TOPIC: DESIGN PROPOSAL OF DRIP IRRIGATION SYSTEM FOR AN EFFICIENT MANAGEMENT OF IRRIGATION WATER FOR MAIZE IMPROVED SEEDS PRODUCTION IN A PART OF SEEDS FARM OF LOUMBILA

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Thesis Submitted to the Istitut Agronomico per l'Oltremare, in Fulfillment of Requirement for Degree of Master

June 2011
ABSTRACT
This study was conducted in the context of our master thesis. The study is carried out to recover a part of the seed farm of Loumbila in the region of Central Plateau/Burkina Faso.
Indeed the aim of the study is to recover 12 hectares of non-functional part of existed surface irrigation scheme and contribute to improve irrigation water management on the site in order to increase productivity, quality and profitability in the context of the fight against food insecurity and poverty.
To achieve this goal, we proposed a drip irrigation system design. For the study of the design, the total area is divided into 06 blocks of 2 hectares each and each block has 8 plots of 0.25 ha for each famer. The design of the irrigation system has been conducted only on a single plot (0.25 ha) and witch is downstream of the scheme. All blocks and plots have the same characteristics (dimensions, surface, and demand of water, 9 m$^3$).
However in the implementation of the project on all 12 ha of the site, the technical data of the studied plot will be reproduced on other forty seven (47) plots.
One could say that the study has a double objective because it will also allow us to compare in many levels the two systems of irrigation practiced in the site, the surface irrigation and the new drip irrigation scheme. It is an opportunity to contribute to popularize the drip irrigation system to famers in Burkina Faso.
Results of the study showed that the system works very well on the whole perimeter. We need 01 h 55 to irrigate the plot of 0.25 ha with a uniformity of 96% of distribution. And also the flow rate of the pump used (Q=80m$^3$/ha) allows to irrigate one block (02 ha) at the same time.
ACKNOWLEDGEMENT

The success of this study was the work and sacrifice of several people to whom I owe gratitude.

Among those involved from afar or close to that success, I would especially like to thank my wife Ms. BAMOUNI/SAWADOGO Aminata and my son BAMOUNI Cherif Ben Sidi

I would like to thank my parents, brothers and sisters and may God grant them good health and long life.

I also want to thank sincerely the Director of Development of Irrigation Facilities and the Irrigation of Agriculture Ministry of Burkina Faso and all his officers for their support and multifaceted encouragements.

Special thanks are due to the General Director of the IAO and the entire staff.

My thanks also go to the place of all the lecturers, particularly Pr. Elena Bresci and Pr. Falchait during various theoretical courses for making me a man seasoned in irrigation.

I thank Dr SOLINAS Ivan for the supervision of my thesis work. I also thank Dr. Paolo Enrico SERTOLI and Mr Andrea Merli for having assisted and accompanied us throughout the training in many levels.

At last, my thanks go to my friends and colleagues who gave me mental and scientific support to complete this study.

Thank you very much to everybody!
DEDICATION

Dedicated to:

From the depth of my hearth I dedicate this thesis to my beloved

- father: BAMOUNI Idrissa,
- mother: KAMA Ebou Amy,
- wife: SAWADOGO Amy,
- son: BAMOUNI Cherif Ben Sidi,
- and siblings.
ABBREVIATIONS

ADB: African Development Bank
BOAD: Banque Ouest Africaine de Développement
DIPAC: Développement de l'Irrigation Privée et des Activités Connexes
ETo: Reference Crop Evapotranspiration
EU: European Union
FAO: Food and Agriculture Organization of United Nations
GDP: Goss Domestic Product
IAO: Istituto Agronomico per l'Otremare
IDB: Islamic Development Bank
JNP: Journée Nationale du Paysan
MAHRH: Ministère de l'Agriculture, de l'Hydraulique et des Ressources Halieutiques
PAFR: Plan d’Action pour la Filière Riz
Peff: Effective Rainfall
PET: Potential Evapotranspiration
PSSA: Programme Spécial de Sécurité Alimentaire
PRP: Projet Riz Pluvial
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I INTRODUCTION

1.1 Justification of the study

The Istituto Agronomico per L’Oltremare (IAO) is a technical-scientific branch of the Italian Ministry of Foreign Affairs, working to fight world poverty and hunger. The Institute is involved in Development Cooperation initiatives on integrated rural development, environmental and natural resources management, fