIP	Project for the Development of Irrigated and Rainfed Rice Cultivation
SDG	Sustainable Development Goals

SEMRY	*The Société d'Expansion et de Modernisation de la Riziculture de Yagoua*
UNVDA	Upper Noun Valley Development Authority

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ABSTRACT

Cameroon is a country in Africa with a diverse climate and culture. More than 70% of its population is employed in the agricultural sector with rice being the staple food. The aim of this study was to assess the risks and opportunities in rice production in Cameroon, using a water productivity tool and assessing the perception of farmers towards the risks and opportunities they have. This was done through the review of literature and field visits to assess the potential of the Highlands zone and the Sudano-Sahel zones. Further, CROPWAT model and WaPOR portal were used to analyze crop water requirements and gross water biomass productivity (GWBP), respectively. Two farms were visited, and their data collected in the respective institutions to analyze their rice crop water requirements and water productivity values. Field interviews were conducted with 100 rice farmers to understand their perception on the risks associated with rice production in their locality. The Sudano-Sahel zone has a potential of 460,181.3 Ha for rainfed rice and 252,128.7 Ha for lowland rice. Also, the highland zone has the potential of 26,520 Ha for rainfed rice and 43,329 Ha for lowland rice. From the results, SEMRY seed farm in Yagoua needs 1260.2 mm (dry season) and 491.4 mm (rainy season) as irrigation water requirement, with mean annual GWBP between 0.4200 and 0.7288 kg/m^3 for the Sudano-sahelian agro-ecological zone. UNVDA seed farm in Ndop needs 201.5 mm (rainy season) as irrigation water requirement, with mean annual GWBP between 2.4499 and 2.7455 kg/m^3 for the Highlands agro-ecological zone. The most perceived risks in rice production by farmers at Yagoua, in the Sudano-sahelian are drought, inadequate funds, and fluctuations in market prices, pests, floods, water borne diseases and exploitation from input suppliers, in order of their degree of severity from the top. For the highland zones, the risks observed in rice production are; low technological know-how, inadequate funds, pests, poor roads, and irregular electricity supplies for milling. Cameroon endowed with natural resources both inland and in water. As such, a layman can say there is no cause for alarm now, but in the nearest future, with the increase in population and the country's vision to be an emerging nation by 2035, water pricing schemes should be the next thing on the government's agenda. The risks in rice production can be mitigated by a close collaboration of the different stakeholders involved from the family level up to the government.

Key words: Rice potential, risks, water requirement and productivity.

ABSTRACT (FRENCH)

Le Cameroun qui est décrit comme l'Afrique en miniature en raison de sa diversité de climat et de culture représentant l'Afrique, plus de 70% de sa population est employée par le secteur agricole avec le riz comme aliment de base. Cette étude vise à évaluer les risques et les opportunités dans la production de riz au Cameroun en utilisant l'outil de productivité de l'eau et la perception des agriculteurs envers les risques et les opportunités qu'ils ont. Ceci a été fait à travers une revue de la littérature et des visites de terrain pour accéder au potentiel de la zone des Hautes Terres et des zones soudano-sahéliennes et l'utilisation des portails CROPWAT et WAPOR pour analyser les besoins en eau des cultures et la productivité brute de la biomasse en eau (GWBP) respectivement. Deux fermes d'étude de cas ont été visitées et leurs données ont été collectées dans les institutions respectives pour analyser les besoins en eau des cultures de riz et les valeurs de productivité de l'eau. Des entretiens sur le terrain ont été menés avec 100 riziculteurs pour comprendre leur perception des risques associés à la production de riz dans leur localité. La zone soudano-sahélienne a un potentiel de 460 181,3 ha pour le riz pluvial et de 252 128,7 ha pour le riz de bas-fond. De même, la zone des Hauts Plateaux a un potentiel de 26 520 Ha pour le riz pluvial et 43 329 Ha pour le riz de bas-fond. D'après les résultats, la ferme semencière SEMRY à Yagoua a besoin de 1260.2mm (saison sèche) et 491.4mm (saison des pluies) comme besoin en eau d'irrigation avec un GWBP annuel moyen entre 0.4200 et 0.7288 kg/m3 pour la zone agro-écologique soudano-sahélienne. La ferme semencière de l'UNVDA à Ndop a besoin de 201,5 mm (saison des pluies) comme besoin en eau d'irrigation (avec un GWBP annuel moyen entre 2,4499 et 2,7455 kg/m^3 pour la zone agro-écologique des Highlands. Les risques les plus perçus dans la production de riz par les agriculteurs de Yagoua, dans la zone soudano-sahélienne, sont la sécheresse, l'insuffisance de fonds, les fluctuations des prix du marché, les ravageurs, les inondations, les maladies hydriques et l'exploitation par les fournisseurs d'intrants, par ordre de gravité en partant du haut. Pour les zones d'altitude, les risques observés dans la production de riz sont le faible savoir-faire technologique, l'insuffisance des fonds, les ravageurs, le mauvais état des routes et l'irrégularité de l'approvisionnement en électricité pour l'usinage. Le Cameroun a été béni par l'abondance de ses ressources naturelles, qu'il s'agisse de l'eau ou de la terre, et un profane peut dire qu'il n'y a pas lieu de s'alarmer aujourd'hui, mais dans un avenir proche, avec l'augmentation de la population et la vision du pays de devenir une nation émergente d'ici 2035, la tarification de l'eau devrait être la prochaine chose à l'ordre du jour du gouvernement. Les risques liés à la production de riz peuvent être atténués par une collaboration étroite entre les différents acteurs impliqués, du niveau familial au gouvernement.

Mots clés : Potentiel du riz, risques, besoins en eau et productivité.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Cameroon is described as Africa in miniature because of its diversity in climate and culture. More than 70% of its population is employed in the agricultural sector; cultivating coffee, cotton, cocoa, rice, potatoes, and beans. Most of the production is exported in its raw form. Rice (*Oryza sativa*) is a staple food in Cameroon cooked in diverse ways; fufu, rice pap, jollof rice, fried rice among others. Rice plays a critical role in fighting food insecurity, as it is consumed in the whole country and it is one of the foods that is distributed to refugees, internally displaced people, or disadvantaged homes to boost their livelihood in Cameroon and the world at large.

Food security is a situation where people have social, physical, economic and stable access to safe, sufficient and nutritious food that meets their food preference for dietary needs, a healthy and active life (FAO, 2013). Stability, accessibility, availability and use are the four dimensions of food security. However, owing to the recent developments, Peng & Berry (2018) cited sustainability as the fifth dimension of food security. Sub Saharan Africa is facing food insecurity even though it is regarded as “the bread basket”. This can be attributed to the great gap between the recorded yields and the potential of its land resources (Guilpart *et al*., 2017). Additionally, the gap is due to low adoption of advanced technologies by farmers. Although, low-tech agro-economical approaches with lower yields per unit land may be better positioned to create socioeconomic conditions under which advanced high technology adoption becomes an economical safe choice (Adenle *et al*., 2019). Low technology, or simple strategies implemented by some farmers to have improved yields can easily set pace for other farmers to follow, while creating an enabling ground for advanced technology implementation. To achieve sustainable agriculture and food security in the future, it is necessary to increase water productivity (Pirmoradian *et al*., 2020). There is an increasing demand for rice, which has seen an expansion of rice-growing areas compared to other crops in Africa (Materu *et al*., 2018).

1.2 Problem Statement

Food production depends on the availability and productivity of land and water. However, unsustainable land and water use threaten most developing countries. There is a need to produce more to feed the growing population, and in a cost-effective manner. The Global Report on Food Crises (GRFC) reported 135 million people in 55 countries and territories needed food, livelihood, and nutrition assistance, as a result of economic shocks, conflict, weather extremes, or a combination of the three drivers (FAO, 2020a; Security & Network, 2020). Moreover, the coronavirus pandemic has created a kind of economic chaos that affects people's economic and material access to food (Growth & Slowing, 2020). This has resulted in farmers having less income, but with the current food crisis around the globe, still there is more demand for food production. Food production relies on water for plant growth; however, water resources are under immense stress from pollution, deforestation, and environmental degradation. This situation requires more efficient use of water to meet food demands. There is a disparity in rainfall frequency and intensity, and farmers have engaged in irrigation to reduce the effects of decreasing water availability per head, whose impact is felt more in the developing countries (Patel, 2015) such as Cameroon. Farmers have different practices, such that on the same type of soil, different yields are produced which leads to different incomes to farmers.

In Cameroon, farmers who cultivate the same crop in different farmlands of the same area have different yields. These farmers face the same livelihood and economic responsibilities with agriculture being the highest sector to employ Cameroonians and many households depending on this source of income. In 1975, Cameroon was producing 80% of its nationally consumed rice, however, by 2007, the country was importing close to 90% of the rice consumed (World News, 2021). Cameroon is at a high risk of deteriorating food security because of the high prices (FAO, 2008). Any problem in the food production and consumption pathway which is food insecurity needs attention as farmers having low yields in good potential areas pose food insecurity (Peng & Berry, 2018). Thus, this study aimed at developing means to bridge this gap by assessing the risks and opportunities in rice production in Cameroon.

1.2.1 Main Objective

The main objective of this study was to assess the risks and opportunities in rice production in Cameroon, using the water productivity tool and also determine the perception of farmers on the risks and opportunities in rice production.

1.2.2 Specific Objectives

The specific objectives of this study were to:

I. assess the potential of rice production in Yagoua (Sudano-Sahel zone) and Ndop plains (Highland zone), Cameroon.
II. assess rice water requirements and the gross biomass water productivity for a period of 10-years at Yagoua and Ndop Plains.
III. establish the risks and opportunities in rice production in Cameroon (Yagoua and Ndop plains).

1.3 Research Questions

I. What is the potential of rice production in Yagoua and Ndop plains, Cameroon?
II. What are the rice water requirements and gross biomass water productivity in the past 10 years in Yagoua (Sudano-Sahel zone) and the Ndop Plains (Highland zone)?
III. Which are the risks and opportunities of rice production in Yagoua and Ndop plains?

1.4 Justification of Study

Policies aimed at improving water productivity for agricultural systems and food availability, combined with social protection and other strategies to increase the income of poor families, can have positive effects and boost rural development. This can be achieved through creation of vigorous markets, employment opportunities and making possible equitable economic growth (FAO et al., 2014). Assessment of risks and opportunities using water productivity tools helps to tackle the issue of food security at the national level. Water productivity of an area further helps managers in making informed decisions by paying close attention to the background of water productivity trends of a particular field. This is possible through analyzing and evaluating the risks ranging from field stresses to market risk.

In this study, strategies to increase water productivity and adaptation strategies against current and future risks in rice production are established. This study helps in formulating water and agricultural policies that seek to improve agricultural water management, promote sustainable farming, and improve the economic returns of agricultural productivity.

There are projects to develop more rice farms in the Northwest region and this study lays a foundation to propose strategies for increasing farmers' yields. Additionally, this study avails vital information that informs Cameroonian institutions towards achieving vision 2035 through increasing agricultural productivity, while also exploiting water resources sustainably. The findings of this study will further help increase rice production, which will help in the attainment of the Africa Union 2063 aspiration, especially the aspiration to reduce food imports. The results of this study will contribute to the attainment of Sustainable Development Goals (SDGs) of the United Nation. Particularly, SDG 2 (zero hunger); by informing strategies to increase crop yields and SDG 1 (No poverty); through increased crop productivity, improved livelihood and economic standards. Further, the findings address SDG 6 (water and sanitation); by informing strategies of increasing water use efficiency in the agricultural sector and lastly, SDG 12 (responsible consumption and production); via the adoption of sustainable management of water and land.

1.5 Scope and Limitations

This study assessed the risks associated with rice production in the study area, the crop and irrigation water requirements, the current and the evolution of water productivity in the area over a 10-year period. Crop modeling was used to evaluate water productivity. Remote sensing and GIS were used to get the needed data for the 10-year period and to analyze it statistically as used by Mainuddin *et al*. (2020).

Throughout the course of this study, some limitations were encountered; low land holding capacity, crisis and insufficient data. Low land holding capacity made it difficult to calculate the water productivity of rice, as farmers plant on different dates and have different management strategies for their farms. In addition, Cameroon's data is only available on the first level of the WAPOR portal, with 250 million pixels, which makes the two seed farms selected as the case studies displayed with only two pixels. The Anglophone crisis made it impossible for questionnaires to be administered at the UNVDA area due to insecurity. The data available was insufficient as many institutions have bureaucratic policies to release data or data not available at all. Consequently, remotely sensed data were used.

CHAPTER TWO

LITERATURE REVIEW

The literature was reviewed according to the research questions under study.

2.1 Rice Production and Opportunities

2.1.1 Overview of Global Rice Production

More than half of the world's population (estimated at 3.5 billion population) consume rice as a staple food. Approximately, 50% of the global rice is produced and consumed in India and China, the rest is produced in other countries except for Antarctica (Muthayya *et al*. 2014; Maclean *et al.* 2013). Rice have different varieties that grow and are preferred in different regions; stick soft rice varieties in South East Asia, and hard texture rice in Africa (International Rice Research Institute, 2018). According to Food Agricultural Organization (2019), rice is cultivated in over 162,055,938 ha worldwide producing 75,547,800 tons of rice paddy (503,901,025 tons of equivalent milled rice). KNOEMA (2021) has in its database that China is the world's largest producer of paddy rice as she produced 211 million tons in 2019, accounting for 27.92% of the world's paddy rice production. The top five countries (China, India, Indonesia, Bangladesh, Vietnam) account for 71.53%. There are two types of rice production: lowland and upland rice farming. About 20% of the world's rice is produced from rainfed lowland farming in most parts of Africa, parts of Southeast Asia and South Asia. Whereas, upland rice accounts for 4% of rice production (Muthayya *et al.* 2014).

The main cropping patterns include rice-rice, rice-mustard, rice-wheat, rice-peanut, rice-sunflower, rice-potato, rice-chickpea, rice-winter maize. Short-duration pulses like cowpea, green gram, black gram, or oilseed crops like sesame can be introduced as a third crop, and rice-winter vegetables (Chauhan *et al*., 2017) systems in irrigated medium land settings. This system has a cropping intensity of 200 percent. However, short-duration pulses like cowpea, green gram, black gram, or oilseed crops like sesame can be introduced as a third crop which can boost cropping intensity. This is only conceivable in regions with the infrastructure to deliver 1–2 lifesaving irrigations to the third crop. Rice-potato-sesame, rice-wheat-green gram, and rice-wheat-jute are the most acceptable varieties in West Bengal. Rice-potato-sunflower, rice-potato-winter maize, and rice-sunflower, have all been found to be more productive than the traditional system of 200 percent cropping intensity with rice-wheat or rice-winter maize under Punjab circumstances (Tiwari *et al*. 2013). In Yagoua and Ndop, the land controlled by SEMRY and UNVDA respectively promote single crop cultivation on the rice plots.

Ferrero and Vidotto (2006) gave an outstanding summary of rice planting in Italy, Spain, and France. European rice is planted during the spring, as it is in most Mediterranean climate regions. In Italy, rice is cultivated towards the end of March or the beginning of April, and harvested between September and October, unlike in most European countries. The planting period, on the other hand, can be extended over a long period of time, even till the end of May. The management of rice in Italy is depicted in Figure 1. Plowing the field is frequently done before planting to prepare the seedbed. Every year or every two years, fields are laser-leveled. In 2012, rice was broadcast-seeded into flooded fields in around 70% of the fields, using a centrifugal spreader that can also be used to apply fertilizers. For the seed to sink and germinate in the flooded field, it is normally immersed in water for 24 hours. Rice was drilled into dry soil in 30% of the acreage in 2012. When Clearfield rice types are employed in the fields, this technology is extremely useful. These variants were chosen from rice tissue cultures that showed resistance to imidazoline. The Clearfield technique allows weedy rice to be controlled, which is a common problem in rice production in Europe. Agrochemical treatment is frequently easier in dry-seeded rice fields than in flooded ones.

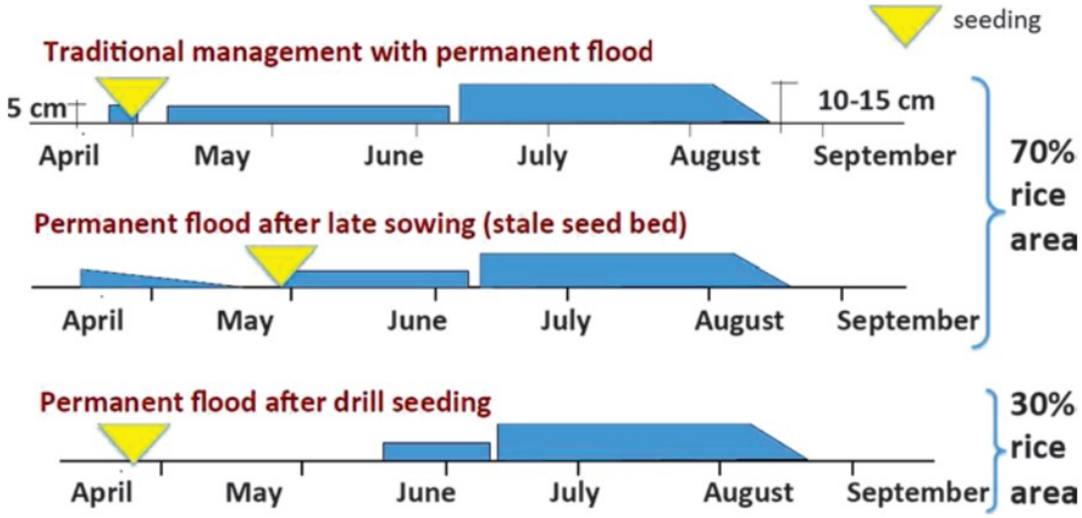


Figure 1 : Italy's Rice Management (Vidotto, 2013)

2.1.2 Rice production in Cameroon

Cameroon is an import-dependent country, as it imports more than 80% of its nationally consumed rice, amounting to 145 billion Francs CFA; 263 million USD yearly (Horwitz, 2014). In Cameroon, rice is cultivated in the Northern, Central and Western regions, in five main areas that are covered by development corporations or centers for their production and technical facilitation in their various supply chain units. Rice is grown in the Sudano Sahel, savannah and forest ecological zones of Cameroon for duration of 6 months in the normal season and 5 months in the off season (Goufo, 2008). Cameroon has over 268,408 ha of land under rice production, with a production capacity of 313,084 tons of paddy rice and 208,827 tons of milled rice (FAO, 2019). Rice production had been fluctuating in Cameroon from 1970 to 2019 (Figure 2).

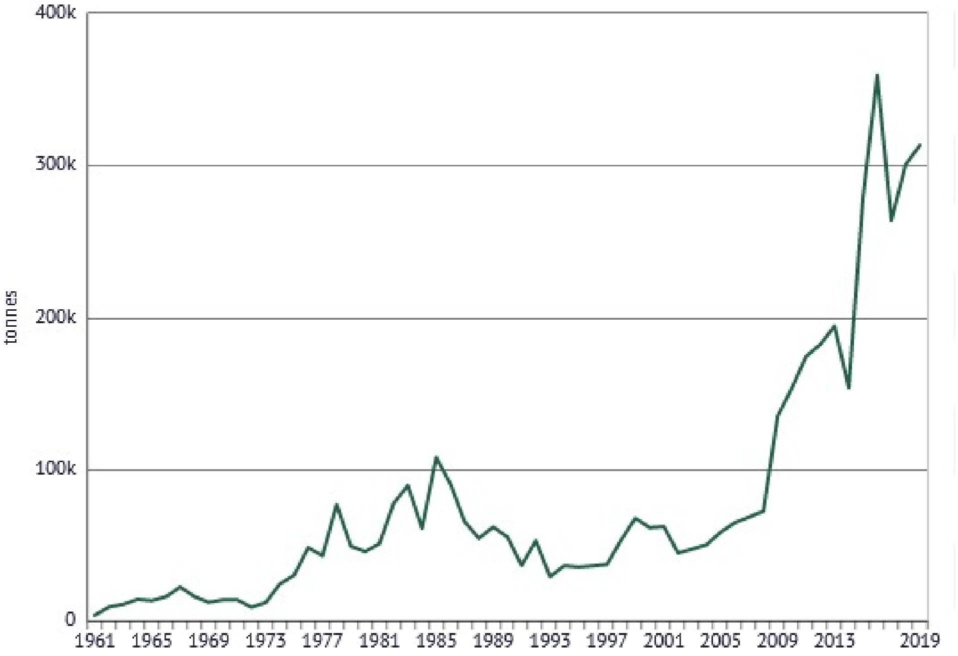


Figure 2: Rice production trend in Cameroon (KNOEMA, 2021.)

Rice production sums up from different production units in different locations in the country. These different units are being aided by either development authorities or projects with the main aim of increasing rice production. Table 1 presents rice production units in Cameroon with development authorities, the populations involved with their dates of existence, the type of rice farming and production capacities.

Table 1: Major Rice Development Authorities and their area of Operation

Name of authority and date of creation	Target population	Functions	Area covering and	REFERENCES
Upper Noun Valley Development Authority (UNVDA) 1970	Works with 14000 rice farmers and targeting 70000 rice farmers in the future	It intervenes in the rice production, processing, and marketing of rice while providing technical support	In the North West and west regions; 2532 hectares area developed under this authority. 15000HA production capacity*	(Iii, 2009; *North-West Region - UNVDA*, n.d, UNVDA report.)
Société de Développent de la Riziculture dans la Plaine de Mbo (SODERIM) 1978	The establishment has closed its doors	To intervene, improve on rice production and reduce unemployment I the district of Santcho	The area under production by farmers in this area is 200ha with a 3000ha production capacity*	(Iii, 2009; *World News CAMEROUN:* n.d.)
The *Société d'Expansion et de Modernisation de la Riziculture de Yagoua* (SEMRY)	Still functioning	It intervenes in the rice production, processing, and marketing of rice while providing technical support	11000ha in production and 20000ha capacity*	(Iii, 2009)

*the available land fit for rice farming

There are other local populations cultivating either upland or lowland rice and being taken care of by local development partners, Non-Governmental Organizations (NGO), and associations (Table 2).

Table 2: Major rice projects and their area of operation

Location	Project name	Type of rice cultivation	Potential capacity (Ha)	Reference
Mbaw-mbonso basin	GP DERUDEP, The Grassfield Participatory Decentralised Rural Development Project	Lowland cultivation	1200Ha to be developed by the project in an area with a 4000ha capacity	(GP-DERUDEP office)
Menchum Valley	PADFA (*Projet d'appui au Développement des Filières Agricoles)*	Upland rice cultivation	2000	(GP-DERUDEP office)
Center, south, east regions	The Grassfield Participatory Integrated Rural Development Project (GP-IRDP)	Upland rice cultivation and lowland rice cultivation in the UNVDA area	unknown	(JICA, 2021)

With the above schemes, Cameroon has sufficient untapped arable land and a great population, that is centered on agricultural production. Thus, it is possible to meet the national demand for rice albeit with challenges that reduce farmer's efforts (Horwitz, 2014). Although Cameroon produces rice, most of it is consumed by the neighboring countries like Nigeria and Chad. FAO (2019), reports that the average yield of rice paddy is 4.6 tons/ha in Cameroon. The varieties of rice produced in Cameroon include IR 46, African rice and Thailand.

2.2 Crop Water Requirements and Water Productivity

2.2.1 Crop Water Requirements

Water is an essential requirement for crop growth. The amount of water needed varies from plant to plant. This is because plants have different crop water requirements, due to their difference in growth patterns. According to Individual agro-ecological units' reference, evapotranspiration ET_0 is computed using the FAO Penman-Monteith technique and FAO decision support software – CROPWAT 8.0, based on FAO Irrigation and Drainage Paper 56 (Surendran *et al.*, 2015; FAO 1998). The FAO CROPWAT software (FAO, 2009) includes techniques for calculating reference crop evapotranspiration and crop water needs. Also, the software performs crop water consumption simulations under a variety of climatic, crop, and soil circumstances (www.fao.org). There are different techniques for determining crop and irrigation water requirements. However, methods such as field measurements are expensive and time consuming. Thus, researchers have adopted modelling as a means to navigate the aforementioned challenges. One of the widely used models to estimate crop and irrigation water requirements is the CROPWAT model. The model was developed to calculate crop water requirement (CWR) and irrigation water requirement (IWR), daily rate of reference and crop evapotranspiration for varying crop patterns based on specific climate, soil, and crop data for a specific location (Moseki et al., 2019). The algorithm for the estimation of CWR and IWR in the model is based on the Penman-Monteith equation. Worldwide, researchers have used CROPWAT and reported reliable results (Aliku & Oshunsanya, 2016; Bokke & Shoro, 2020; Doria & Madramootoo, 2012; Surendran *et al.*, 2015). Several studies have also been conducted in Africa using CROPWAT (Akinbile et al., 2020; Desta et al., 2015; Fitsume et al., 2017; Laouisset & Dellal, 2016; Moseki et al., 2019)

Irrigation water needs can be defined as the amount (or depth) of irrigation water necessary, in addition to effective rainfall to generate the desired crop yield and quality, as well as to maintain a satisfactory ionic balance in the root zone (Bokke & Shoro, 2020). The irrigation demands of crops are determined by the crop water requirements and the precipitation quantities accounted on a daily time step (Doria & Madramootoo, 2012). Fixed proportion of rainfall, reliable rainfall, empirical formula, and USDA Soil Conservation Service Method are the 4 techniques used by CROPWAT to have effective rainfall for irrigation design and planning. According to a study carried out by Bokko & Shoro (2020), in water scarce locations (areas like Yagoua in the Sudano-Sahelian zone), the USDA SC technique is recommended, whereas in water-abundant ones (areas like Ndop in the Highlands zone), the dependable Rain method is recommended. Several researcherss have used CROPWAT and reported reliable results (Aliku & Oshunsanya, 2016; Bokke & Shoro, 2020; Doria & Madramootoo, 2012; Surendran *et al.*, 2015).

2.2.2 Water productivity

Productivity is a measure of the benefit generated per unit of resource used. The resource ranging from land used, water supplied or consumed, and benefits categorized into economic, biophysical, and social output for the case of water productivity. The crop yield per unit of water evaporated is known as crop water productivity (Bastiaanssen & Steduto, 2016). The production of rice is greatly dependent on water and ways to improve water productivity is necessitated with the help of irrigation management procedures (Pirmoradian *et al.*, 2020). Water productivity is a performance indicator for most irrigation schemes as it gives out the crop yield per given environmental conditions in the form of evapotranspiration water productivity. There have been recent studies to analyze water productivity in relation to rice production by several researchers (Anika *et al.*, 2019; Djaman *et al.*, 2017; Liyantono *et al.*, 2019; Pirmoradian *et al.*, 2020). Some of these studies show that water productivity varies according to the season and irrigation system in use (Anika *et al.*, 2019; Pirmoradian *et al.*, 2020). A decrease in water productivity comes from field stresses like temperature, water nutrient, salinity, aeration, weeds, diseases, and pests, which make up the risks encountered in the field by farmers.

Water productivity can be measured using crop models, which have been used as supporting tools in decision-making, to increase the efficiency of planning and management of crop production. For example, AQUACROP model demonstrates how yield responds to water with a few parameters and other input data (Pirmoradian *et al*., 2020). The AQUACROP model estimates biomass production from actual crop transpiration through a water productivity parameter (FAO, 2012). It simulates crop yield in steps; simulating the green cover development, crop transpiration above-ground biomass and the yield, making the modeling approach very clear as opposed to other models (Vanuytrecht *et al*., 2014). Water productivity is a performance indicator for most irrigation systems and needs to be improved to achieve food security. All irrigation systems strive to utilize water in the highest efficient manner. Looking into water productivity in an area, the risks common in the crop production area is paramount to be studied to be able to explain the results of the model. To produce 1 kg of rice, we need 1,432 liters of water for irrigating lowland rice and about 400 mm of water in heavy clay soils to 2000 mm in sandy soils (IRRI, 2021b).

Water productivity that gives the mass of crop produced with respect to the water consumed can be calculated using manual data from farmers. This can be done by measuring the water consumed and weighing the mass of crop harvested. The manual method has a lot of challenges in regions where farmers have low farm holding, inadequate equipment to measure the water input and with little record-keeping skills. With the shortcomings of the manual method, remote sensing helps to a greater extend to cover these gaps. This is a method of collecting information about objects not in contact using remote sensors mounted on satellites or aircraft which detect energy that is reflected from earth (US Department of Commerce, n.d.). Remote sensing is used in rice production through precise mapping of rice areas, assessing changes and fluctuations in the growing seasons, assessment of; plant diseases, greenhouse gas emission, ecosystem services in the production zones and investigation of erosion control adapted agricultural systems (Kuenzer & Knauer, 2013). It has been used in studies to estimate rice yields by various authors (Rahman *et al*., 2012; Shiu & Chuang, 2019).

Remote sensing aids in faster assessment of rice yield in the field. For instance, in a study carried out in Cibarusah Jaya, rice productivity was analyzed through Normalized Difference Vegetative Index (NDVI) and K-means clustering, using data from Sentinel-2 and Unmanned Aerial Vehicle (UAV) (Liyantono *et al*., 2019). Remote sensing is also utilized in demonstrating how satellites can measure crop water productivity on a pixel-by-pixel basis which can be fruitful in grading the globe on a water productivity score (Bastiaanssen & Steduto, 2016). Although remote sensing has a shortcoming in forecasting yields as they are empirical in nature, this can be overcome by calibration and validation before implementing this procedure over a geographical area to give good results (Mosleh *et al.*, 2015). GIS and remote sensing have also been used to assess water deficiency in near-real-time, using imagery from satellites (Yousaf *et al.*, 2021).

The FAO Portal, which monitors water productivity through open access to Remote Sense Derived Data (WaPOR), provides access to 11 years of continuous observations in Africa and the Near East as of today. The portal provides open access to various layers of spatial data related to land and water use for agricultural production. This enables direct data query time series analysis, data download of local statistics and key variables, and productivity gaps in water and land in rain-fed and irrigated agriculture (FAO, 2020b). WaPOR version 2 was released in June, 2019 following various internal and external validations and quality assessments. This portal has data in 3 different levels 250 m (Level 1), 100 m (Level 2), and 30 m (Level 3). This portal uses the following methodology to calculate gross crop water productivity and net crop water productivity (FAO, 2020).

- By associating harvest with total evapotranspiration (total soil evaporation, canopy transpiration and interception), this indicator provides insight into the impact of crop development for the use of consumed water, and provides insight into the balance of water in given areas. Gross crop water productivity (GCWP) is calculated in WaPOR using seasonal evaporation, transpiration and interception, phenology, harvest index (HI ranging from 0 to 1) and seasonal total biomass production (Equation 1).

$$GCWP = \frac{TBP * HI * AoT/(1 - \theta)}{E + T + I}$$

Equation 1

Where TBP is in kgDM/ha, AoT is the ratio between the above ground and total biomass production, θ the moisture content, and E, T and I in mm

- The Net Crop Water Productivity (NCWP) communicates the amount of the major crop yields in connection to the volume of water beneficially expended (through canopy transpiration) within the season and hence net of soil dissipation. Contrary to GCWP, NCWP is valuable in checking how viable crops utilize water to produce yields. We can have this on WaPOR on seasonal (level 3), decadal or user defined temporal aggregations basis (level 1 and 2). Equation 2 shows the formula for calculating NCWP.

$$NCWP = \frac{TBP * HI * AoT/(1-\theta)}{T}$$

Equation 2

Where NCWP is the Net Crop Water Productivity, TBP is in kgDM/ha, AoT is the ratio between the above ground and total biomass production, θ the moisture content, and E, T and I in mm.

2.3 The Rice production process and risks

2.3.1 The Rice Crop

Rice has been cultivated in parts of Africa for more than 3,000 years. The scientific name of African rice is *Oryza glaberrima*, which is unique to Africa and is a part of the culture of some communities (*AfricaRice*, 2021). Rice, depending on the variety and environmental conditions, takes about 3-6 months to reach maturity from seed. Rice grows under a variety of climatic conditions; from the wettest Myanmar's Arakan Coast with 5,100 mm of rainfall, to Al Hasa Oasis in Saudi Arabia with 100 mm of rainfall. In Pakistan with temperatures of 33^0 C and to Japan with 17^0 C, and a solar radiation of 25% in Myanmar and 95% of potential in Egypt and Sudan (Maclean *et al,* 2013). Rice undergoes three general growth stages: vegetative, reproduction, and maturity.

Cultivated rice is generally regarded as a semi-aquatic annual herb, although it can survive as a perennial herb in tropical regions and grow new tillers from the nodes after harvest (regeneration). When mature, rice has one main stem and several tillers. Every prolific tiller has a top flower head or a panicle. Plant height varies with varieties and environmental conditions. The plant height of floating rice ranges from about 0.4 m to more than 5 m (Maclean *et al,* 2013).

Rice crop takes 3 to 5 months in the field depending on the variety and the environmental conditions.

Every farmer normally follows a set of guidelines in order to guarantee good yield, known as a step-by-step process. This process is divided into three; Pre-planting, growth and post-production. Pre-planting activities include selecting suitable varieties, developing a growth calendar, and preparing rice fields for planting. As rice crops grow, important management factors should be considered. These include planting methods, water, fertilizers, weeds, and pests. After harvesting, the rice has to undergo post-harvest processes such as drying, storage and milling to ensure good food quality and marketability. Figure 3 shows all the steps followed by a farmer in rice production (International Rice Research Institute, 2018).

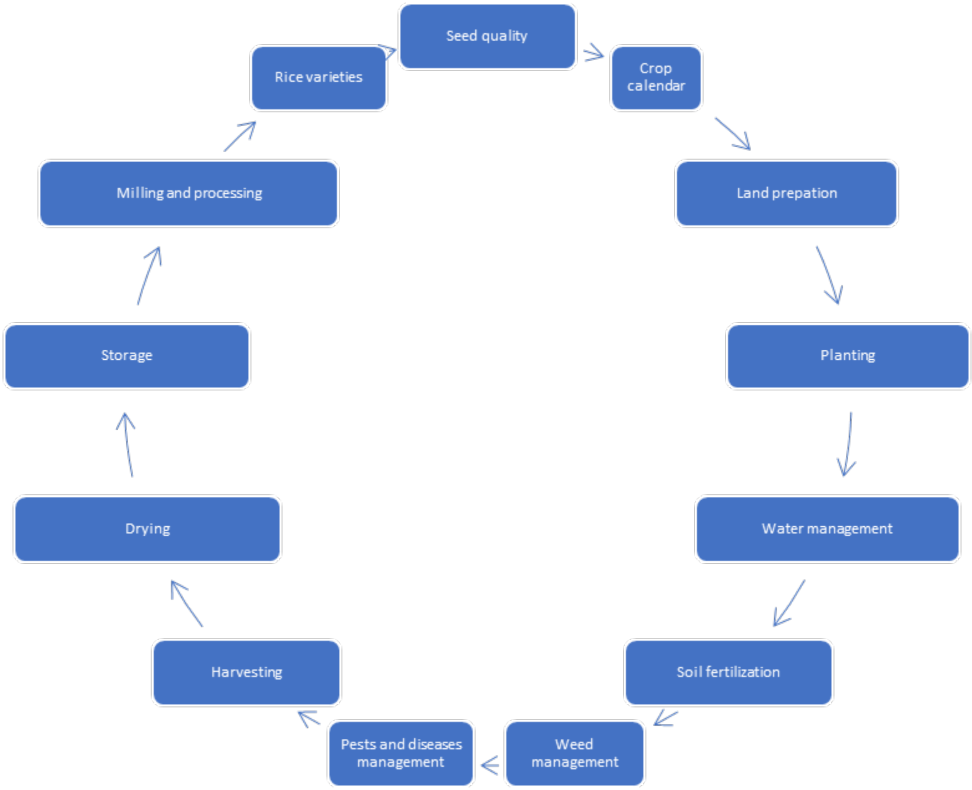


Figure 3: Step by step rice production process

2.3.2 Risks in the Rice Crop Growth Cycle Risks

Risk is a probability of a negative event occurring because of an action, and it is mostly used in the decision-making context. Identification of risks and possibly reduction of the production or price risks helps rice farmers to increase their production and subsequent income (Saito *et al*., 2019; Yardha *et al*., 2021). The rice production process involves land preparation, seedbed preparation, planting, maintenance of farm (weed management, application of fertilizer, and water management), harvesting, and post-harvest management. Each activity has its constraints which sum up to reduce the farmer's yield, especially during the flowering stage. These constraints include: developing water and work deficiencies, imbalanced utilization of inputs (fertilizer, pesticides, and water); competition between land for rice and land for other crops; climate change (Rao *et al*., 2017). According to Yardha *et al.* (2021), the factors affecting lowland rice production are seed production, type of fertilizer, insecticides, labor, and land area. Productivity is low with little land, and fertilizers augment the production only when it is carried out efficiently and effectively and in the right dose meeting the plant needs (Yardha *et al.,* 2021).

2.3.3 Environmental Challenges Related to Rice Production

Rice fertilizers contribute significantly to environmental pollution. Just about a third of the nitrogen fertilizer applied is taken up by the rice crop, with the remaining two-thirds being lost to surface runoff, leaching, ammonia volatilization, and denitrification and a tiny portion of which is immobilized by soil organisms (Pathak, 2013). While ammonia and nitrous oxide generated by volatilization and denitrification are lost to the atmosphere, nitrates are leached down the profile or carried by surface runoff, resulting in eutrophication of both surface (lakes and estuaries) and groundwater (Prasad and Shivay, 2014). Also, phosphorus fertilizers used for rice have a recovery effectiveness of about 15–30%.

However, in some nations, the costs of registering new items are excessively high in comparison to the low acreage, making product innovation a big issue. The acreage of Clearfield rice is steadily expanding, owing to the growing problem of wild rice. Irrigated rice is home to a wide variety of animals, especially migrating birds, and requires special care in terms of biodiversity conservation. In the past, greenhouse gas emissions and heavy metal concentrations in rice fields were a concern in some locations (Ferrero and Vidotto, 2010). By introducing new varieties and sound agricultural techniques, these yield discrepancies can be bridged. As a result, there is a lot of room to increase yields (Becker *et al*. 2003). A complete collection of crops, soil, water, and weed management methods is referred to as Good Agricultural Practice (GAP) (Nhamo *et al*., 2014). Some examples of GAP for the lowland ecology include: using animal or motorized traction for fine soil tillage, proper bund making and leveling, using certified seeds of improved varieties, sowing, or transplanting in lines, application of judicious doses of composite fertilizers, and optimally timed weed control using appropriate herbicide dosages followed by weeding with mechanical weeders (Senthilkumar *et al*. 2014).

In Africa, there has been promotion of integrated rice management (IRM) solutions such as mechanization, soil fertility control, and weed management (Lancon, 2002). Consequently, there has been increased yields by about 2 ton/ha, which has benefited farmers in Burkina Faso, Mauritania, and Senegal (Segada *et al*., 2004, 2005). Small-scale types of machinery, on the other hand, are essential for timely and optimal field management operations.

Another key constraint that makes rice production in Africa tedious and time-consuming is a lack of proper instruments for land preparation, harvesting, and postharvest operations. Lack of adequate machinery, for example, might cause rice harvesting to be delayed and worsen crop quality (Rickman *et al*., 2013).

Water quality has become a major concern in the previous two decades (Mohapatra *et al*., 2013). Due to salty water intrusion and injudicious fertilizer and pesticide usage, groundwater quality has worsened, with high arsenic, iron, and fluoride concentrations. Water quality is expected to deteriorate considerably in the next years because of overexploitation, urbanization, and industrialization.

2.3.4 Opportunities in Rice Production

In terms of area of land under rice and production of rice, India ranks first and second in the world, respectively. Despite the country's development of modern varieties and good agronomic processes, there are still considerable discrepancies between farmers' actual yield and their potential production (CRRI, 2011). Postharvest losses are estimated to be between 20 and 30%. The efficiency of nitrogen fertilizer or water use is still between 30 and 50 percent, which can be improved by creating effective management methods. As a result, narrowing yield and efficiency gaps, valuing improvements to cropping or farming systems, and minimizing postharvest losses are given high priority to increase rice output and farmers' net profit while maintaining environmental safety.

Hybrid rice is predicted to boost India's overall rice production by a factor of ten in the coming decades (Mohapatra *et al*. 2013). Hybrid rice has already made some headway in irrigated sections of subhumid to semiarid countries. Increased heterosis and the introduction of known disease and pest resistance genes into the parents, on the other hand, will enhance yield. Rainfed lowland habitats in heavy rainfall locations require hybrids as well (Mohapatra *et al*., 2013). In such cases, it is necessary to improve the size of heterosis by creating acceptable parental lines in order to boost hybrid yield potential. Furthermore, by utilizing existing genetic variability, grain protein and micronutrient content in rice can be improved using both traditional and modern biotechnological approaches. It is necessary because, despite the country's tremendous progress in rice production, malnutrition owing to micronutrients, protein, and calorie deficits continues to be a source of concern for the impoverished population living in rural areas.

Africa under the Coalition for African Rice Development (CARD) program, has aided many countries in developing their national rice development strategy (NRDS) (JICA 2009). A progressive shift in policy has occurred in favor of developing the entire rice value chain. The "rice sector development hubs", are a unique institutional solution to the rice value chain mechanism. Rice hubs are locations where rice value chain research, services, and local innovations are combined to create development outcomes and impact. Hubs serve as testbeds for new rice technologies, employing a "reverse-research" method that begins with the market. The hubs test, modify, and integrate research breakthroughs, outputs, and products into "baskets of good agricultural practices." Hubs are built around big groups of farmers and include other value chain actors and extension organizations that work together to analyze technical and institutional improvements, improve information dissemination, and establish linkages across the rice value chain.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of the Study Area

This research was conducted in Yagoua and the Ndop plains (Figure 4). These locations were chosen because they represent the high production zones of rice in Cameroon and with contradictory climatic conditions; Yagoua being a semi-arid area and the Ndop plains is mainly dominated by grasslands.

3.1.1 Yagoua

Yagoua is located in the Mayo-Dannay Division of the Far North region of Cameroon. It is located at 14°55' E and 15°10' E longitude and 10°20'N and 11°35' N latitude. The development authority for rice production SEMRY, which aids rice farmers in their rice production chain and buy the rice for processing, is located in this area. It has a uniform plain relief and a Sudano-Sahelien climate with three to four months of rains, and eight to nine months of dry season. The development society SEMRY has objectives to reduce food insecurity in the region, reduce rural exodus and use on the rice farms, improve on the livelihood of the population concerned and contribute to the food supply of rice produced in Cameroon.

3.1.2 Ndop Plains

Ndop plains is in Ngoketunjia division in the Northwest region (Figure 5). This area has the development authority for rice production (UNVDA), which aids rice farmers in their rice production chain and buy the rice for processing. Ndop is a subdivision located between 10^0 23'E to $10^0$33'E and $5^0$37'N to $6^0$14'N (Edongo *et al*., 2019), and consists of four villages; Bamunka, Bamali, Bambalang and Bamali. The climate in the research region is humid-tropical-equatorial, and it is only about 244 kilometers Northeast of the Atlantic Ocean (Wirmvem *et al*., 2017).

This location has the highest number of rice producers in the Northwest region of Cameroon and second in the whole country after the farmers in the Northern region under SEMRY (Maga and Yagoua). Rice production in Ndop is under UNVDA which is a development authority with objectives to ameliorate agricultural productivity, reduce the level of poverty, help farmers in processing and also market their produce and in overall contribute to the food security of Ndop and Cameroon as a whole

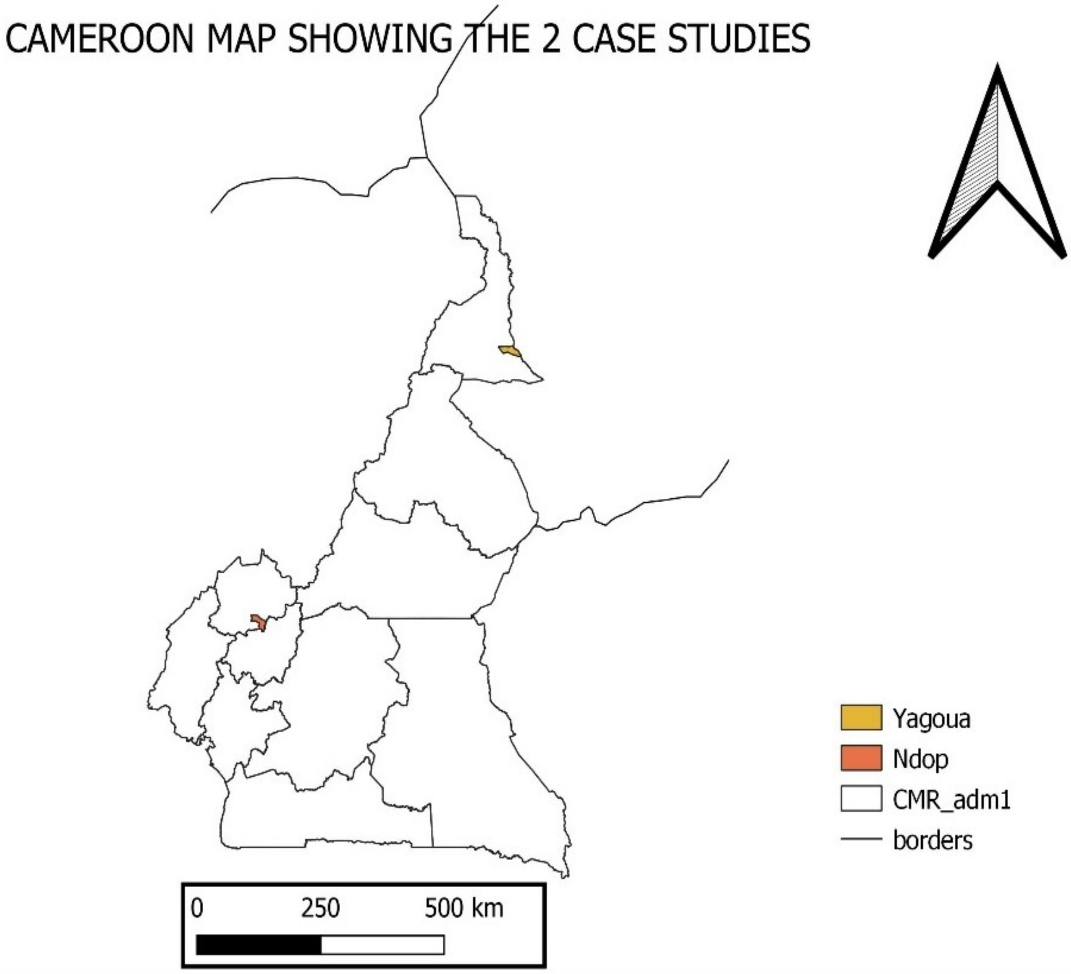


Figure 4: Map of Cameroon showing Yagoua and Ndops

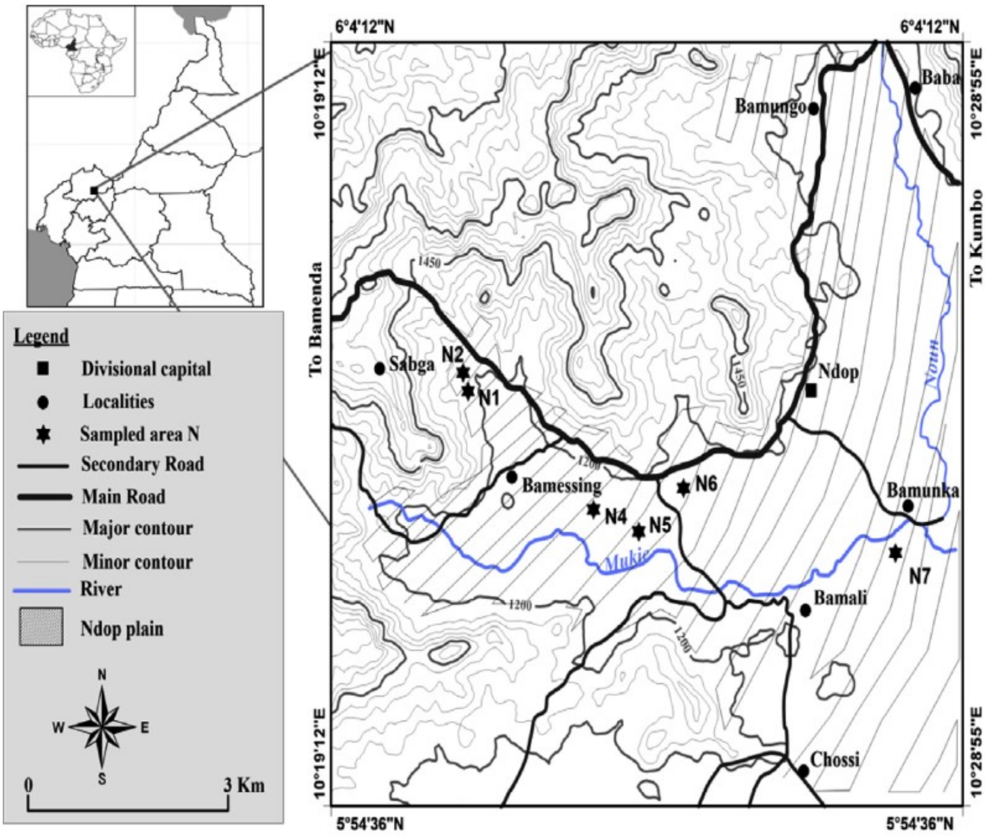


Figure 5: Location map of the chosen seed farm, Ndop in Cameroon (Source: Yongue-Fouateu *et al.*, 2016)

3.2 Research Design

In the quest to fill the research gap, this study sought out to know where rice is produced, the water productivity and the risks associated with rice production in Cameroon. Secondary data was obtained through the review of literature, from past published works and reports from the institutions concerned with rice farming, and from the computerized WaPOR database. Also, primary data obtained from the field during site visits and reconnaissance survey was used. The research design adopted for this study is illustrated in Figure 6.

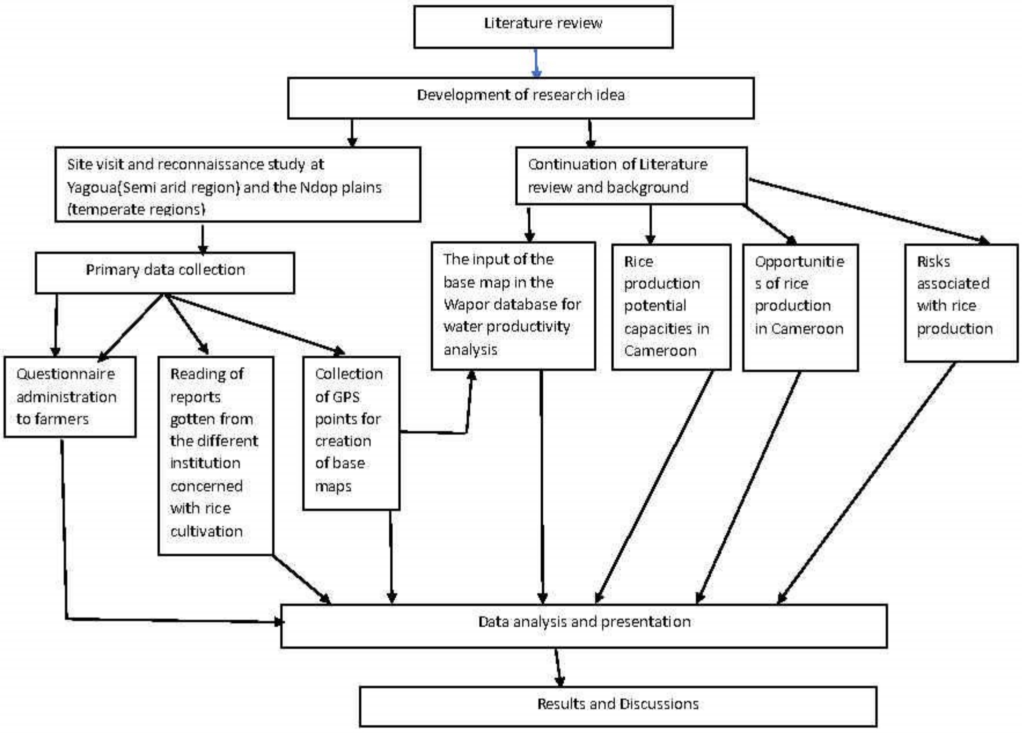


Figure 6: Research design method developed by the author

3.3 Sampling Method

Rice is grown in both the semi-arid and tropical regions. This research chose 2 case studies; one from the semi-arid and the other from the temperate region to have results that are representative of the situation in the country. Tentatively, the number of rice farmers in UNVDA is 14,230, whereas in SEMRY, there are 13,000 families involved in rice farming. Using random sampling, 100 farmers were selected to fill the questionnaires alongside 30 extension and administrative workers in UNVDA and SEMRY. The sample size was calculated using Equation 3 (Ghisi and Ferreira, 2007; Mourad, Berndtsson and Berndtsson, 2011)

$$n \geq \frac{\frac{1}{e^2} * N}{\frac{1}{e^2} + N} \qquad \mathit{Equation}\ 3$$

With N being the total population, e is the sample error between 1 % to 20% and n being the number of the sample population.

Using the total population and a 10 % error margin, the sample population was established to be 100 for the two case studies. The questionnaires were distributed according to the farmer's convenience and acceptance to fill.

3.4 Data Collection

3.4.1 Primary Data

a. Boundary Layer of the Selected field

GPS Garmin Montana 680 was used to collect GPS points around the perimeter. These points were later used in QGIS to develop the shapefile which would later be used for downloading other datasets in the WaPOR portal and in the Google Earth Engine to download climatic data for crop water requirement analysis.

b. Administration of Questionnaire

The questionnaires were administered using stratified sampling in the 4 stations. Interiews were based on the willingness of the farmers to provide information and their availability since the questionnaires were administered in-person. One hundred (100) questionnaires were administered in the 4 different stations under SEMRY, Yagoua, and the number of people per village from the stations depended on the willingness of the farmers to spare their time to respond to the questionnaires as they were not allowed to fill it by themselves. The questionnaires for the Ndop area were prepared but not administered due to insecurity that led to shut down of activities in the area.

c. Interview with Key Informants

Interviews were done with the heads of the institutions involved in the rice production value chain to understand the risks and opportunities available in the rice production zones. The key informants provided valuable information which aided in the discussion of results in this study.

d. Observation

The researcher went on field trips to observe the fields and the farmers to understand the rice production process and related activities and infrastructure. The information obtained was then used to discuss the results.

3.4.2 Secondary Data

a. Review of Literature

Publications related to the topic and reports of the institutions involved in rice production were reviewed. These documents were gotten from online public and private libraries and reports collected from the institutions concerned. The institutions gave out data concerning their production trends, the purchase of paddy and their practical harvest on the chosen parcel of land which will be used to determine the water productivity in the area.

b. WaPOR Datasets

The base layer was used to download the related datasets for the analyses of the water productivity from the WaPOR platform (https://WaPOR.apps.fao.org/home/WAPOR_2/1)

3.5 Analytical Approach According to Objectives

- **Objective 1**

Secondary data from the Ministry of agriculture and the PADFA project was used to evaluate rice production potential in the 2 Agro-ecological zones. The production capacity in the chosen case studies was analyzed based on the data collected from the agricultural production and commercialization departments.

- **Objective 2**

The base maps of the two seed farms; each for the chosen agro ecological zone was used to download climatic data and their mean calculated using codes in Google earth engine. The climatic data were then imported into the CROPWAT software to calculate the irrigation water requirements for their respective seasons. Table 3 gives a summary of the climatic datasets used with their characteristics. Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) is a semi-global precipitation dataset. As the title suggests, it combines real-time meteorological station data with infrared data to estimate precipitation. The dataset has been protracted from 1981 to the present. IDAHO EPSCOR TERRACLIMATE is the monthly climate and climate water balance of the Earth's surface from 1958-2019.

Table 3: Climatic data source for CROPWAT analysis

Climatic dataset	**Years considered**	**Source**
Precipitation	1991 to 2020	https://developers.google.com/earth-engine/datasets/catalog/UCSB-CHG_CHIRPS_DAILY
Maximum temperature	1991 to 2020	https://developers.google.com/earth-engine/datasets/catalog/IDAHO_EPSCOR_TERRACLIMATE
Minimum temperature	1991 to 2020	https://developers.google.com/earth-engine/datasets/catalog/IDAHO_EPSCOR_TERRACLIMATE
Humidity/ vapor pressure	1991 to 2020	https://developers.google.com/earth-engine/datasets/catalog/IDAHO_EPSCOR_TERRACLIMATE
Wind speed	1991 to 2020	https://developers.google.com/earth-engine/datasets/catalog/IDAHO_EPSCOR_TERRACLIMATE

The total volume of water to be pumped for the season was calculated using equation 4.

$$Total\ water\ to\ be\ pumped = Total\ gross\ irrigation(m) * area\ of\ land\ (m2) \quad \text{Equation 4}$$

The crop data used in CROPWAT have been presented in the Table 4 (Allen *et al.*, 1998)

Table 4 : Crop data considered for CROPWAT analysis

Initial stage	Mid stage	End stage	Crop height	Maximum root depth	Depletion fraction	Planting date(dry)	Planting date(rainy)
1.05	1.20	0.7	1	0.6	0.2	12/22	4/20

The shapefiles of the 2 seed farms were used to calculate the gross water productivity with that of Yagoua having an area of 15 ha and Ndop plains covering an area of 12 ha. The shapefiles were then uploaded in WaPOR to calculate the water productivity trend of rice for the said locations using the protocol in Figure 7 available at https://github.com/wateraccounting/WAPORWP . Due to the small areas as compared to the pixel sizes, the results could not be visible enough for analysis. As a substitute, 10 points were chosen by induction to get the productivity time series in the 2 seed farms; and the mean of the GBWP was calculated and plotted using Microsoft Excel. The results were compared and conclusions made. Appendix 9 and 10 show the different points chosen at random

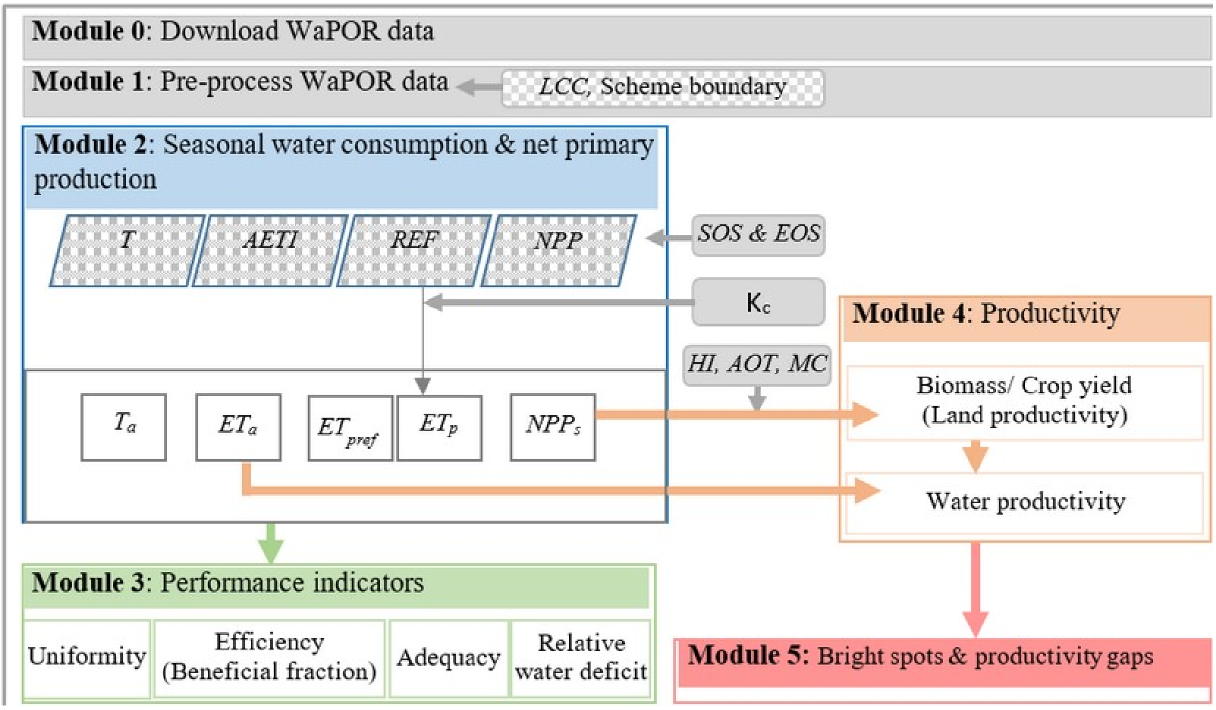


Figure 4: WaPOR Protocol

Reference evapotranspiration (ETo) was calculated using the Penman-Monteith method (Equation 5) in CROPWAT (FAO, 2009).

$$\mathrm{ET_o} = \frac{0.408\,\Delta(R_n - G) + \gamma \dfrac{900}{T+273} U_2(e_a - e_d)}{\Delta + \gamma(1 + 0.34U_2)}$$ Equation 5

where, ETo is the reference crop evapotranspiration in mm/d; R_n is the net radiation at the crop surface in MJ/(m2·d); G is the soil heat flux in MJ/(m2·d); T is the average air temperature in ^{0}C; U_2 is the wind speed measured at 2 m height in m/s; $(e_a - e_d)$ is the vapor pressure deficit in kPa; Δ is the slope of the vapor pressure curve in kPa/^{0}C; γ is the psychrometric constant in kPa/^{0}C; and 900 is the conversion factor.

Further, to estimate the crop evapotranspiration (ETc), reference evapotranspiration (ETo) was multiplied by the crop coefficient (Kc) (Equation 6).

$$ETc = Kc*ETo$$

Equation 6

where, ETc is the crop evapotranspiration; Kc is the crop coefficient; and ETo is the reference crop evapotranspiration.

To calculate the irrigation water requirement, the USDA Soil Conservation Service (SCS) method in CROPWAT was used to calculate effective rainfall (ER) whilst employing the following criteria:

I. When the total rainfall (TR) is less than 250 mm, ER was calculated using Equation 7;

$$ER = TR * (125 - 0.2 * TR)/125$$ Equation 7

II. When the total rainfall is greater than 250 mm, ER was calculated using Equation 8;

$$ER = 125 + 0.1 * Total\ Rainfall$$ Equation 8

Thus, IWR was calculated using evapotranspiration rate of rice and the value for effective rainfall (Equation 9);

$$IWR = ETc - ER \qquad \text{Equation 9}$$

Where; IWR is the irrigation water requirement (mm); ETc is the crop evapotranspiration (mm); ER is the effective rainfall (mm).

CROPWAT model was validated using the input data for the specific environment and the crop parameters (Raes et al., 2012; Adeboye et al., 2017; Akinbile et al., 2020). Environmental data was downloaded for the two case study seed farms. The soil parameters were obtained from the soil portal in addition to literature review on studies carried out in the study area. Saha et al. (2019) used the crop parameters in the CROPWAT 8.0 file, and the results were found to be satisfactory in estimating crop water requirements.

Objective 3

This research employed both qualitative and quantitative data analysis methods. The responses were filled into an excel sheet and later analyzed using python. Results from the analysis were presented using charts, tables, and figures. Information obtained from the key informant interviews and observations were used to discuss the results. Literature was reviewed and information obtained from the reports to evaluate the opportunities available in rice production in Cameroon in terms of resources and institutions available to boost rice production.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Rice production potential zones and their opportunities

Rice production is carried out in two Agro-ecological zones; the highlands and the Sudano-Sahelien zones. The Sudano-Sahel zone is bounded between 8^0 36 N and 12^0 54 N latitude and 12^0 30 E to 15^0 42 E longitude. The climate is characterized by a mono Mondial rainfall, with varying intensity of 400 mm to 1200 mm per year. The temperatures vary with an average of 28 ^{0}C in Garoua and high temperatures fall between 40 ^{0}C and 45 ^{0}C in April. In a study conducted in Punjab, Pakistan, it was established that potential areas for rice cultivation had temperatures of between 21 and 32 ^{0}C (Muhammad et al., 2017). Rice has been found to be very sensitive to temperature changes, and temperatures higher than 35 ^{0}C can have an impact on both the quality and quantity of rice (Hat & Prueger, 2015). According to Yoshida (2012), a decrease in temperature by 1 ^{0}C can result to a delay in heading by 13 days.

The area is characterized with different types of soils; ferruginous, hydromorphic, and lithosols. The principal crops cultivated are cotton, millet, sorghum, onion, sesame and rice. This is the zone that produces most rice in Cameroon and offers employed to most locals. This zone has 11 Divisions under which rice production is being carried out. These divisions include: Diamare, Mayo Danay, Mayo-Kani, Logone et Chari, Waza, Mayo-Tsanaga, Benoue, Lagdo, Mayo-Louti, Faro and Mayou-rey. The divisions have different rice production potentials for both rainfed rice (upland rice) and lowland rice (swamp and irrigated rice) cultivation. Further, this zone has a potential of over 460,181.3 ha for rainfed rice and 252,128.7 ha for lowland rice. Figure 8 demonstrates the different rice production potential in relation to the type of rice farming in each subdivision in the Sudano-Sahelian region (MINADER/DESA, 2020).

The highland zone includes the Northwest and West regions, and is located between 4^0 54 to 6^0 36 North and 9^0 18 to 11^0 24 East. It covers over 3.1 million ha (MINADER/DESA, 2020). The zone has two seasons; the dry season starting from mid-November to mid-March and the rainy season from mid-March to mid-November. It has an average temperature of 19 ^{0}C and receives heavy rains (1500-2000 mm). The zone is very fertile and is characterized with cultivation of crops such as cocoa, coffee, corn, beans, potatoes, rice and market gardening crops like onion.

This zone has 5 divisions that cultivate rice; Menchum, Mezam, Ngoketunjia, Nde, and Ndonga Mantung. These divisions have different rice production potentials, 26,520 ha for the upland rice (rainfed) and 43,329 ha for the lowland rice (marsh and irrigated rice). Figure 9 shows the different rice production potentials, data was obtained from the Ministry of agriculture and PADFA (MINADER/DESA, 2020).

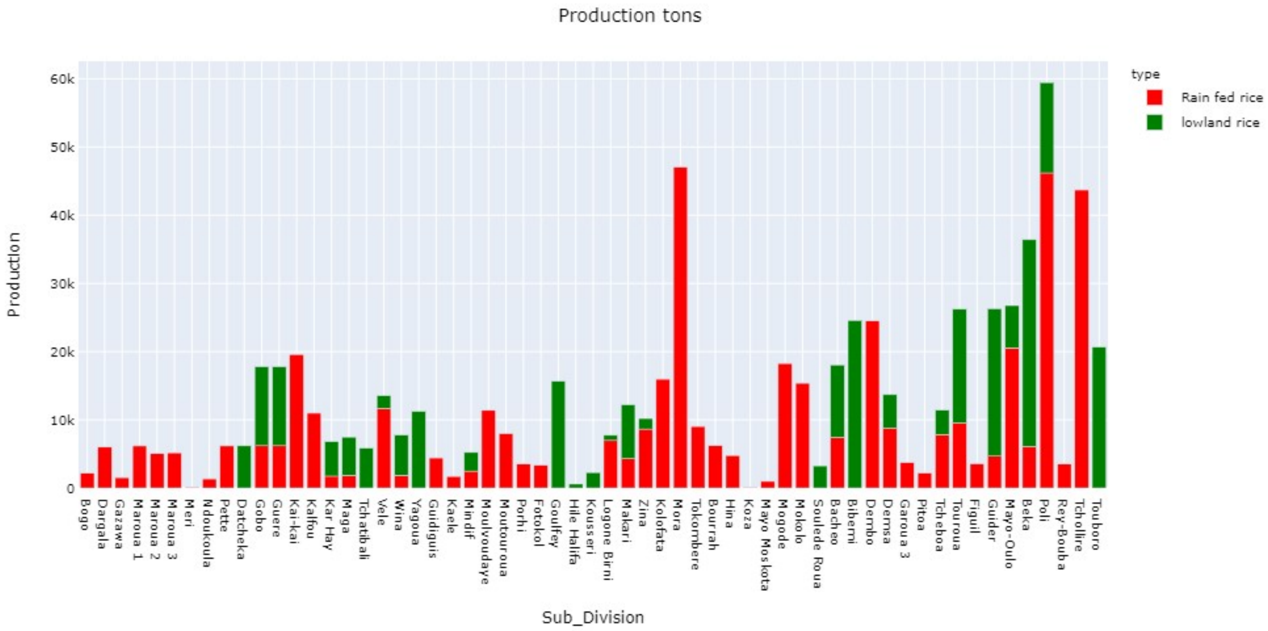


Figure 5: Rice production potentials in the Sudano-Sahel zone according to territorial Sub Divisions

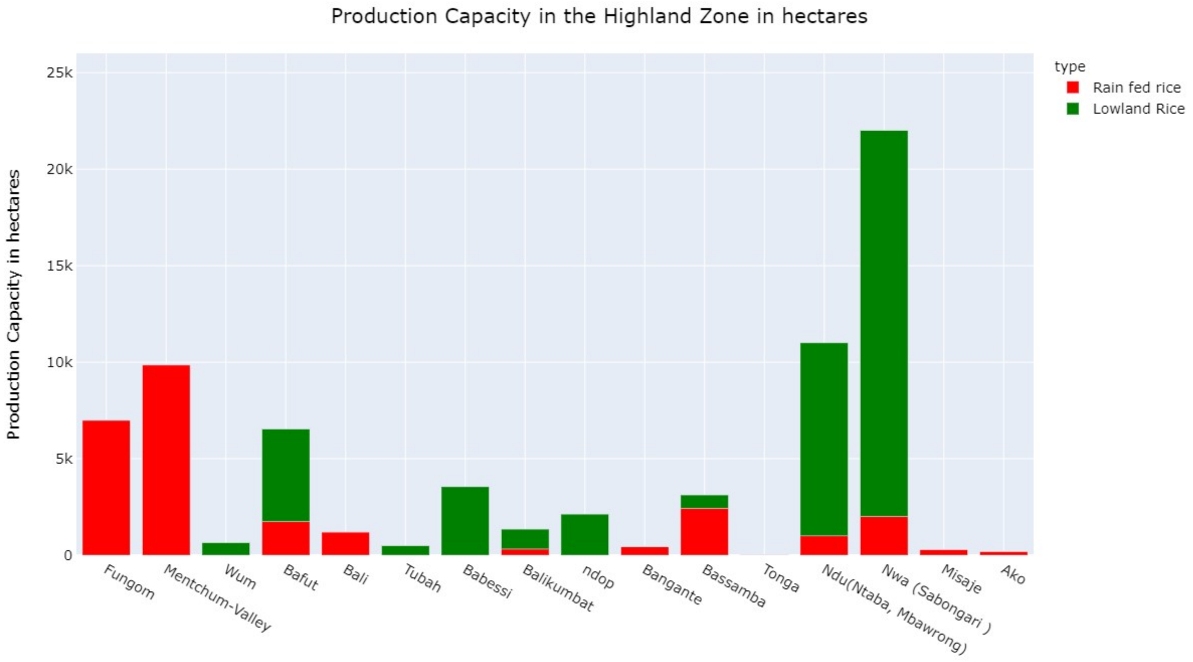


Figure 6: Rice production potentials in the Highlands zone according to territorial Sub-Divisions

Comparatively, the Sudano Sahelien zone has a rice production potential of 712,310 hawhich is 10 times that of the highland zone (69,849 ha) (Figure 10). This can be attributed to the soil types and temperature ranges in Sudano Sahel zone, which tend to favor rice production.

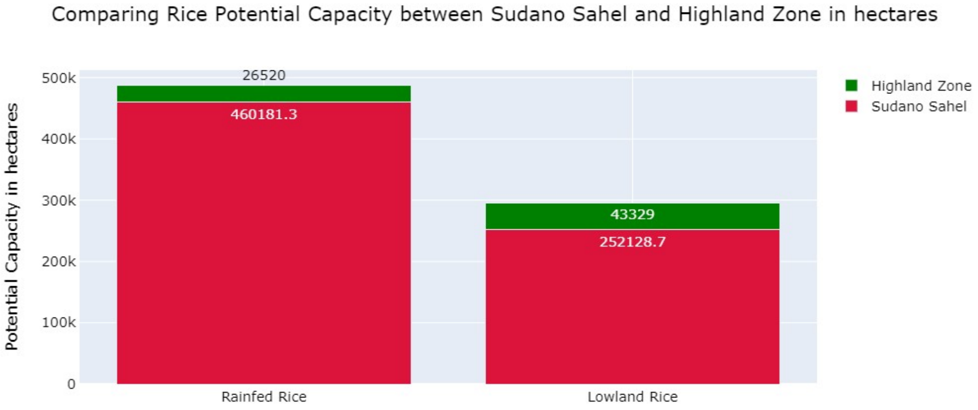


Figure 7: Comparison between the rice potential capacity of the Soudano-Sahel and the highland zones

In Yagoua, the area under cultivated rice is about 11 ha, and the yield varies depending on the seasons and the year. Figure 11 presents the variation in yield between 2006 and 2020. The data was obtained from the chief of production office record at SEMRY 2021.

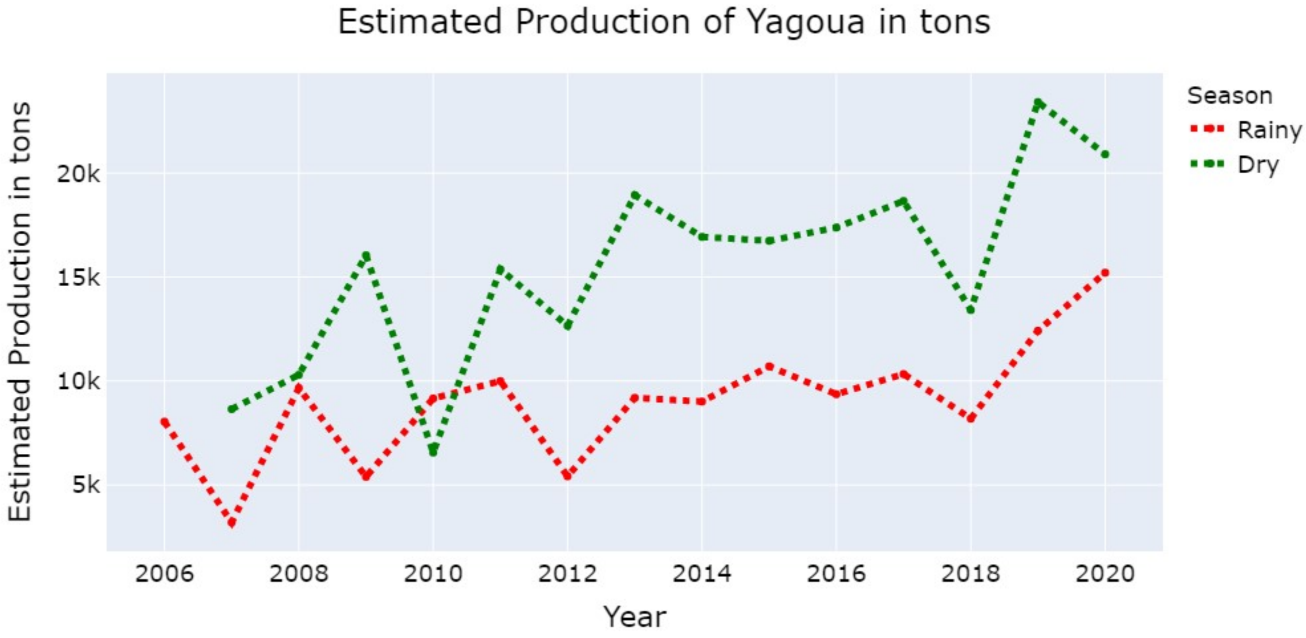


Figure 8: Estimated Paddy production in Yagoua

When production is estimated, the reality on the ground varies depending on the environment, and the efficiency of the farmer in following the right itinerary for its production. Figure 12 shows the observed yields in Yagoua from 2006.

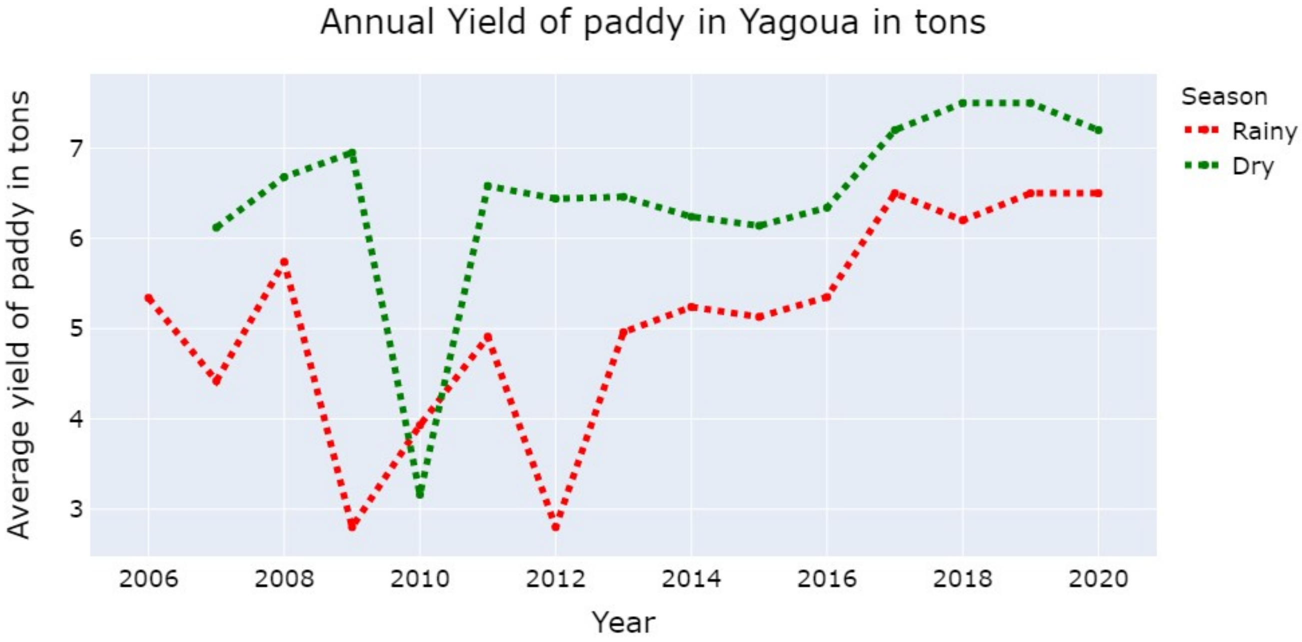


Figure 9: Trend of the average yield of Paddy in Yagoua from 2006 to 2020

It was established that rice production tended to be more during the dry season as compared to the rainy season. This was attributed to more sunshine in the latter and less rains to flood the lands, as the Northern region landscape is a plateau. Climate change has resulted to erratic rainfall patterns leading to events such as flooding. Yagoua being a plateau makes the region more vulnerable to flooding. This explains the higher rice production during the dry season compared to the wet season. According to Rashid et al. (2012), floods causes a decline in rice production by between 8-17%. Our results also corroborate with findings from other studies (Rashid et al., 2012; Ansari & Lin, 2021), which found that high rainfall results to a decrease in rice production due to flooding that influences rice growth. However, contrary results were found in a study conducted in India. It was established that rice production tended to be higher during the wet season as compared to the dry season (Nuryati, 2020). This was attributed to underutilization of production factors during the dry season. The variation in the quantity of paddy produced is presented in Figure 13.

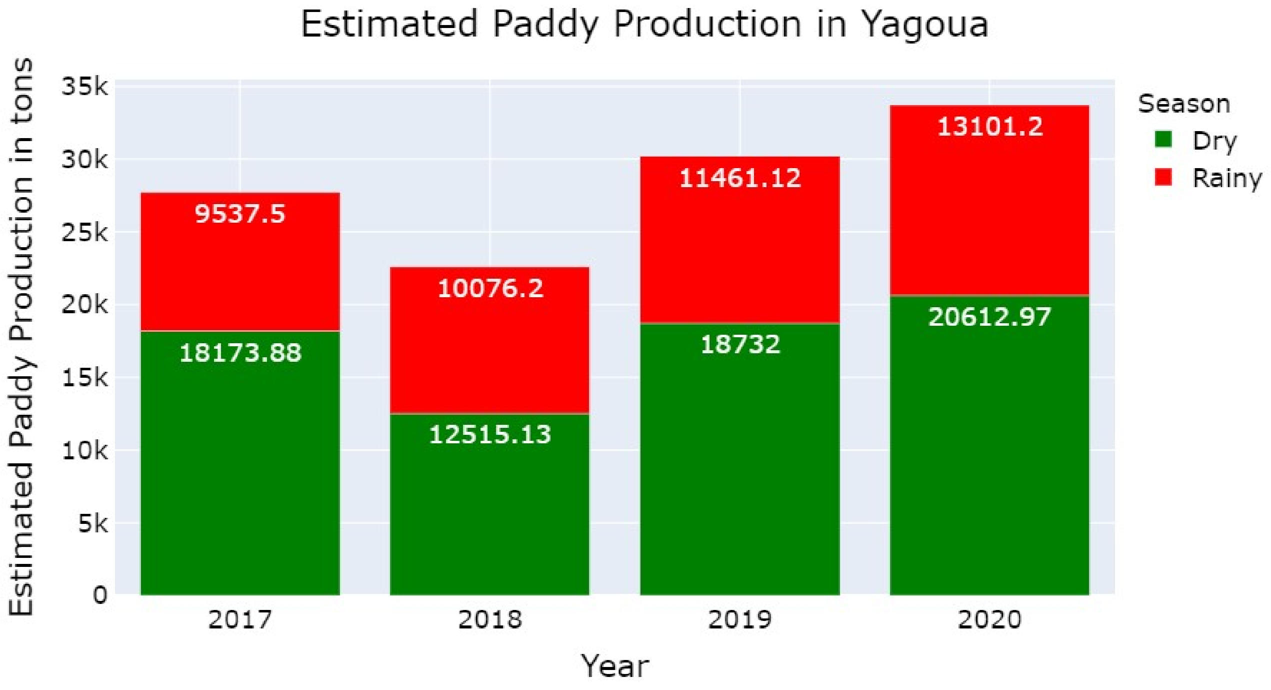


Figure 10: Estimated Paddy Production in Yagoua from 2017 to 2020

The estimated paddy produced from 2017 clearly shows that the amount of paddy produced in the dry season is greater than that produced during the rainy season. With agricultural production, success is always recorded after the sale of produce as most farmers rely on the sales for their livelihood. There are two main buyers of paddy from farmers which are SEMRY and foreign businessmen (Nigerians, Chadians, etc.). It was established that both buyers compete for the purchase of Paddy from the farmer, and the farmer is of a higher authority to choose who to supply his or her produce to. SEMRY's one main objective is to aid farmers in the rice value chain. SEMRY receives varying amounts of paddy during each production season (Figure 14).

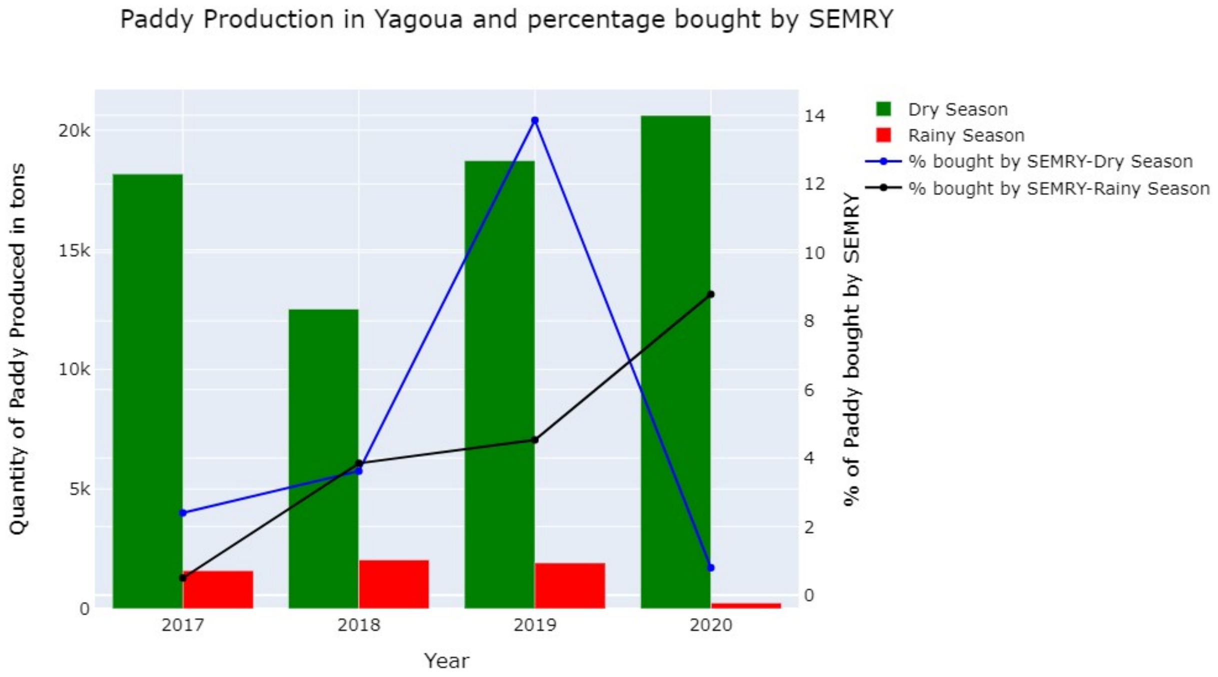


Figure 11: Paddy production in Yagoua and percentage bought by SEMRY for transformation

SEMRY bought 13.86% of the total rice produced in 2019. This was their highest purchase between 2017 and 2020 (Figure 14). The purchasing power of SEMRY is low since it is a state owned corporation, and its budget to buy Paddy is not self-controlled. Although, the purchase cost SEMRY hundreds of millions of francs CFA (Figure 15), with the highest amount being 363,405,280 FCFA which represented just over 13 % of the total paddy sales in Yagoua for the season.

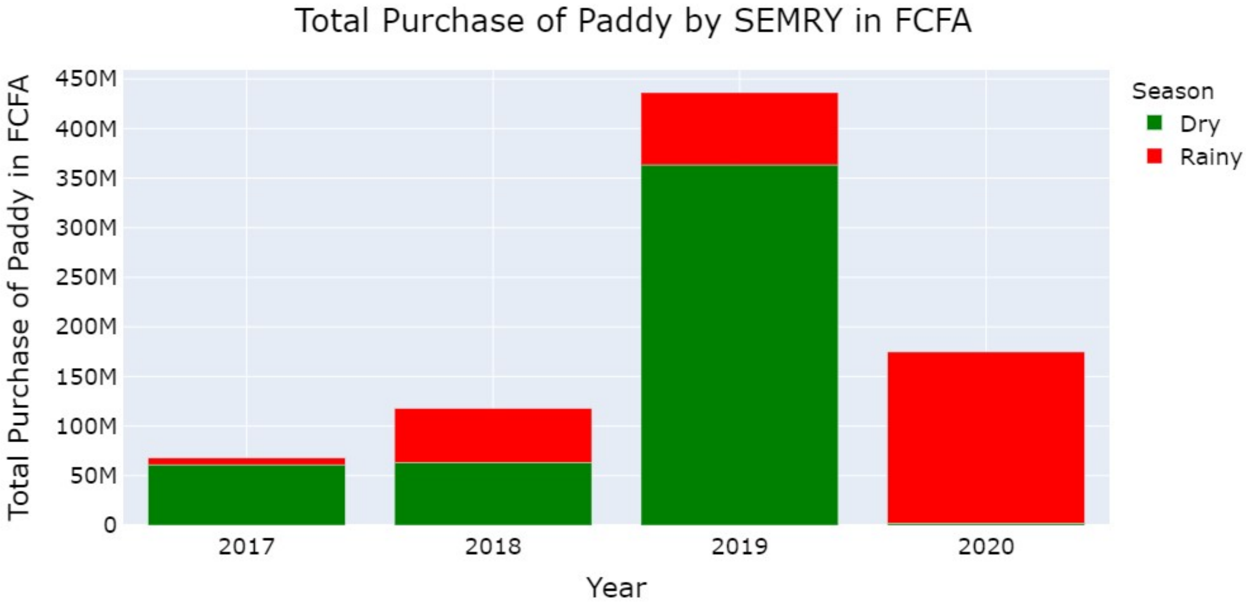


Figure 12: Total purchase of Paddy by SEMRY between 2017 and 2020

The production pattern at the Ndop plains is only for the rainy season, unlike in Yagoua where they have two production cycles.

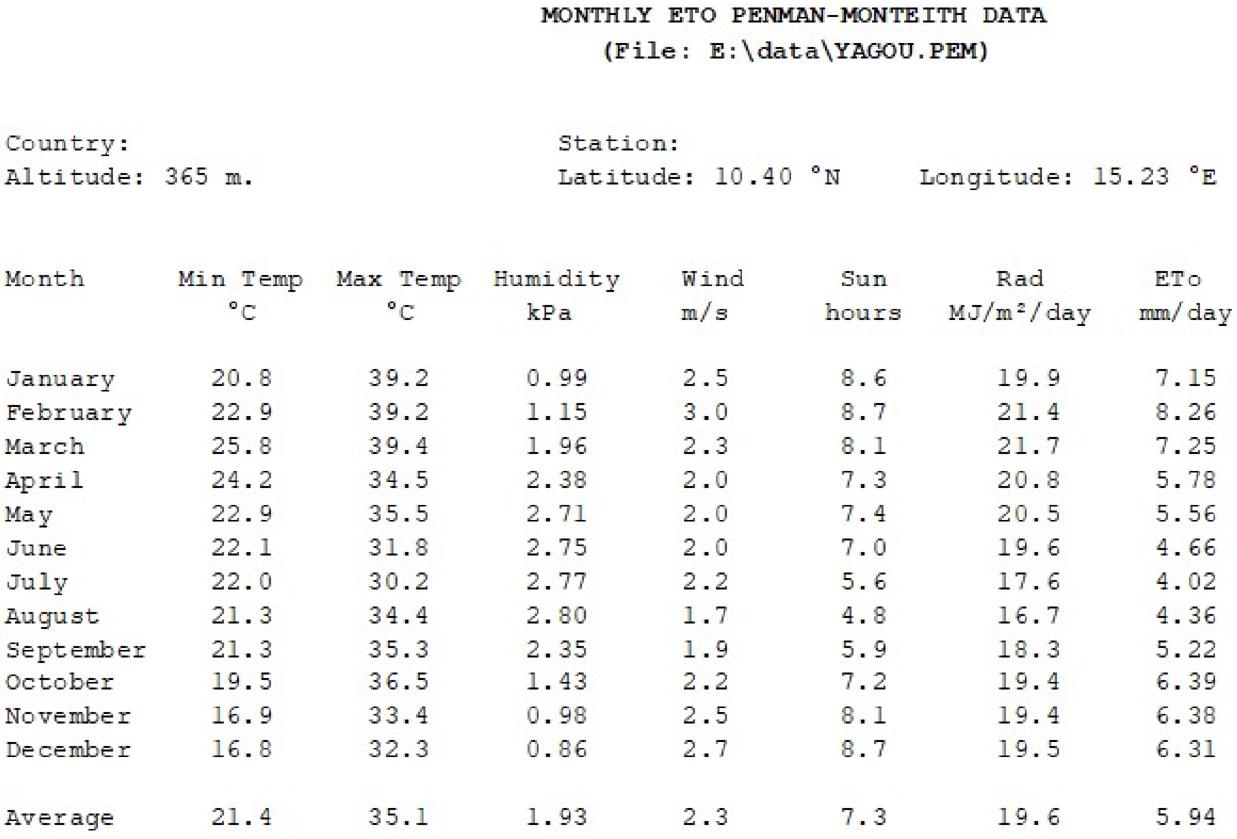
4.2 Irrigation Water Requirement for Rice and Water productivity trend

All the production schemes in both Yagoua and Ndop are irrigated (lowland rice), but due to their different climatic conditions and soil texture, they have different crop water requirements.

4.2.1 Irrigation water requirement for rice in Yagoua

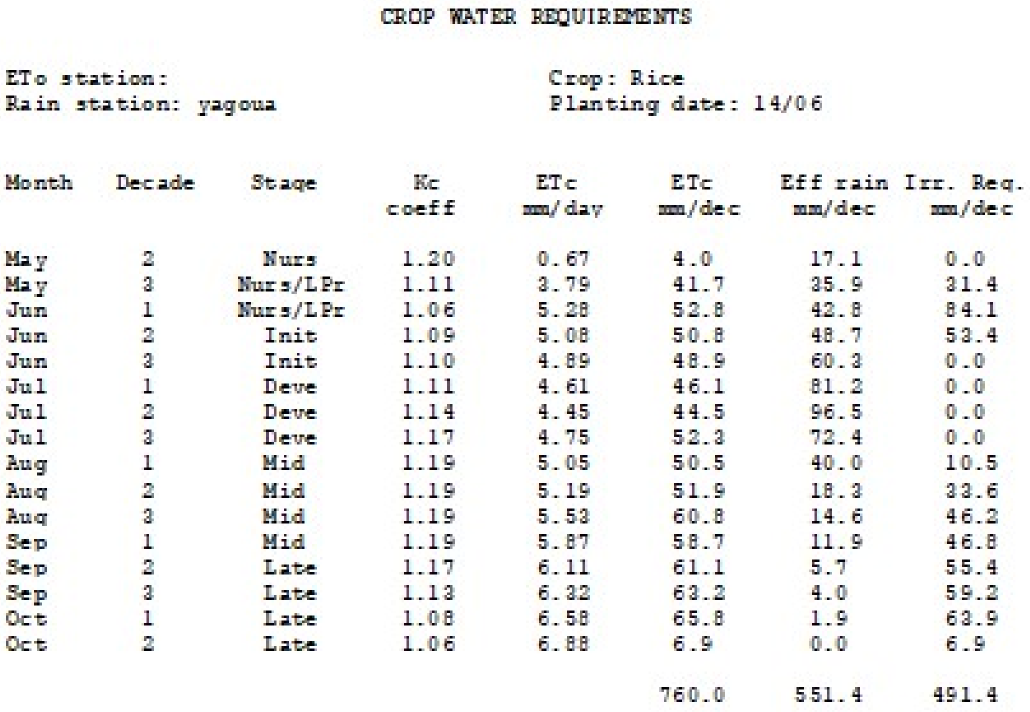
Yagoua has two cycles of rice production, which is irrigated by a pumping system supplied with water from River Logone. Using the remotely sensed climatic data in CROPWAT, which calculates the ETo using the Penman monteith equation, the ETo for the SEMRY seed farm was determined (Figure 16). The months of January to March had the highest ETo values (7.15-8.26 m/day), and the months of April to September had the lowest values (4.02-5.78 mm/day). The periods between January and March, and between April and September coincide with the dry and wet season, respectively. In a related study, it was found that evapotranspiration was highest during the dry season as compared to the wet season (Bouraima et al., 2015). In the dry season, the relatively high evapotranspiration was due to the low humidity coupled with high temperatures recorded within the period. Whereas, the low evapotranspiration can be attributed to the high rainfall along with the low temperatures between April and September. Similarly, Arunadevi et al. (2020) associated low evapotranspiration in Guixi, China to low humidity levels within the study area.

During the rainy season, the rice crop evapotranspiration (ETc) was found to be approximately 760 mm (Figure 17), whereas, during the dry season, it was estimated to be 1144 mm (Figure 19). ETc was fond to be higher during the dry season compared to the rainy season. This is because crops growing during the dry seasons often require more water compared to those growing during the rainy season (FAO, 2009). Additionally, during the rainy season, ETc increased from 0.67 mm/day to 6.88 mm/day. However, during the dry season, ETc increased from 0.76 to 6.03 mm/day. Similar trends were observed by (Bouraima et al., 2015).



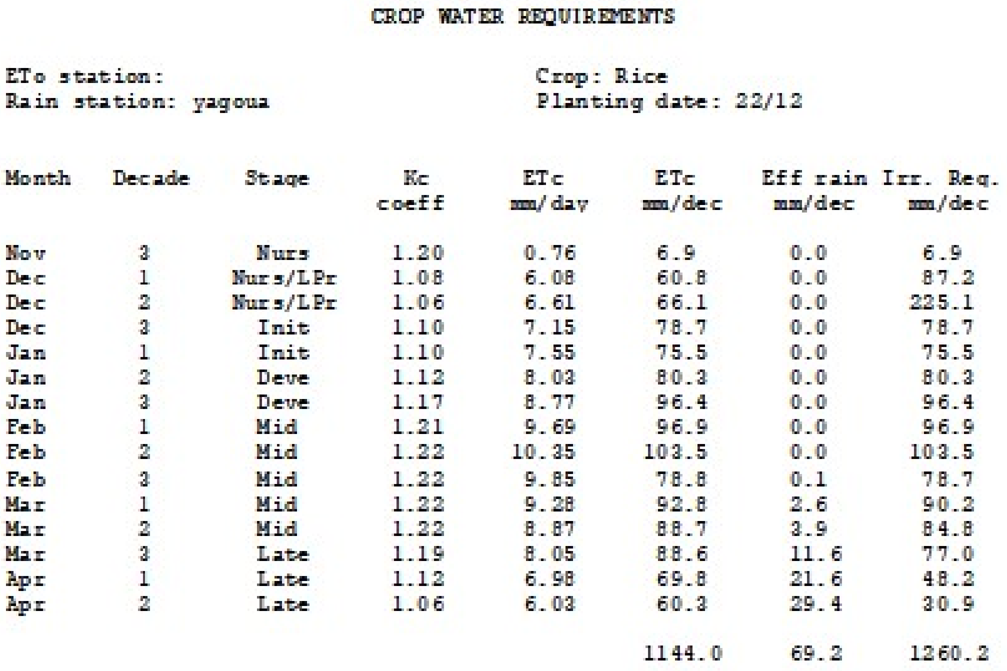
```
                              MONTHLY ETO PENMAN-MONTEITH DATA
                                (File: E:\data\YAGOU.PEM)


Country:                              Station:
Altitude: 365 m.                      Latitude: 10.40 °N     Longitude: 15.23 °E


Month        Min Temp   Max Temp   Humidity    Wind       Sun        Rad        ETo
                °C         °C         kPa       m/s       hours    MJ/m²/day   mm/day

January        20.8       39.2       0.99       2.5        8.6       19.9       7.15
February       22.9       39.2       1.15       3.0        8.7       21.4       8.26
March          25.8       39.4       1.96       2.3        8.1       21.7       7.25
April          24.2       34.5       2.38       2.0        7.3       20.8       5.78
May            22.9       35.5       2.71       2.0        7.4       20.5       5.56
June           22.1       31.8       2.75       2.0        7.0       19.6       4.66
July           22.0       30.2       2.77       2.2        5.6       17.6       4.02
August         21.3       34.4       2.80       1.7        4.8       16.7       4.36
September      21.3       35.3       2.35       1.9        5.9       18.3       5.22
October        19.5       36.5       1.43       2.2        7.2       19.4       6.39
November       16.9       33.4       0.98       2.5        8.1       19.4       6.38
December       16.8       32.3       0.86       2.7        8.7       19.5       6.31

Average        21.4       35.1       1.93       2.3        7.3       19.6       5.94
```

Figure 16: Reference evapotranspiration at the SEMRY seed farm



```
                         CROP WATER REQUIREMENTS

ETo station:                              Crop: Rice
Rain station: yagoua                      Planting date: 14/06

Month   Decade    Stage       Kc       ETc       ETc     Eff rain Irr. Req.
                            coeff    mm/day    mm/dec    mm/dec    mm/dec

May       2       Nurs       1.20     0.67      4.0       17.1      0.0
May       3     Nurs/LPr     1.11     3.79     41.7       35.9     31.4
Jun       1     Nurs/LPr     1.06     5.28     52.8       42.8     84.1
Jun       2       Init       1.09     5.08     50.8       48.7     53.4
Jun       3       Init       1.10     4.89     48.9       60.3      0.0
Jul       1       Deve       1.11     4.61     46.1       81.2      0.0
Jul       2       Deve       1.14     4.45     44.5       96.5      0.0
Jul       3       Deve       1.17     4.75     52.3       72.4      0.0
Aug       1       Mid        1.19     5.05     50.5       40.0     10.5
Aug       2       Mid        1.19     5.19     51.9       18.3     33.6
Aug       3       Mid        1.19     5.53     60.8       14.6     46.2
Sep       1       Mid        1.19     5.87     58.7       11.9     46.8
Sep       2       Late       1.17     6.11     61.1       5.7      55.4
Sep       3       Late       1.13     6.32     63.2       4.0      59.2
Oct       1       Late       1.08     6.58     65.8       1.9      63.9
Oct       2       Late       1.06     6.88     6.9        0.0       6.9

                                              760.0      551.4    491.4
```

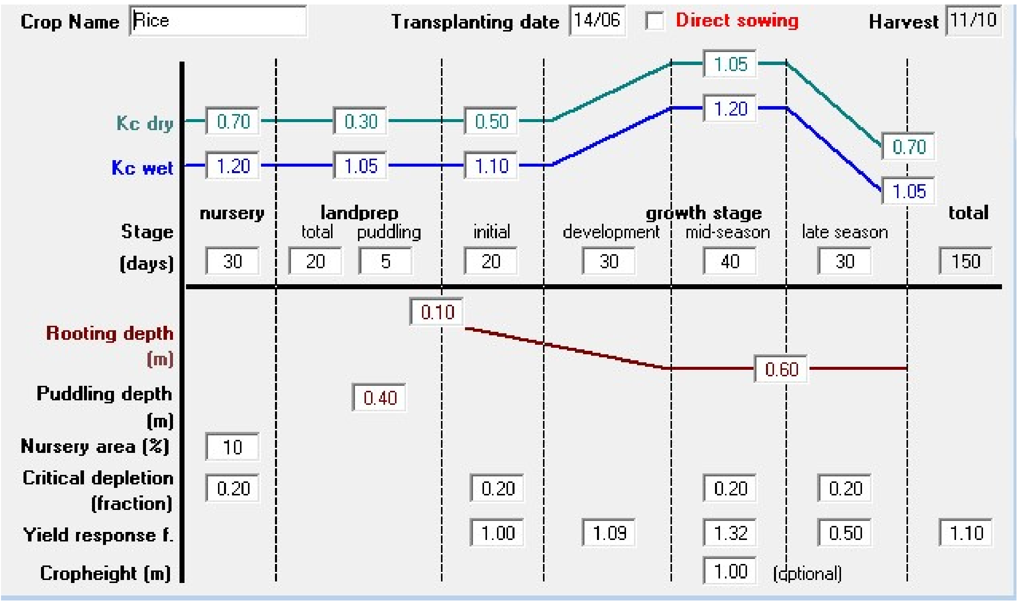
Figure 13: Crop water requirements of Rice at the SEMRY seed farm during the rainy season.



```
                         CROP WATER REQUIREMENTS

ETo station:                              Crop: Rice
Rain station: yagoua                      Planting date: 22/12

Month   Decade    Stage       Kc       ETc       ETc     Eff rain Irr. Req.
                            coeff    mm/day    mm/dec    mm/dec    mm/dec

Nov       3       Nurs       1.20     0.76      6.9       0.0        6.9
Dec       1     Nurs/LPr     1.08     6.08     60.8       0.0       87.2
Dec       2     Nurs/LPr     1.06     6.61     66.1       0.0      225.1
Dec       3       Init       1.10     7.15     78.7       0.0       78.7
Jan       1       Init       1.10     7.55     75.5       0.0       75.5
Jan       2       Deve       1.12     8.03     80.3       0.0       80.3
Jan       3       Deve       1.17     8.77     96.4       0.0       96.4
Feb       1       Mid        1.21     9.69     96.9       0.0       96.9
Feb       2       Mid        1.22    10.35    103.5       0.0      103.5
Feb       3       Mid        1.22     9.85     78.8       0.1       78.7
Mar       1       Mid        1.22     9.28     92.8       2.6       90.2
Mar       2       Mid        1.22     8.87     88.7       3.9       84.8
Mar       3       Late       1.19     8.05     88.6      11.6       77.0
Apr       1       Late       1.12     6.98     69.8      21.6       48.2
Apr       2       Late       1.06     6.03     60.3      29.4       30.9

                                             1144.0      69.2     1260.2
```

Figure 18: Crop water requirement for Rice at the SEMRY's seed farm during the dry season.

The crop water requirements are scheduled across the crop growth period which is in stages as demonstrated in Figure 19, which also has the crop coefficient (Kc) values for each growth stage of the crop. The Kc can be used to explain the variations observed for ETc between the dry and rainy season. This is because Kc is the ratio of ETc to ETo. Kc varied across the crop growth stages in both the dry and wet season, and it gives the crop water requirements in a particular season.

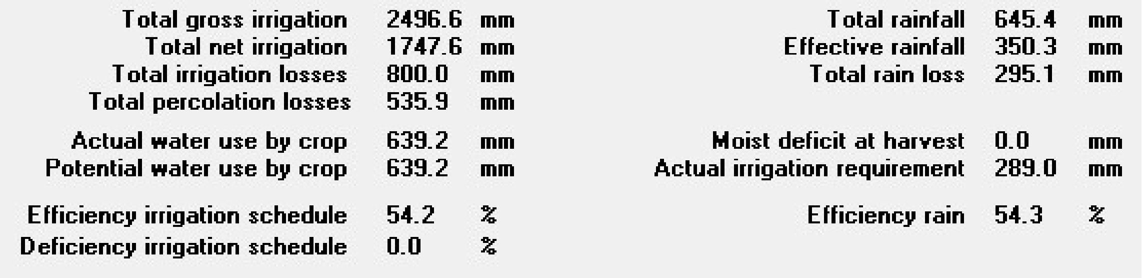


Crop Name: Rice
Transplanting date: 14/06
☐ Direct sowing
Harvest: 11/10

	nursery	landprep total	landprep puddling	initial	development	mid-season	late season	total
Kc dry	0.70	0.30		0.50		1.05	0.70	
Kc wet	1.20	1.05		1.10		1.20	1.05	
Stage (days)	30	20	5	20	30	40	30	150
Rooting depth (m)				0.10		0.60		
Puddling depth (m)		0.40						
Nursery area (%)	10							
Critical depletion (fraction)	0.20			0.20		0.20	0.20	
Yield response f.				1.00	1.09	1.32	0.50	1.10
Cropheight (m)						1.00	(optional)	

Figure 19: Crop Characteristics of Rice used for Analyses

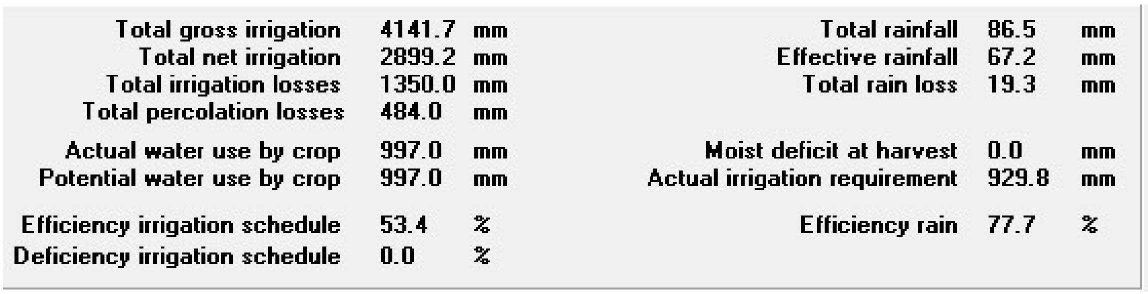
With the irrigation water requirements, there are irrigation losses and water that percolates the ground. These loses must be accounted for so that the water pumped in is sufficient to meet the CWR which entails a total gross irrigation need (Figure 20).



Total gross irrigation	2496.6	mm	Total rainfall	645.4	mm
Total net irrigation	1747.6	mm	Effective rainfall	350.3	mm
Total irrigation losses	800.0	mm	Total rain loss	295.1	mm
Total percolation losses	535.9	mm			
Actual water use by crop	639.2	mm	Moist deficit at harvest	0.0	mm
Potential water use by crop	639.2	mm	Actual irrigation requirement	289.0	mm
Efficiency irrigation schedule	54.2	%	Efficiency rain	54.3	%
Deficiency irrigation schedule	0.0	%			

Figure 20: Total gross irrigation needs at the SEMRY seed farm

s

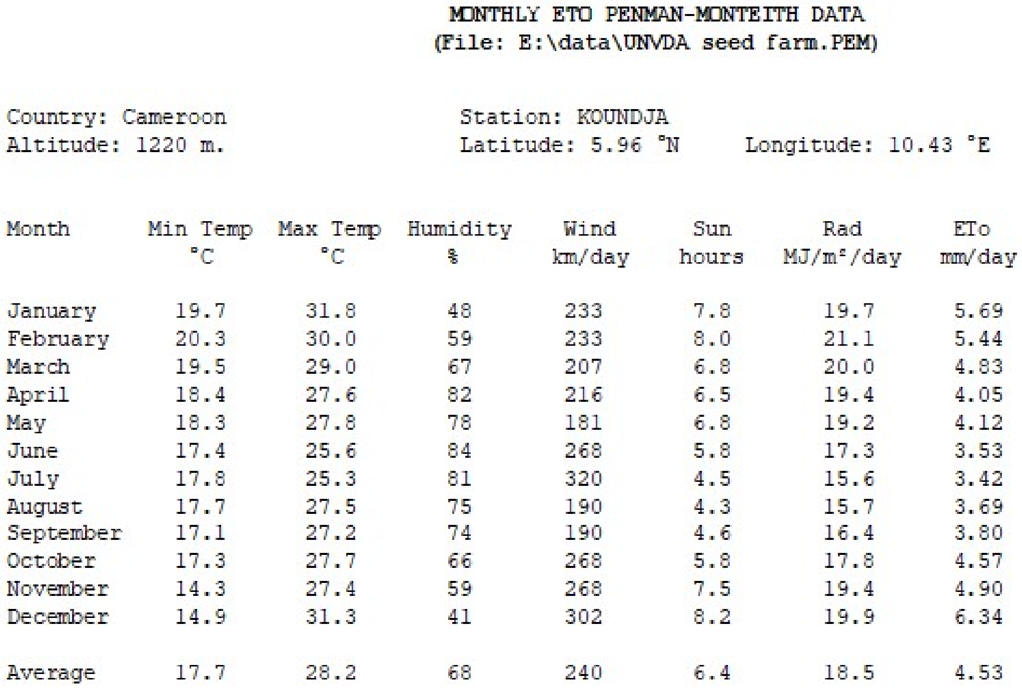


```
       Total gross irrigation   4141.7  mm                  Total rainfall   86.5   mm
         Total net irrigation   2899.2  mm              Effective rainfall   67.2   mm
      Total irrigation losses   1350.0  mm                 Total rain loss   19.3   mm
    Total percolation losses    484.0   mm

       Actual water use by crop  997.0  mm           Moist deficit at harvest  0.0    mm
    Potential water use by crop  997.0  mm    Actual irrigation requirement   929.8  mm

  Efficiency irrigation schedule  53.4  %                  Efficiency rain   77.7   %
  Deficiency irrigation schedule  0.0   %
```

Figure 23: Total Gross irrigation water need for SEMRY seed farm dry season

4.2.2 Irrigation Water Requirement for Rice in the Ndop Plains

Ndop is a plain, hence water from the surrounding areas drain into it. Consequently, the water used for irrigation is mainly driven by gravity. In addition, the farm is supplied by water from a dam. The first cycle of the rainy season coincides with that of Yagoua, starting in May, with land preparation. The transplanting date as observed from the fields was 14th June, which results in the harvest being on 2nd October. The transplanting and harvesting time was similar to that of the seed farm in Yagoua. This was necessary as it enabled assessment of the different water requirements between the two sites. The water requirements for the 12-ha seed farm in the UNVDA is presented in Figure 24.

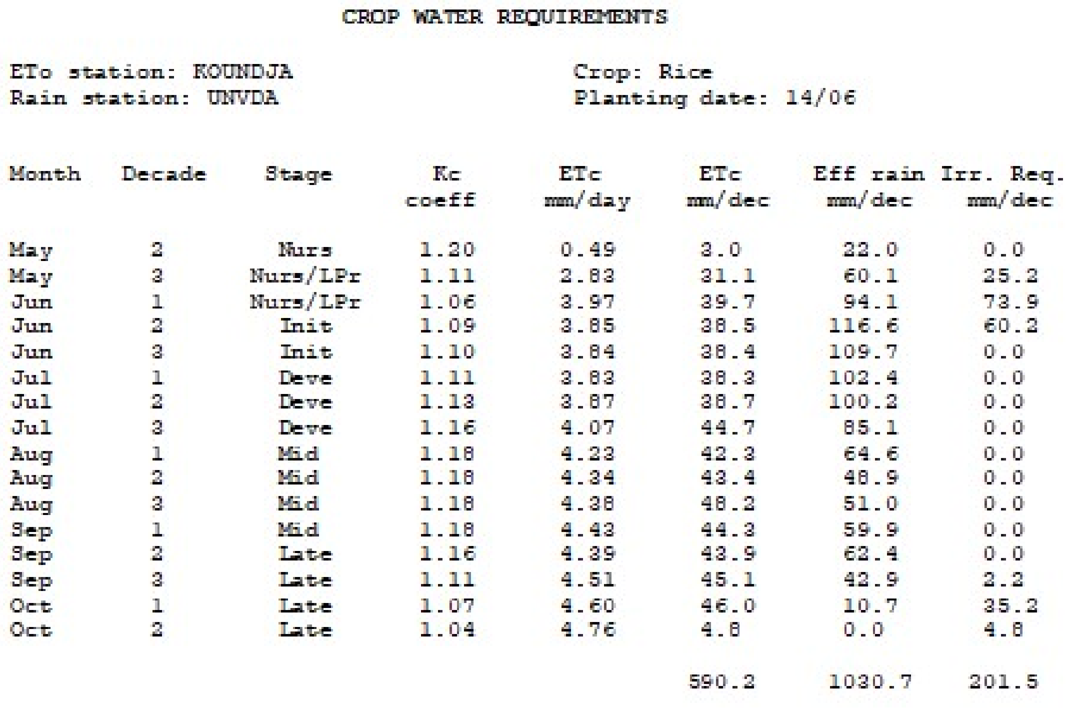


```
                          MONTHLY ETO PENMAN-MONTEITH DATA
                         (File: E:\data\UNVDA seed farm.PEM)

Country: Cameroon                 Station: KOUNDJA
Altitude: 1220 m.                 Latitude: 5.96 °N     Longitude: 10.43 °E

Month       Min Temp   Max Temp   Humidity     Wind      Sun        Rad       ETo
               °C         °C         %        km/day    hours   MJ/m²/day   mm/day

January       19.7       31.8        48         233       7.8       19.7       5.69
February      20.3       30.0        59         233       8.0       21.1       5.44
March         19.5       29.0        67         207       6.8       20.0       4.83
April         18.4       27.6        82         216       6.5       19.4       4.05
May           18.3       27.8        78         181       6.8       19.2       4.12
June          17.4       25.6        84         268       5.8       17.3       3.53
July          17.8       25.3        81         320       4.5       15.6       3.42
August        17.7       27.5        75         190       4.3       15.7       3.69
September     17.1       27.2        74         190       4.6       16.4       3.80
October       17.3       27.7        66         268       5.8       17.8       4.57
November      14.3       27.4        59         268       7.5       19.4       4.90
December      14.9       31.3        41         302       8.2       19.9       6.34

Average       17.7       28.2        68         240       6.4       18.5       4.53
```

Figure 24*:* Monthly Evapotranspiration at the UNVDA seed farm

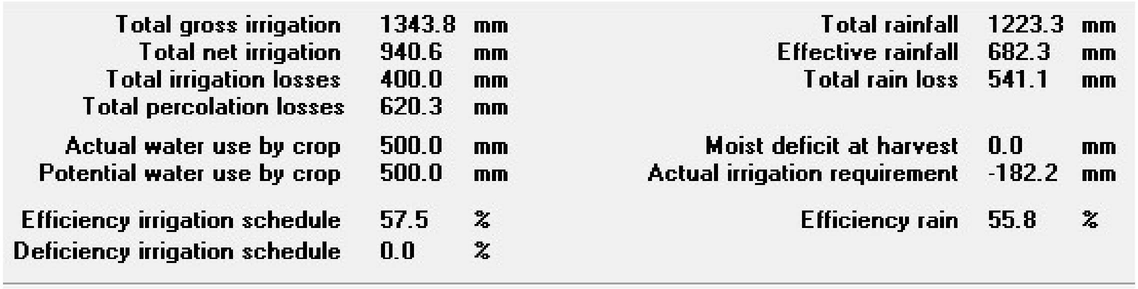
Monthly evapotranspiration values were used along with the crop characteristics (Figure 20) to compute the crop water requirement during the dry season, using the CROPWAT model. The results are as presented in Figure 25.

The irrigation requirement that supplements the rainfall during the rainy season was established to be **201.5 mm** for **the 12 ha** seed farm. With rice cultivation, water is needed to puddle and maintain the water depth. The results show that the total gross irrigation need is **1343.8 mm,** which gives a total water need of **120,000 m^3 (Figure 26).** The amount of water required comparatively less, since the region receives more rainfall than in Yagoua, and the evapotranspiration is much less than in Yagoua.



```
                          CROP WATER REQUIREMENTS

ETo station: KOUNDJA                      Crop: Rice
Rain station: UNVDA                       Planting date: 14/06

Month   Decade    Stage      Kc       ETc       ETc     Eff rain  Irr. Req.
                            coeff    mm/day    mm/dec    mm/dec    mm/dec

May       2       Nurs       1.20     0.49      3.0      22.0       0.0
May       3     Nurs/LPr     1.11     2.83     31.1      60.1      25.2
Jun       1     Nurs/LPr     1.06     3.97     39.7      94.1      73.9
Jun       2       Init       1.09     3.85     38.5     116.6      60.2
Jun       3       Init       1.10     3.84     38.4     109.7       0.0
Jul       1       Deve       1.11     3.83     38.3     102.4       0.0
Jul       2       Deve       1.13     3.87     38.7     100.2       0.0
Jul       3       Deve       1.16     4.07     44.7      85.1       0.0
Aug       1       Mid        1.18     4.23     42.3      64.6       0.0
Aug       2       Mid        1.18     4.34     43.4      48.9       0.0
Aug       3       Mid        1.18     4.38     48.2      51.0       0.0
Sep       1       Mid        1.18     4.43     44.3      59.9       0.0
Sep       2       Late       1.16     4.39     43.9      62.4       0.0
Sep       3       Late       1.11     4.51     45.1      42.9       2.2
Oct       1       Late       1.07     4.60     46.0      10.7      35.2
Oct       2       Late       1.04     4.76      4.8       0.0       4.8

                                             590.2    1030.7     201.5
```

Figure 25: Irrigation requirement of the Rice crop at the UNVDA seed farm



```
     Total gross irrigation   1343.8  mm              Total rainfall   1223.3  mm
       Total net irrigation    940.6  mm          Effective rainfall    682.3  mm
     Total irrigation losses   400.0  mm             Total rain loss    541.1  mm
   Total percolation losses    620.3  mm

    Actual water use by crop   500.0  mm       Moist deficit at harvest  0.0    mm
 Potential water use by crop   500.0  mm  Actual irrigation requirement  -182.2 mm

  Efficiency irrigation schedule  57.5  %              Efficiency rain   55.8   %
 Deficiency irrigation schedule    0.0  %
```

Figure 26: Total gross irrigation requirement for the UNVDA seed farm

4.2.3 Water Productivity Trend in Yagoua

The area of the seed farm was uploaded to calculate Gross Biomass Water Productivity (GBWP) using python scripts. Owing to the small size of the farm, which could only be seen on 2 pixels, made it difficult to interpret the results. Consequently, the study adopted a new method which involved choosing 10 points randomly and input them in the WaPOR portal (FAO, 2020b) to get the point series GBWP between 2009 and 2020. Afterwards, the mean GBWP was calculated for the 10 points throughout the study period and plotted to get the results (Figure 27).

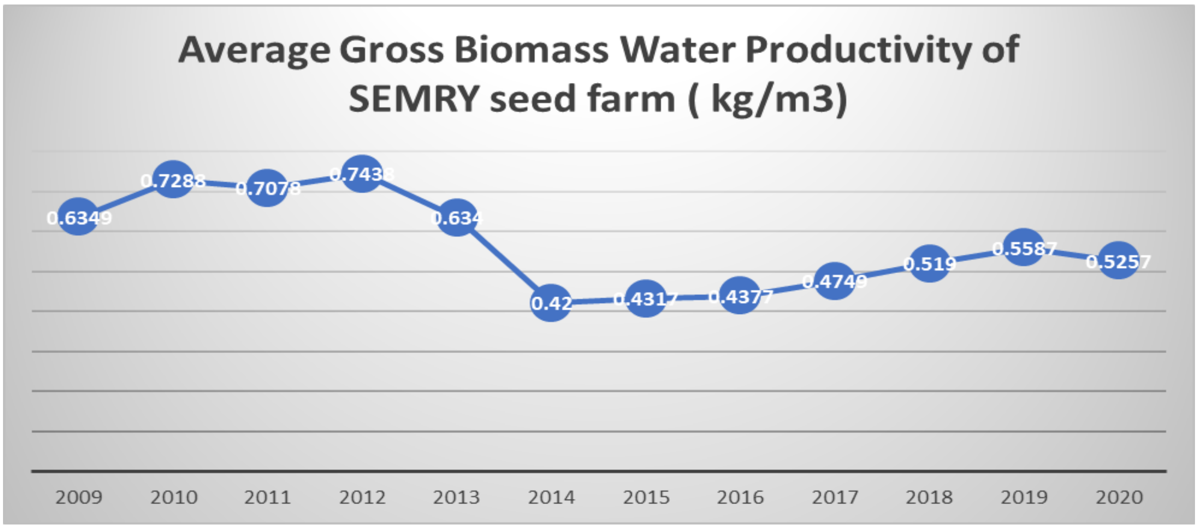


Figure 27: Average Gross Biomass Water productivity at the SEMRY seed farm (kg/m^3)

With an approximation of water used per year, it can be observed how much water is used by agriculture. The water required for irrigation is far greater than that approximated; only the degree of how huge the value is considered for conclusion since water use was not measured practically in the field. Given the huge amounts of water at stake, and the widespread belief that agricultural water usage is unsustainable, even little increases in agricultural water productivity are thought to have significant consequences for local and global water resources (Scheierling *et al.*, 2016). Considering other parts of the plant that make up the biomass, it can be deduced that the approximate amount can be the least practical used water in the farm.

4.2.4 Water productivity trend in the Ndop Plains

The area of the seed farm was uploaded to calculate Gross Biomass Water Productivity (GBWP) using python scripts. The results of the exercise have been presented in Figure 28.

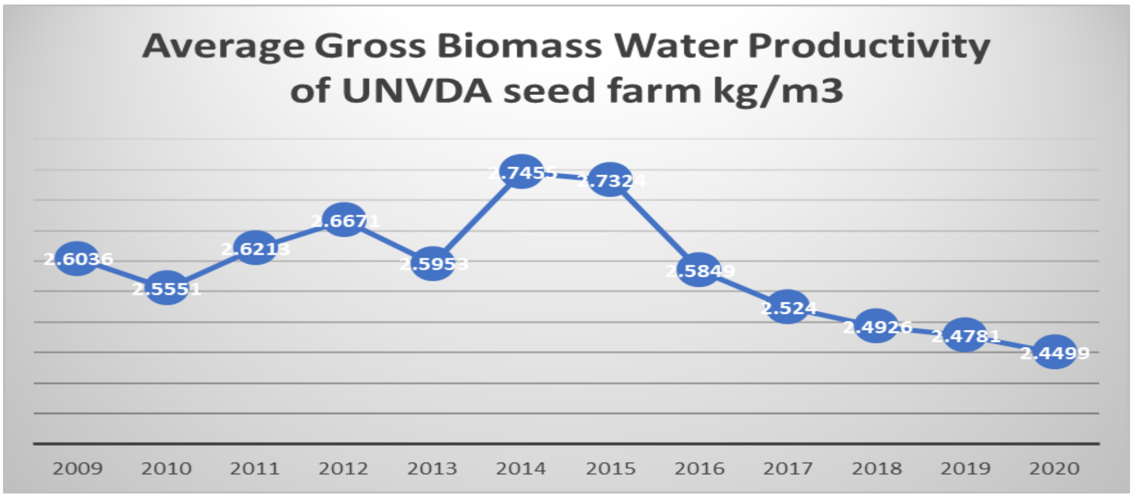


Figure 28: Average Gross Biomass Water Productivity of UNVDA seed farm kg/m3

From the results, it can be seen that the more water consumed, the more the GBWP. The highest GBWP was recorded in 2015, where the amount of water consumed was 119, 310 mm. Whereas, the least GBWP was 32 in 2016 with an approximate water consumption of 78, 396 mm (Table 5).

Table 5: Approximation of water consumed in relation to GBWP results and practical yields on site

Production Year	Tonnage produced	Approximate water consumed
2015	48.7	119310.13
2016	32	78396.8
2017	42.5	104120.75
2018	37.4	91626.26
2019	33	80846.7
2020	47	115145.3

4.3 The risks in rice production in Cameroon

4.3.1 Demographics

Of the 100 respondents selected for the interview, 76% were males and the females made up only 24% of the respondents (Figure 29). This is because most farms are owned by men and
most women who o ercentage of women who
own fields is in cont alue chain of rice. Rice is
mainly a female's c they are responsible for
most of the work fi d marketing (*AfricaRice*,
2021).

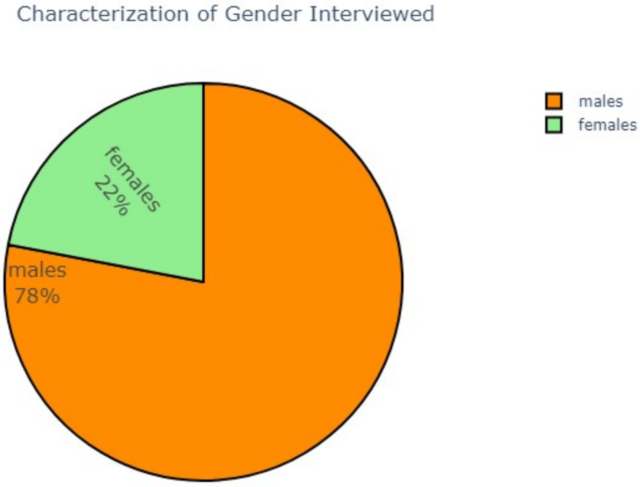


Figure 29: Gender difference among the respondents

With regard to level of education, most of the respondents only attended school up to the primary school level (Figure 30). Some of the respondents either finished or dropped out in their secondary school level or finished and continued to the tertiary. The famers in the tertiary educational level are either retired or youths who are farming to support their education as paddy production boost their incomes. Most explained that they were from polygamous homes which had more kids, and the fathers could not afford training them beyond the primary school level. Meanwhile others dropped from school since the activities in rice production employ them at a young age and their aspirations to have income overwhelms that of studying which they do not have any motivation in.

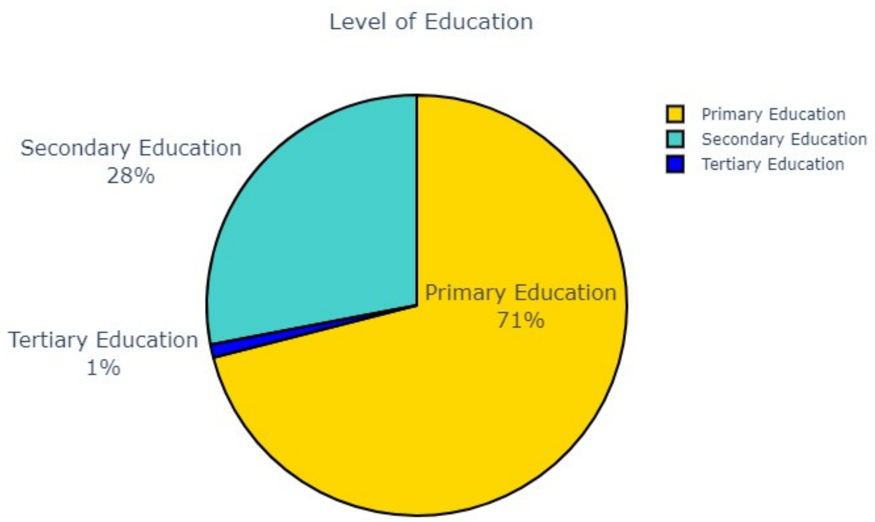


Figure 30: Level of education of the respondents

Generally, most respondents were from Vounaloum locality, followed by Toukou and Douresou. Most farmers in these localities are open to change in their locality. Figure 31 demonstrates the characterization of the respondents according to the different localities in which the questionnaires were administered.

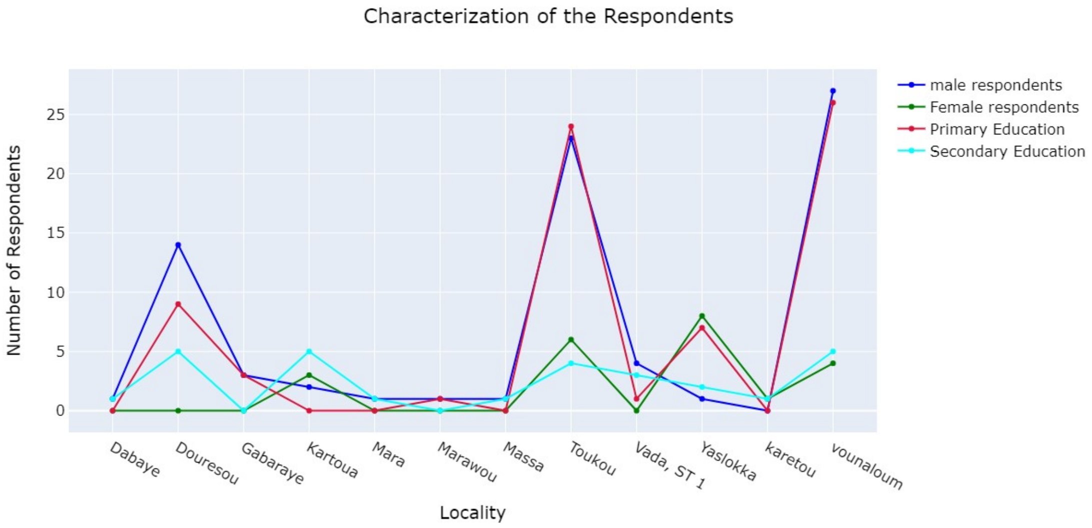


Figure 141: Characterization of respondent’s localities

4.3.2 Size of Developed Land as a Risk

Farmers have low land holding capacities since the rice fields were developed in the past and there has been a population increase. The population keeps increasing while the land size they depend on remains the same. A study conducted in West Kalimantan Province, Indonesia established a negative correlation between land pressure caused by increase in population and food sufficiency (Thakur & Uphoff, 2017). Some farmers have sought out to work out land by themselves and make it conducive for rice, but the risk here is there is no assistance from SEMRY as these farmers take care of all activities from ploughing to farm maintenance.

Rice is lucrative and many families want to get involved in the production but land that has been developed is a limiting factor. With small farm holdings, farmers result to employ labor from their children which results in dropping out o school at a young age, thus contributing to the low level of education in the area. Activities of rice production like transplanting, weeding, cutting, and threshing require a lot of labor which is handled manually as there is inadequate machinery to facilitate. After harvesting, the next activity is to either sell in the farm as the buyers from neighboring countries get to the farms to buy the produce during harvesting as it is relatively very cheap at the time; 12000 FCFA (about 24$) for 100 kg of paddy. The alternative is carrying the paddy home where they use motorbikes mostly as their main means of transportation. The cost depends on the distance of the developed land (farm) from the farmer’s home. Figure 32 presents the different cost in transportation according to the respondents. Even if a farmer spends more on transportation, the price of paddy remains the same no matter the distance. Those with farms far off, mostly sell at their farms during harvest and only carry a little home for consumption as they consume millet more in their household.

Figure 153: Correlation between the farm distance from home to the transport paid by farmers

4.3.3 Risk at Farm Level

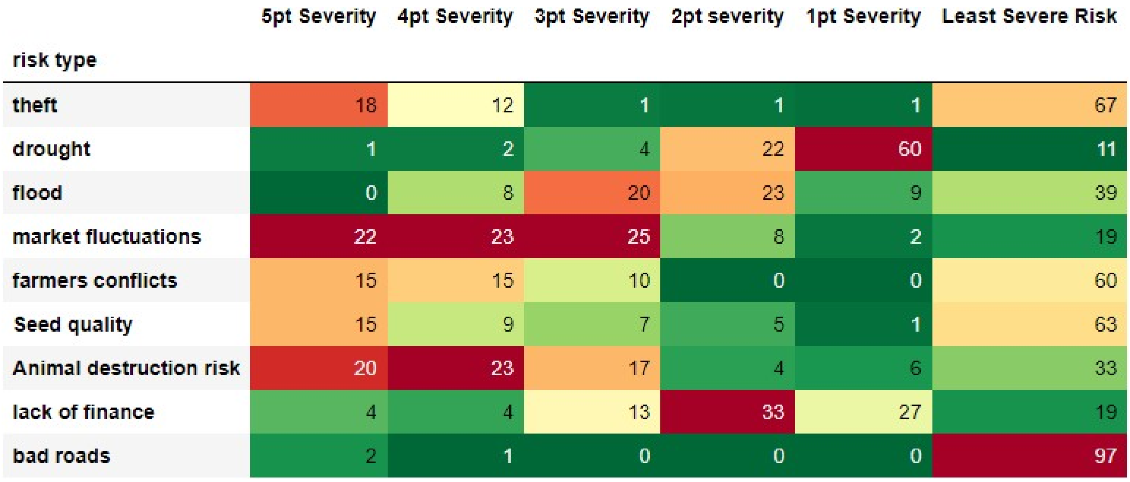
There are many factors at the farm level that reduce the yields. These include seed quality, lack of finance, water extremes (floods or drought), weeds, destruction by animals, bad roads, theft and market price fluctuations during harvest as the farmers do not have power to set the prices. Each of these factors was presented to respondents to give their grading in terms of the highest factor that greatly affects them. The 1st degree severity, meaning very pertinent, and 5th degree severity meaning least pertinent regarding yield reduction. Only 5 risks were randomly graded, and the others not graded, however, the risk still affects their farmers.

The respondents identified drought as the highest risk factor (1st-degree). This is because drought results to reduced availability of water in the rice farms. In addition, low water volumes due to drought lead to constant blackouts, which impede pumping of water into the rice fields. The overall impact of climate change on rice will be negative, as lack of forward-looking adaptation to changes in temperature and precipitation conditions (for example, through water and soil moisture management) will result in considerable losses in yields (Paul *et al.*, 2016). Heat stress will continue to be a significant threat to rice crops as these will cause drought which affects rice yields.

After drought, respondents identified lack of finance as a 2nd degree severity risk factor. Lack of finance causes a lot of slowdowns in terms of purchasing inputs for the field, like fertilizers and paying for labor. Lack of finance makes most farmers victims of exploitation from farm input vendor who give them loans of 1 bag of 50 kg fertilizer which cost roughly 18,000 to 20,000 FCFA (36 to 40 $), in exchange to 3 bags of 100 kg paddy during harvest which cost at least 36,000 FCFA (72$). This exploitation reduces the income of farmers and keeps them in the loan cycle. Further, lack of finance also slows down labor intensive activities as workers are paid on a daily basis, or according to the size of the field worked on. Without pay, the activities are delayed and this greatly reduces the yield as the right itinerary is not followed.

The 3rd degree severity identified was market fluctuations, which is as a result of farmers not having the power to set the market prices. This is because the farmers are not organized into common initiative groups or cooperatives. This problem has been taken up by some organizations to organize the farmers into groups to facilitate the price fluctuation problems. The price fluctuations cause farmers to sell when there is a high price and when the money comes in without a plan, they spend it recklessly not saving for other activities like children's school fees or demand of farm inputs for the next season. Animals like goats, cows destroy farms as the owners do not restrain their animals. However, this problem has been greatly reduced as farmers group themselves to watch over their fields although it increases their expenses and time spent in the fields.

Floods also affect their fields because of the flat nature of the fields and the non-maintenance of some water drains makes the floods to advance faster and cause more destruction. Maintenance of canals is one of the sustainable solutions to direct flood waters out of the fields. Farmers' conflicts are common especially in water management issues as some farmers abstract water to irrigate their fields only. This problem is solved when the farmers group themselves and bring in a neutral person to control the water into the different fields without bias. Seed quality was not a great risk as most farmers get subsidized high-quality seeds from the international rice (IR) breed; IR 46. Theft is mostly seen during harvest when the farmers bring in laborers to harvest or after harvest when they pack the paddy in the farm. This can however be reduced when the farmers form groups and get someone to watch over their farms to secure their paddy before they transport it home. In a related study, Thi et al. (2015) identified drought, storm, pest and diseases as the main cause of losses in rice production in Central Highlands of Thailand. Figure 33 shows the different risks faced by the farmers with their degree of superiority according to farmer's perception.



risk type	5pt Severity	4pt Severity	3pt Severity	2pt severity	1pt Severity	Least Severe Risk
theft	18	12	1	1	1	67
drought	1	2	4	22	60	11
flood	0	8	20	23	9	39
market fluctuations	22	23	25	8	2	19
farmers conflicts	15	15	10	0	0	60
Seed quality	15	9	7	5	1	63
Animal destruction risk	20	23	17	4	6	33
lack of finance	4	4	13	33	27	19
bad roads	2	1	0	0	0	97

Figure 163: The risk assessment of rice production

When one or more of the risks mentioned above reduces the paddy yield, which consequently reduces the income of the farmer, most of farmers turn to millet cultivation and market gardening as a backup plan. It is recommended that farmers should have crop insurance schemes so as to reduce the effects of the outcome when the risks cannot be mitigated, while farmers continue to use high quality seeds that can withstand most of the risks (Samal & Pandey, 2005). The risks associated with water management; floods and drought can be reduced by adopting stable electricity supply and organizing the farmers to plan their water management system, because improving on water management can increase the yields by 20% (Singh *et al*., 2013).

Most farmers perceive their yields are greatly influenced by enough water quantities (Figure 34). The farmers believe that when there is adequate water supply throughout the growing season, they are guaranteed of good harvest. In addition, the famers identified good soils to have a significant influence on the rice yield. Soil type has been found to have an influence on rice productivity. For instance, Dou et al. (2016) established that rice grain yield was higher in clay soil as compared to sandy loam soils. In addition, the study found that clay soil was 25% higher in water productivity in comparison to sandy loam soils.

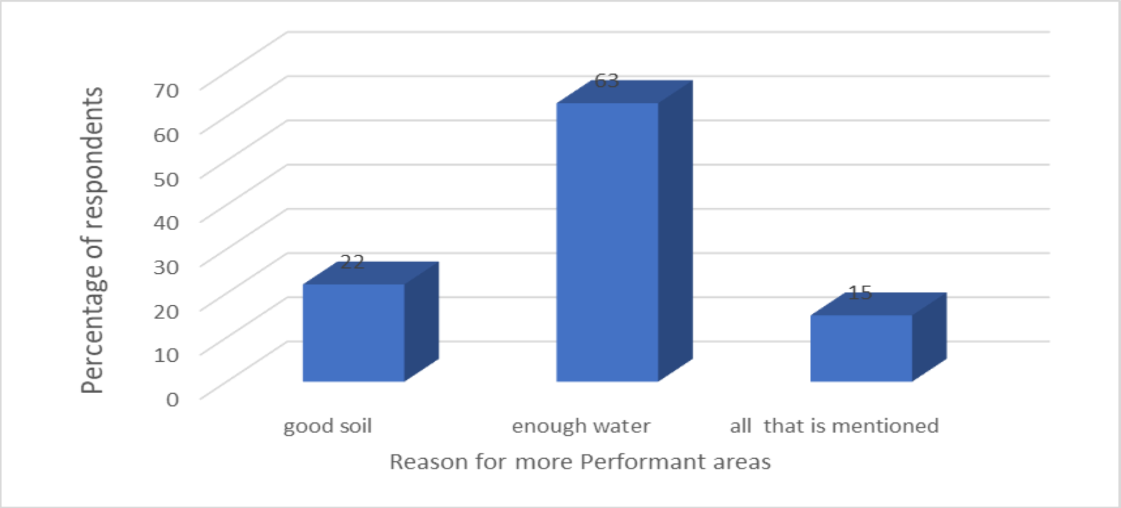


Figure 174: Farmers Perception on reason for varying performance in different areas in the Paddy fields at Yagoua.

Other risks identified by the farmers were pests, water borne diseases and exploitation from input suppliers. Pest when not managed reduces yield in terms of both quantity and quality. Table 7 shows the different types of pests and their control methods.

Table 5: Diseases/Pests symptoms and damages with their control methods

Diseases/pests	Symptoms and damages	Control methods
Blast	- Black spots on the leaves and the last node before the spike - Partial infertility or total drop in plant production	- Use resistant varieties - Carryout deep ploughing - Avoid too much nitrogen in the plant
Blight	Small round brown spots on leaves and stems - Fall in production	Use of resistant varieties

Insects	-Perforation of the leaves and stems - Death of plant	Apply an insecticide on the planting row during planting or tilling
Birds	-Eating of ripe grains and seed - Fall in production	-Shoot birds with stones

The risks are distributed according to the parties involved in the rice value chain. SEMRY's task is to: ensure that rice farmers have water to irrigate their fields, prepare the land for farmers, maintain secondary canals, open / maintain agricultural and commercial roads, supply farmers with good seeds and inputs and capacity building of farmers. On the other hand, rice farmers must: prepare nurseries, transplant seedlings, weed, apply inputs, harvest rice fields and pay a sum of 102,000 F / ha, which is 50% of the fees for the services provided by SEMRY at the start of each management season and, if necessary, working capital loans. This can be paid for in cash or in kind with rice during harvest time. The state pays the remaining 50% of the fees. Although SEMRY control the water management in the field it faces some challenges.

From the interviews with the Chief of Antenna, Mbo Mbonso Production basin, GP-DERUDEP, the Chief of production at UNVDA Ndop, the Regional Technical head office chief at the Ministry of Agriculture, the following challenges were identified:

- Most farmers have not mastered the rice production itinerary
- Risks in the Highland zone
- Farmers unable to procure enough seeds, fertilizers and chemicals for their fields
- Farmers have poor storage facilities
- There are poor road networks
- At the farm level there are pests which destroy crops and insects that infect the farmers with water borne diseases
- The farmers don’t have sufficient water as the quantity has been decreasing by the years which results to dry spells and worst still drought when prolonged (Mbonso Area)
- Most farmers employ manual labor which makes the production process slow
- Insufficient electrical power for milling as there are always blackouts in the production areas.

4.3.4 Opportunities in Rice Production in Cameroon

Cameroon is blessed with fertile land and abundance of water resources, which are two essential factors in rice production. Other strengths depend on each mini environment, but any weakness is overcome by institutions set in place by the government and non-governmental organizations. The study identified the following potentials in Sudano-Sahel zone: there is abundant water in the Logone River and in the artificial lakes in Maga*,* 27 km long dike in Maga that can successfully hold 625,000,000 m^3 of water, with a surface area of 40,000 ha. There is an active population in the area who are willing to provide labour, the soils (Vertosol) are very fertile and good for rice production, and the area receives adequate sunshine.

The highland zone has abundance of water as most rivers drain into the areas where rice is cultivated. Additionally, the zone is blessed with fertile land as most fertile soils eroded in the uplands get deposited into this plain. Rice production remains an opportunity as there are institutions that work hand in gloves to help the government and farmers increase their production like the Coalition for African Rice Development (CARD), the ministry of agriculture and rural development, Grass field Participatory and Decentralized Rural Development (GP DERUDEP), Grass field Participatory and Integrated Rural Development (GP IRDP).

CARD is an advisory group made up of 32 sub-Saharan African countries (including Cameroon), 5 regional economic communities and 13 development partners, whose objective is to increase rice production in member countries. CARD itself does not conduct surveys or research. CARD is unique in that it helps its member countries formulate their National Rice Development Strategy (NRDS), and its member institutions provide support by implementing projects in the key areas of intervention specified in their NRDS (CARD, 2021). The strategy drafted by and operating under CARD has the following specific goals (Iii, 2009)**:**

- Promote large-scale production of certified rice seeds by the private sector and control farmer seed production through community seed systems;
- Carry out production through mechanization and effective use of inputs, Modernization of tools;
- Organize the sector by supporting producer organizations and establishing multi-stakeholder platforms and agencies;

- Sustainable management of water and land resources through the promotion of good agricultural practices;
- Adopt quality promotional labels to meet national needs and occupy regional borders and markets;
- Support employment in rural areas, especially for women and youth.

The strategy is implemented by the Ministry of Agriculture and rural development which has the following functions in relation to agriculture and serve as opportunities in the promotion of rice production (MINADER, 2021):

- The formulation, planning and execution of government programs related to agriculture and rural development;
- Formulation of laws and regulations and control of their application; monitoring and protection of the different agricultural sectors;
- Phytosanitary protection;
- Design of strategies and methods to guarantee food security and self-sufficiency and supervise their implementation;
- The identification and promotion of new agricultural products for export; the collection, production and analysis of agricultural statistical data;
- The dissemination of agricultural information and advice to producers;
- Coordination of the management of agricultural crises;
- Coordination of professional agricultural organizations monitoring.
- Promote investment in the agricultural sector, large and medium farms;
- Agricultural cooperative education, control of agricultural cooperative education and control of private agricultural education, contact the department in charge of professional training.

Under the ministry of agriculture, there are projects that promote rice production specifically funded by the government and its partners; Grass field Participatory and Decentralized Rural

Development (GP DERUDEP), Grass field Participatory and Integrated Rural Development (GP IRDP).

Another major project boosting rice production is Project for the Development of Irrigated and Rainfed Rice Cultivation (PRODERIP) which targets the East, South and Central regions, and in the irrigated sector of UNVDA Ndop, and involving 10,000 families in the 3 rainfed regions and 5000 families in the irrigated systems. PRODERIP runs from 2016 to 2021 with MINADER and UNVDA being the implementation agencies. This project produces and multiplies rice seeds in their project sites and trains extension workers and key rice farmers on upland rice production with onsite trainings for general rice production. PRODERIP has the following objectives (JICA, 2021);

- To increase the production of high-quality seeds for irrigation and highland rice varieties.
- To increase the number of farmers growing and consuming upland rice in the project areas.
- To improve farmer irrigation techniques in the UNVDA irrigation sectors.
- To improve harvest and postharvest processing for commercialization in the irrigation sectors of the UNVDA.

4.4 Adaptation Measures and Policy Framework to Reduce Rice Production Risk

To every risk in rice production, there is a degree to which it can be managed. The low percentage of women involved in rice production (owners of farms) should be increased so that they participate more in their family’s decision making. Most females in the rice production fields are temporal workers who are paid daily to fend for their families. The average land holding capacity should be increased with the help of the government, since developing more land for rice production is expensive. This can lead to farmers having more income to fend for themselves and families, including taking children to school, thus increasing the number of literates in the secondary and tertiary levels. Farmers should plan in advance for each forthcoming season so as not to fall prey to exploiters with heavy fertilizer loan schemes that make them to labor in vain.

Creation of farmer Cooperative for the collaboration of farmers to reduce the risk in the rice value chain is very critical as this can help in controlling the market prices, provide collateral for group loans for their farm inputs, re-organize farmers to manage the waterways, thus reducing the effects of floods and drought caused by disorganization at field level.

The stakeholders in rice production should work hand in gloves to boost farmer's production by utilizing the opportunities and managing risks in rice production through a participatory-collaborative approach. This approach helps stakeholders to contribute to the process, evaluate the available information, consider the likely consequences of certain actions, propose possible alternative strategies and the results to accept these processes of decision making (OECD, 2020).

Table 6; Policy framework to manage risks in rice production in Cameroon

stakeholders	Farmers	Agricultural experts	Research institutions	Non-Governmental Organizations
Roles	Form cooperatives, make seasonal plans before the season starts. Provide information to other stake holders for decision making	Transfer possible technologies to mitigate or manage risks to farmers	Research on possible ways to reduce the risks in rice production	Support local farmers in their day-to-day activities to improve on their livelihood and support farmers to purchase farm inputs
Management of rice production risks				
Government				
Increase the yearly budgets for SEMRY and UNVDA	Allow local authorities to propose and implement their developmental projects; effective decentralization	Provide incentives to workers and farmers and create loan schemes for input acquisition by farmers	Improve on conflict management schemes	Provide stable supply of electricity to agricultural areas so as to reduce the risks of

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

Rice is a staple food in Cameroon and the neighboring countries. Like agriculture, which is the highest consumer of water, rice also is the highest crop that consumes water in its production cycle, especially lowland rice cultivation. Contrasting the Sudano-Sahel and Highlands Agro-ecological zone in Cameroon, the former produces more rice tonnage as compared to the latter. Meanwhile, Sudano-Sahel receives lesser rainfall as compared to Highlands Agro-ecological zone, with higher gross biomass water productivity. The study established great potential for rice production in Sudano-Sahel region owing to the fertile soils and availability of labor. From the results of the crop water requirements and water productivity analysis for the SEMRY seed farm in Yagoua; it was established that irrigation water requirement was higher during the dry season as compared to the rainy season. Further, the findings show that rice production tended to be higher during the dry season than in the rainy season. This was mainly attributed to the effect of flooding in the rainy season on rice productivity. The most perceived risks in rice production by farmers at Yagoua, in the Sudano-Sahel zone are; drought, inadequate funds, fluctuations in market prices, pests, floods, water-borne diseases and exploitation from input suppliers, in order of their degree of severity from the top. For the highland zones, the risks observed in rice production are; low technological know-how, inadequate funds, pests, poor roads and irregular electricity supplies for milling. Cameroon is endowed with natural resources both inland and in water, and a layman can say there is no cause for alarm now, but in the nearest future with the increase in population and the country's vision to be an emerging nation by 2035, water pricing schemes should be the next thing on the government's agenda. The risks in rice production can be mitigated by a close collaboration of the different stakeholders involved from the family level up to the government.

5.2 Recommendations

I. Water management regulations should be placed on rice production schemes, as many farmers rely on this activity which depends a lot on availability of water.

II. Farmers should group themselves into cooperatives to facilitate technology transfer, increase in farm sizes per group, which can aid in loan assessment, selling in bulk to the market and controlling market prices and employment of workers in the farms who are not underage so as to stop child abuse. There should be sensitization and advertisement on homemade rice so that the market for SEMRY and UNVDA's rice produce is expanded.

III. The government should give autonomy to these institutions (SEMRY and UNVDA) to operate as a profit-making entity which will increase their competitive advantage, and the government only coming in with incentives to aid the farmers. There is need for further research to quantify water productivity of rice and the practical quantity of water needed for irrigation in the two agroecological zones should be investigated.

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APPENDIX

Appendix 1; Potential Capacity of the Sudano-Sahelien Agro-ecological Zone

Division	Sub Division	Rain fed rice(Ha)	lowland rice(Ha)	Division	Sub Division	Rain fed rice (Ha)	lowland rice(Ha)
Diamare	Bogo	2247	0	Mayo-Tsanaga	Bourrah	6285	0
	Dargala	6055	0		Hina	4810	0
	Gazawa	1559	0		Koza	141	0
	Maroua 1	6217	0		Mayo Moskota	1016	0
	Maroua 2	5120	0		Mogode	18299	0
	Maroua 3	5200	0		Mokolo	15415	0
	Meri	155	0		Soulede Roua		3243
	Ndoukoula	1374	0				
	Pette	6220	0	Benoue	Bacheo	7433	10609
					Bibemi		24575
Mayo Danay	Datcheka		6187		Dembo	24573	0
	Gobo	6201	11608		Demsa	8809	4888
	Guere	6201	11608		Garoua 3	3802	0
	Kai-kai	19624	0				
	Kalfou	11020	0	Lagdo	Pitoa	2264	0
	Kar Hay	1741	5055		Tcheboa	7821	3592
	Maga	1831	5633		Touroua	9568.3	16656.7
	Tchatibali		5862				
	Vele	11663	1877	Mayo-Louti	Figuil	3615	0
	Wina	1831	5944		Guider	4668	21631
	Yagoua		11243		Mayo-Oulo	20510	6244
Mayo-Kani	Guidiguis	4452	0	Faro	Beka	6096	30322
	Kaele	1736	0		Poli	46203	13241
	Mindif	2480	2740				

	Moulvoudaye	11438	0	Mayou-rey	Rey-Bouba	3591	0
	Moutouroua	8043	0		Tchollire	43747	0
	Porhi	3591	0		Touboro		20654
Logone et Chari	Fotokol	3417	0	Waza	Makari	4306	7905
	Goulfey		15656		Zina	8643	1544
	Hile Halifa		580		Kolofata	16000	0
	Kousseri		2266		Mora	47118	0
	Logone Birni	6968	765		Tokombere	9064	0

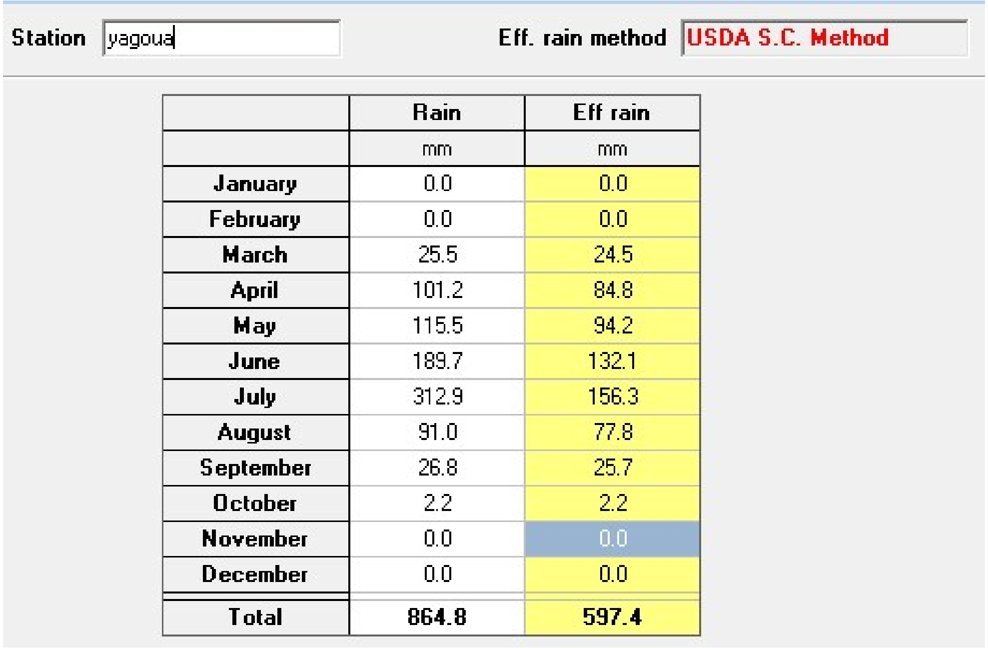
Appendix 2; Potential Capacity of the Highlands Agro-ecological Zone

Division	Sub Division	Rain fed rice(Ha)	Lowland rice
Menchum	Fungom	6995	
	Mentchum-Valley	9862	
	Wum		644
Mezam	Bafut	1738	4800
	Bali	1205	
	Tubah		495
Ngoketunjia	Babessi		3546
	Balikumbat	318	1031
	ndop		2128
Nde	Bangante	447	
	Bassamba	2436	685
	Tonga	19	
Ndonga Mantung	Ndu(Ntaba, Mbawrong)	1000	10000
	Nwa (Sabongari)	2000	20000

Misaje	300
Ako	200

Data gotten from MINADER Regional Delegation office Bamenda

Appendix 3; Precipitation of SEMRY seed farm Yagoua

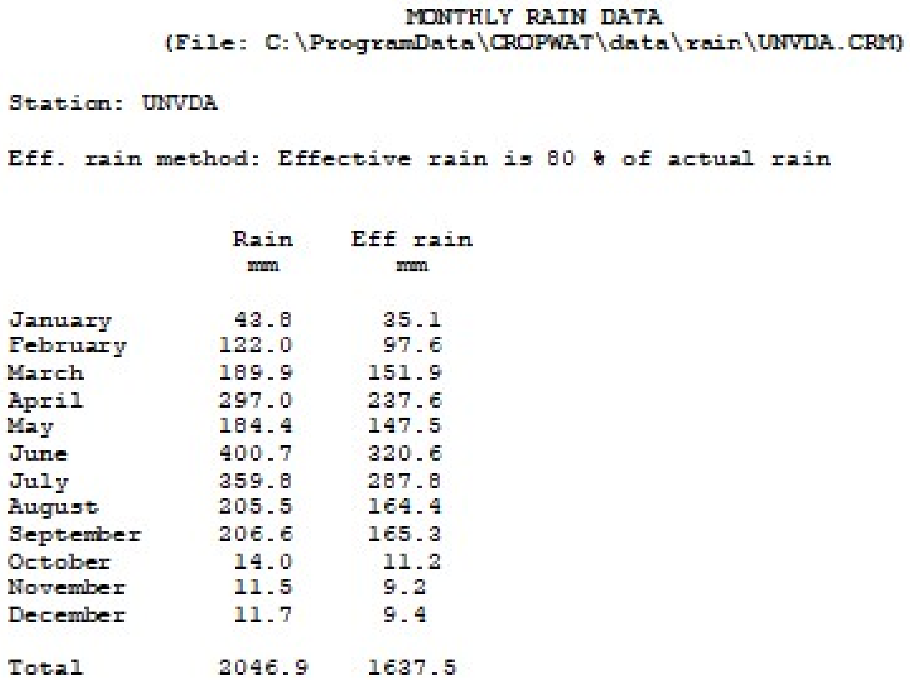


Station yagoua

Eff. rain method USDA S.C. Method

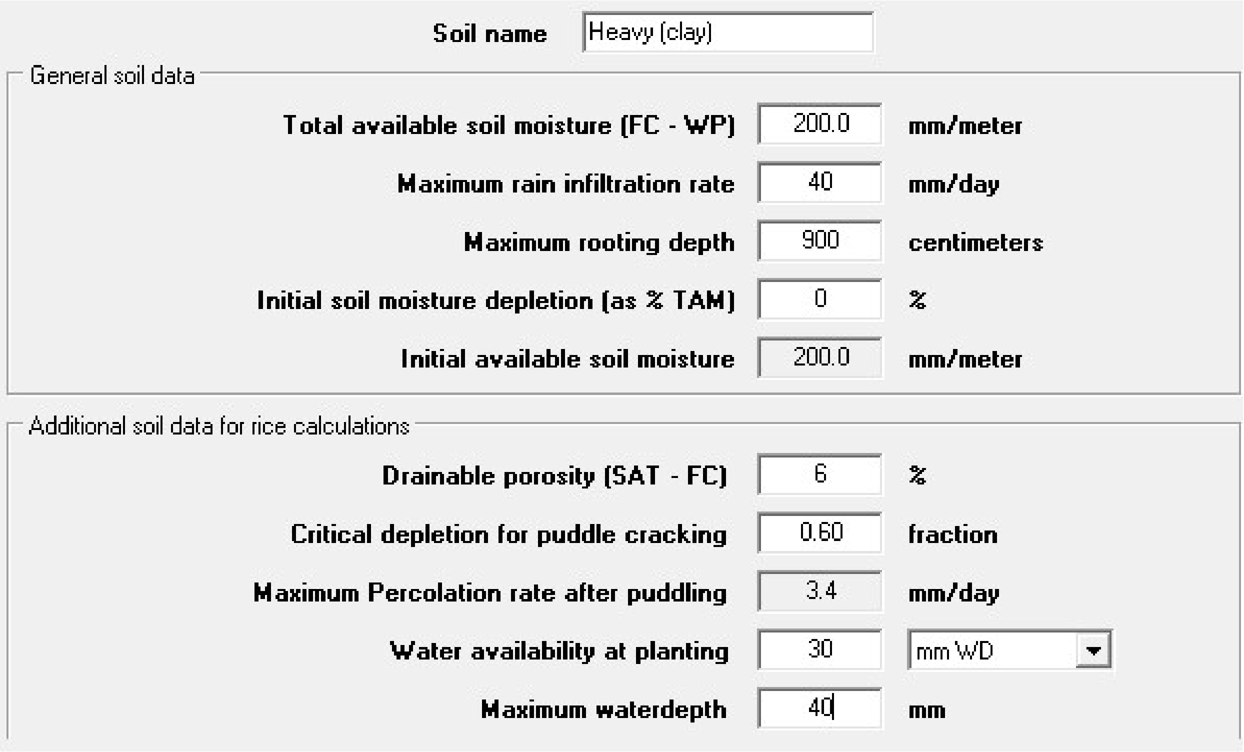
	Rain	Eff rain
	mm	mm
January	0.0	0.0
February	0.0	0.0
March	25.5	24.5
April	101.2	84.8
May	115.5	94.2
June	189.7	132.1
July	312.9	156.3
August	91.0	77.8
September	26.8	25.7
October	2.2	2.2
November	0.0	0.0
December	0.0	0.0
Total	864.8	597.4

Appendix 4; Precipitation of UNVDA seed farm



```
                        MONTHLY RAIN DATA
          (File: C:\ProgramData\CROPWAT\data\rain\UNVDA.CRM)

 Station: UNVDA

 Eff. rain method: Effective rain is 80 % of actual rain


                Rain     Eff rain
                 mm         mm

 January        43.8       35.1
 February      122.0       97.6
 March         189.9      151.9
 April         297.0      237.6
 May           184.4      147.5
 June          400.7      320.6
 July          359.8      287.8
 August        205.5      164.4
 September     206.6      165.3
 October        14.0       11.2
 November       11.5        9.2
 December       11.7        9.4

 Total        2046.9     1637.5
```

Appendix 5; Soil properties considered for SEMRY seed farm



Soil name: Heavy (clay)

General soil data

Total available soil moisture (FC - WP): 200.0 mm/meter

Maximum rain infiltration rate: 40 mm/day

Maximum rooting depth: 900 centimeters

Initial soil moisture depletion (as % TAM): 0 %

Initial available soil moisture: 200.0 mm/meter

Additional soil data for rice calculations

Drainable porosity (SAT - FC): 6 %

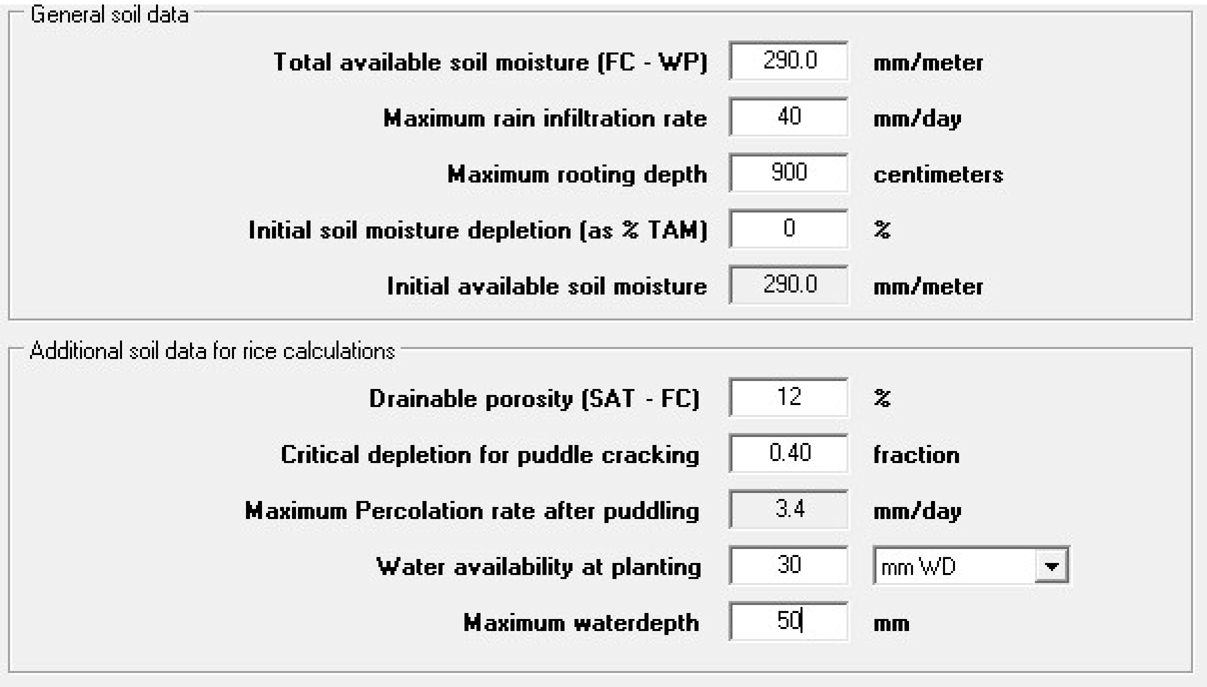
Critical depletion for puddle cracking: 0.60 fraction

Maximum Percolation rate after puddling: 3.4 mm/day

Water availability at planting: 30 mm WD

Maximum waterdepth: 40 mm

Appendix 5; Soil properties considered for UNVDA seed farm



General soil data

Total available soil moisture (FC - WP): 290.0 mm/meter

Maximum rain infiltration rate: 40 mm/day

Maximum rooting depth: 900 centimeters

Initial soil moisture depletion (as % TAM): 0 %

Initial available soil moisture: 290.0 mm/meter

Additional soil data for rice calculations

Drainable porosity (SAT - FC): 12 %

Critical depletion for puddle cracking: 0.40 fraction

Maximum Percolation rate after puddling: 3.4 mm/day

Water availability at planting: 30 mm WD

Maximum waterdepth: 50 mm

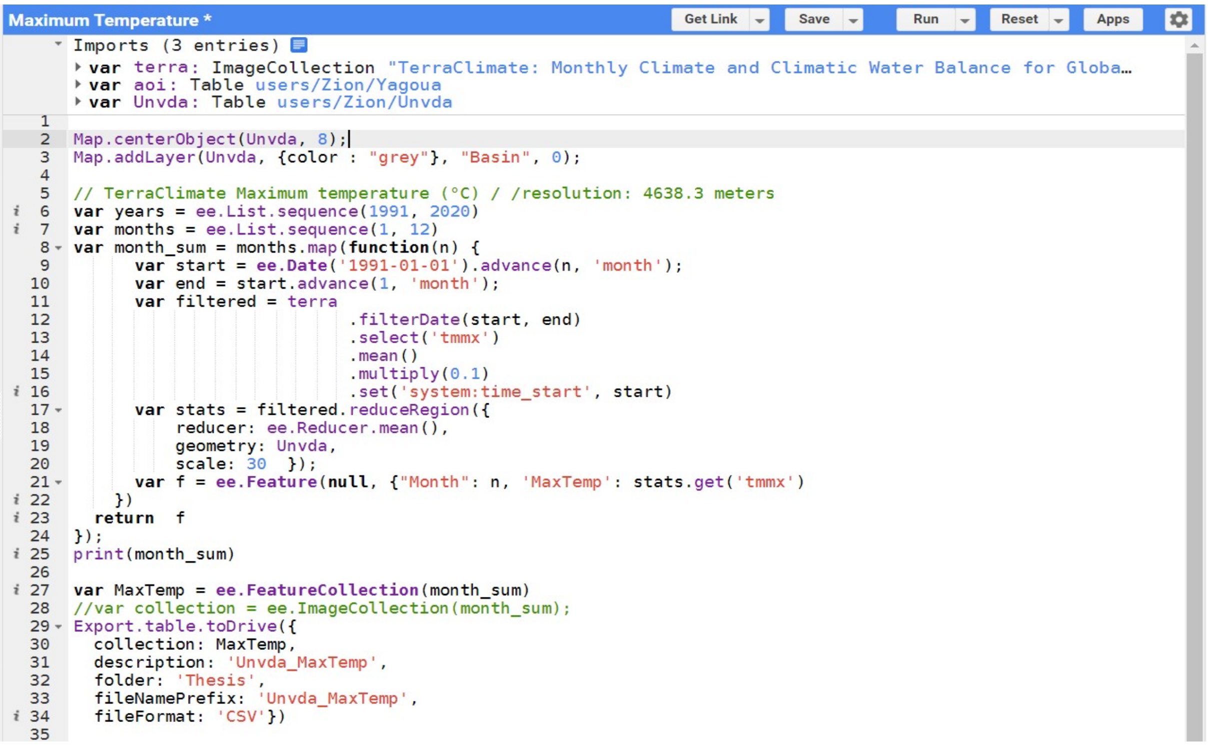
Appendix 6; Codes to download Maximum Temperature

```
Map.centerObject(Unvda, 8);

Map.addLayer(Unvda, {color : "grey"}, "Basin", 0);

// TerraClimate Maximum temperature (°C) / /resolution: 4638.3 meters

var years = ee.List.sequence(1991, 2020)

var months = ee.List.sequence(1, 12)

var month_sum = months.map(function(n) {

    var start = ee.Date('1991-01-01').advance(n, 'month');

    var end = start.advance(1, 'month');

    var filtered = terra

                  .filterDate(start, end)

                  .select('tmmx')

                  .mean()

                  .multiply(0.1)

                  .set('system:time_start', start)

    var stats = filtered.reduceRegion({

      reducer: ee.Reducer.mean(),

      geometry: Unvda,

      scale: 30  });

    var f = ee.Feature(null, {"Month": n, 'MaxTemp': stats.get('tmmx')

   })

  return  f

});

print(month_sum)

var MaxTemp = ee.FeatureCollection(month_sum)
```

```
//var collection = ee.ImageCollection(month_sum);

Export.table.toDrive({

  collection: MaxTemp,

  description: 'Unvda_MaxTemp',

  folder: 'Thesis',

  fileNamePrefix: 'Unvda_MaxTemp',

  fileFormat: 'CSV'})
```

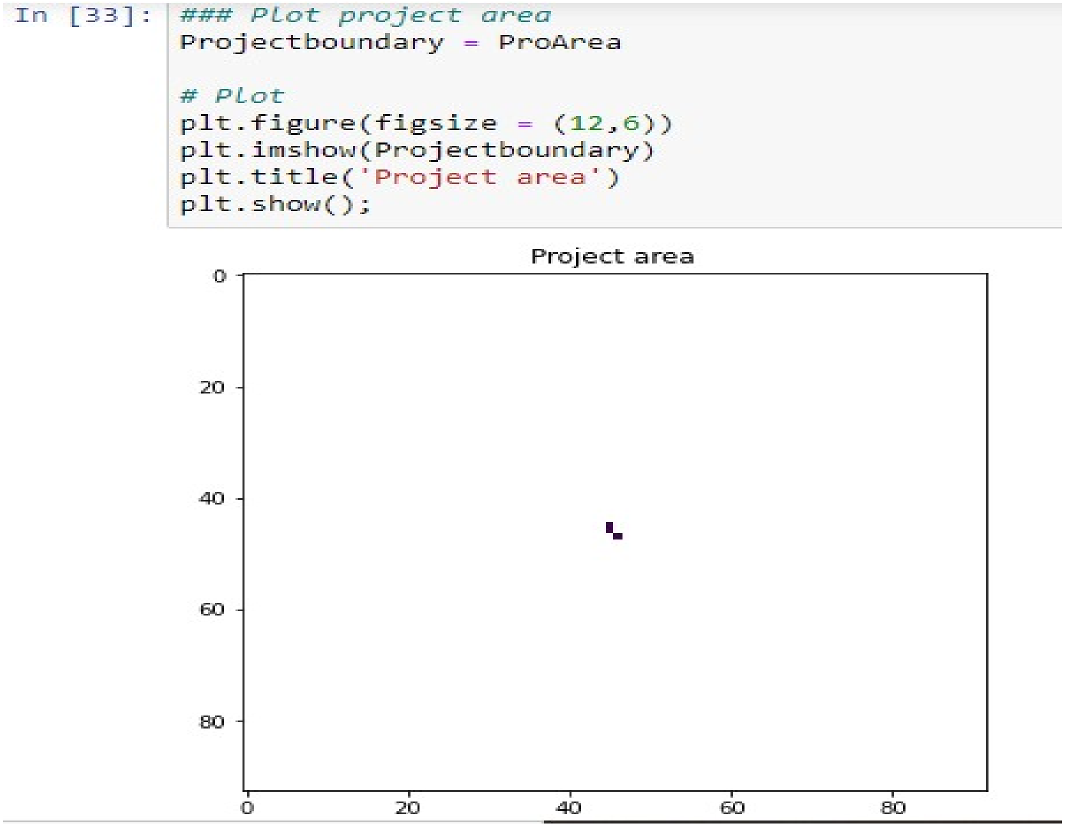
Appendix 7; Codes to download Maximum Temperature(screenshot from google earth engine)

Code: https://code.earthengine.google.com/b7e60f32e0d9998331215129ca92eb8a



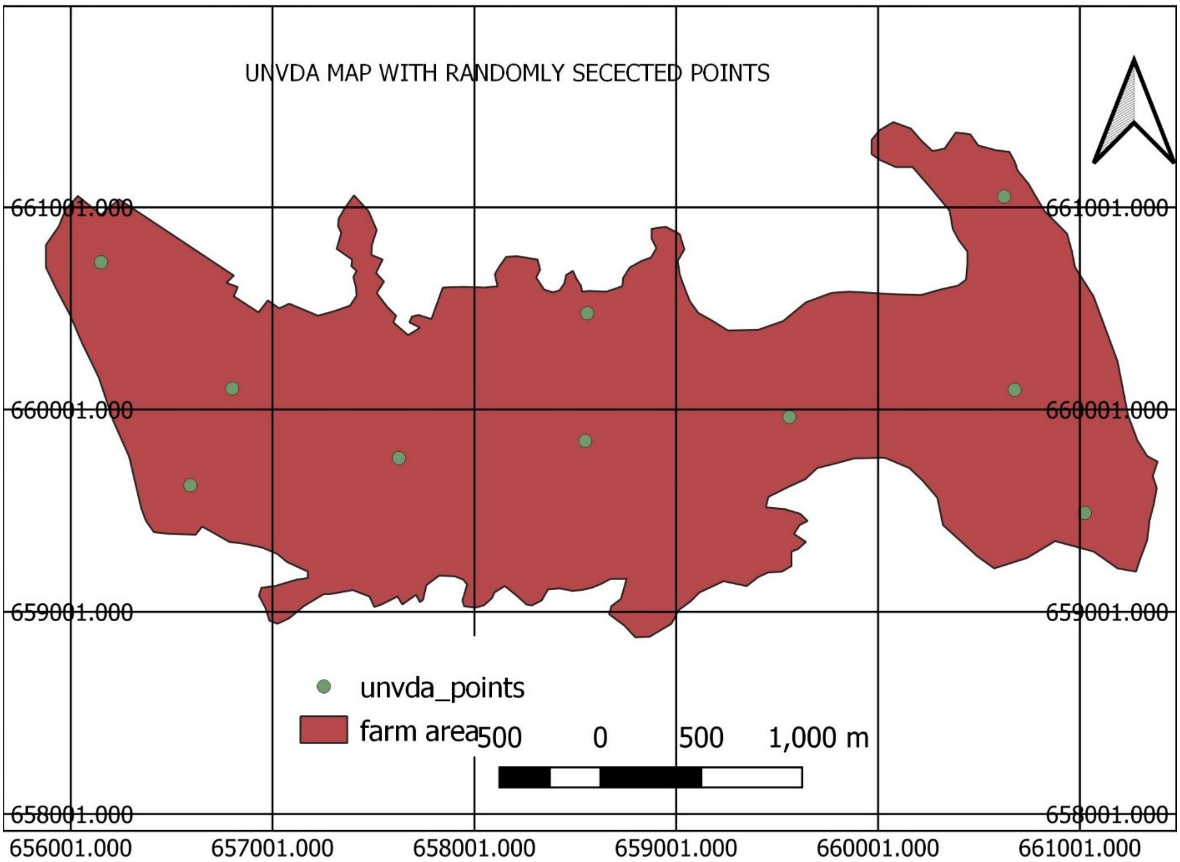
```
Imports (3 entries)
 var terra: ImageCollection "TerraClimate: Monthly Climate and Climatic Water Balance for Globa…
 var aoi: Table users/Zion/Yagoua
 var Unvda: Table users/Zion/Unvda

Map.centerObject(Unvda, 8);
Map.addLayer(Unvda, {color : "grey"}, "Basin", 0);

// TerraClimate Maximum temperature (°C) / /resolution: 4638.3 meters
var years = ee.List.sequence(1991, 2020)
var months = ee.List.sequence(1, 12)
var month_sum = months.map(function(n) {
      var start = ee.Date('1991-01-01').advance(n, 'month');
      var end = start.advance(1, 'month');
      var filtered = terra
                           .filterDate(start, end)
                           .select('tmmx')
                           .mean()
                           .multiply(0.1)
                           .set('system:time_start', start)
      var stats = filtered.reduceRegion({
          reducer: ee.Reducer.mean(),
          geometry: Unvda,
          scale: 30  });
      var f = ee.Feature(null, {"Month": n, 'MaxTemp': stats.get('tmmx')
    })
  return  f
});
print(month_sum)

var MaxTemp = ee.FeatureCollection(month_sum)
//var collection = ee.ImageCollection(month_sum);
Export.table.toDrive({
  collection: MaxTemp,
  description: 'Unvda_MaxTemp',
  folder: 'Thesis',
  fileNamePrefix: 'Unvda_MaxTemp',
  fileFormat: 'CSV'})

```

Appendix 8 ; The SEMRY seed farm Plot representation when the different shapefiles have been downloaded from WaPOR Portal

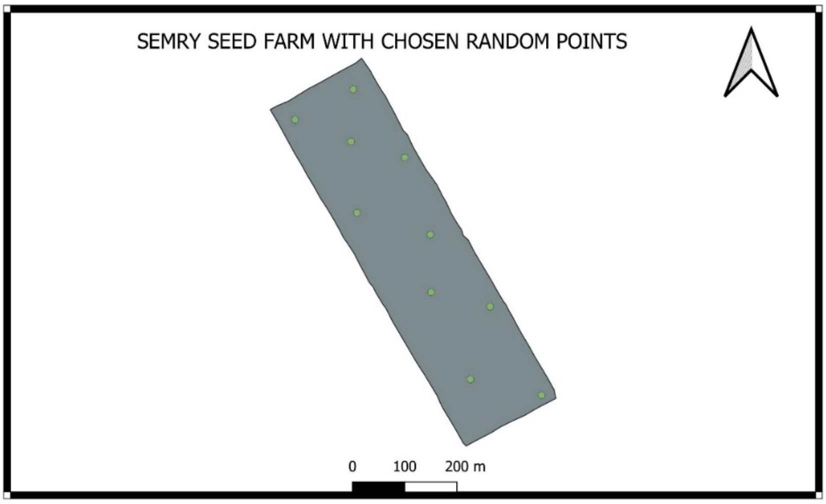


```
### Plot project area
Projectboundary = ProArea

# Plot
plt.figure(figsize = (12,6))
plt.imshow(Projectboundary)
plt.title('Project area')
plt.show();
```

Appendix 9; UNVDA seed farm with randomly selected points

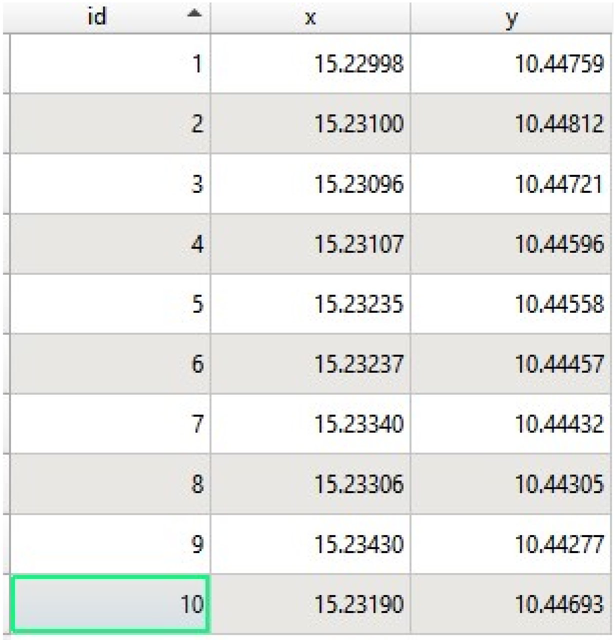


Appendix 10; SEMRY seed farm with randomly selected points



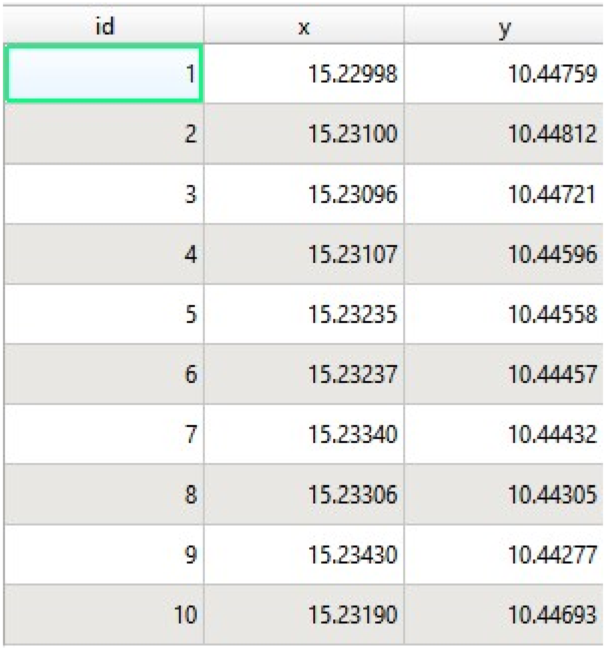
Appendix 11; GPS coordinates of the randomly selected points

Attribute table for randomly chose points at UNVDA seed farm



id	x	y
1	15.22998	10.44759
2	15.23100	10.44812
3	15.23096	10.44721
4	15.23107	10.44596
5	15.23235	10.44558
6	15.23237	10.44457
7	15.23340	10.44432
8	15.23306	10.44305
9	15.23430	10.44277
10	15.23190	10.44693

Attribute table for randomly chose points at SEMRY seed farm



id	x	y
1	15.22998	10.44759
2	15.23100	10.44812
3	15.23096	10.44721
4	15.23107	10.44596
5	15.23235	10.44558
6	15.23237	10.44457
7	15.23340	10.44432
8	15.23306	10.44305
9	15.23430	10.44277
10	15.23190	10.44693

Appendix 12; Questionnaire Administered in Yagoua

Je me nomme Nkenen Brendaline, étudiante à Pauwes, dans le cadre de mes travaux de recherche sur les risques et opportunités de production du riz, je sollicite votre aide pour l'obtention des informations suivantes

Numéro du questionnaire: .... Date de l'entretien........................

Localisation…………………………………………….............................

La distance entre la maison de l'agriculteur et sa parcelle…………………….............. kilomètre

Informations générales

Nombre de parcelle .... Superficie totale .... Ha

Travailleurs ou famille

Sexe	Nombre de travailleurs /famille	Temporel ou permanent	Âges (écrire les âges séparés par une virgule) des enfants	Niveau d’education
Mâles				
Femelles				

Quelles cultures apportent un meilleur revenu ?

Cultures	rang
Maïs	
Riz	
Haricots blanc	
Arachide	
Patates douces	

1. **Cultures cultivées (les 2 premières du rang, le riz et l’autre culture la mieux classée)**

Culture 1 .... Superficie cultivée .... Km^2; rendement..................... tonne; ventes................... Fcfa

- Quelle part de la production est consommée au niveau des ménages?

ventes

☐ Nous vendons environ un quart de la production.

☐Nous vendons environ la moitié de la production

☐ Nous vendons à peu près toute la production Nous ne vendons rien de la production

☐ Nous vendons uniquement en cas d'urgence

irrigation

Irriguez-vous Oui☐ Non☐

Si Oui, quelle quantité d'eau cette région consomme-t-elle .... m^3;

Système d'irrigation

☐ Irrigation goutte à goutte ☐ Irrigation par aspersion ☐ Irrigation de surface

Type de système de drainage

☐ Sous-surface

☐Surface

Noms d'engrais par ha .... ; ....;..........................

Coûts connexes par campagne

Coût de l'eau .... FCFA Engrais .... FCFA Frais de travail du sol .... FCFA Coût de la main-d'œuvre .... FCFA Autres coûts: nommez-le .... Fcfa

Culture 2 ....

Superficie cultivée .... Km^2; rendement.................... tonne; ventes.................. Fcfa

irrigation

Irriguez-vous Oui☐ Non☐ : Si Oui, quelle quantité d'eau cette région consomme-t-elle .... m^3;

Système d'irrigation

☐ Irrigation goutte à goutte ☐ Irrigation par aspersion

☐ Irrigation de surface ☐pas irrigation

Type de système de drainage

☐ Sous-surface ☐Surface ☐Noms d'engrais ………………………………

Coûts connexes par campagne :

Coût de l'eau …………………. FCFA Coût Engrais …………………… FCFA

Frais de travail du sol ……………………. FCFA Coût de la main-d'œuvre …………… FCFA

Autres coûts: nommez-le ………………………… ………………. FCFA

Autres questions

En ce qui concerne le rendement, y a-t-il des endroits qui donnent une bonne production plus que d'autres sur le terrain

☐ Oui Non ☐

Si oui, qu'est-ce qui rend ces spots plus performants

☐ Bon sol ☐Assez d'eau ☐ Assez d'engrais ☐Tout ce qui est mentionné

Avec les spots à faibles rendements, ce qui les fait moins performants que l'ensemble de la ferme

☐ mauvais sol ☐moins eau ☐engrais insuffisant ☐Tous ceux mentionnés

En tant qu'agriculteur, y a-t-il une bonne et une mauvaise année? Oui ☐ Non☐

Qu'est-ce qui fait de bonnes années?

☐ Ventes de rendement pluviométrique

Quelle est la pertinence de l'eau pour leur saison agricole?

Y a-t-il des institutions qui offrent de l'aide aux agriculteurs? Oui/Non

Si oui, ☐ SEMRY ☐AUE ☐ GIC ☐Autres

<u>Risques</u>

Quels sont les risques ou les facteurs qui réduisent votre rendement? Sélectionnez-en un ou plusieurs ! Et les classer

☐Sécheresses

☐Inondations☐Marché (prix) ☐ Conflits

☐ La qualité des semences ☐Les vols ☐les animaux détruisant votre champ,

☐ manque ou insuffisance de fonds ☐Autres risques, nommez-les ....

☐ irrigation

Rang	Risque

D’autre difficultés ?

Comparison des acheteurs

	SEMRY	LES AUTRES
Conditionnemt(kg/sac)		
Frequence		
Pourcentage d’achat (%)		
Preference		

Appendix 13; Photos From the Field

Administration of Questionnaires

Pumping out point from the Logone River

5 pumps of 600 m3/s Capacity at station 1

Primary canal irrigation at SEMRY

ANNEX 1. BUDGET DETAILS

BUDGET FOR THESIS							
S/No.	Item	Quantity	Unit price DZD/FCFA /USD	Total price DZD/XOF/USD	Equivalent amount in USD	Link to Research Activity	**Comment (For Evaluator Only)**
Material and Supplies							
1	Internet recharge (FCFA)	5	21500	107500	200	For literature review, data collection from secondary sources, watching of online video tutorials on software utilization and communication with supervisor and administration. For data analyses from the remote sensing satellites	
2	Printing of questionnaires (4 pages)	115	400	46000	86	For easy filling and grasp of information from the farmers, the extra 5 is to test the questionnaires with farmers and	

						extension workers to know which are sensitive questions and to know their reaction for the final field questionnaire print out. Extra 10 were as a backup as the rains soaked some sheets	
3	Printing of thesis for proof reading by peers(FCFA)	2	10100	20200	37	To correct errors on the thesis, for verification if it meets all the specified standards as recommended by the guide booklet	
4	Printing of thesis for defense(FCFA)	1	9600	9600	18	For the jury assessment	
5	Printing of final thesis with binding (DZD)	1	2500	2500	23	1 To be kept in the school library.	
7	Face masks and sanitizer	5	16000	80000	150	For protection against covid 19 and also respect of national rules against covid	
9	PCR test(DZD)	1	7000	7000	65	Regulation before	

						travelling	
EQUIPMENT/DATA COLLECTION							
1	Renting of GPS	15	5000	75000	140	GPS to track points for the base map to use for the machine learning algorithm and also for the primary data input into WaPOR to download the secondary datasets. Tracking of the different farms to verify the success of the machine learning algorithm. For the verification of hot spots from the analyses	
TRANSPORTATION							
2	Algers to Douala(round trip) DZD	1	161833	1228.31247	1228	To go to my research	

3	Tlemcen to Algers, DZD	1	12000	12000	91	site. I choose to reside in Bamenda because it is calm as opposed to the Case Study Ndop plains with the effects of the anglophone crises. Also, it's the chief town with good internet connection for my research.	
5	Bamenda to far North, round trip for data collection(bus from Bamenda to Yaounde, flight from Yaounde to Maroua, maroua to Yagoua)	1	181440	181440	338	To check the rice farms which are continuous and have not have other crops for at least 5 years. Track points for the chosen farm for this case study, collect input and yield (tonnage and money) data of the chosen farm and also the challenges faced by some of these farmers. some questionnaires will be issued out to some of the stakeholders to understand the challenges in this region. The flight from Yaounde to Garoua was 163440,	

						Bamenda to Yaounde (6000) , Garoua to Yagoua (3500), Yagoua to Garoua (3500) and Yaounde to Bamenda (5000)	
6	Field transportation for data collection	7	10000	70000	127	4 trips were made to ascertain the research proposal was accepted. 3 other trips made to collect data in the offices	
SPECIAL ACTIVITIES							
1	Incentives for chiefs to allow me issue out questionnaires in their villages	4	5000	20000	36	with experience most farmers don’t like responding to students’ questionnaires as they say they do not derive any gain. This will motivate the chiefs to encourage the farmers to listen and understand the objective of the questionnaire and to also	

						fill the questionnaires. This will also serve as my protection as the chiefs can talk to the separatist fighters on my behalf to allow me do my research. Due to insecurity I was advised to not administer the questionnaires as they timing was wrong with many casualties in the localities. 5000 was used to pay a local daily to help out in the local language where we meet farmers who can’t communicate in French	
				Total	**2540**		
	Material and Supplies	**577**				1 USD = 536.57014 XAF	
	EQUIPMENT/DATA	**140**				1 DZD = 0.00759 USD	

	COLLECTION						
	TRANSPORTATION	**1785**					
	SPECIAL ACTIVITIES	**36**					
	CONTIGENCIES	**462**					
		3000					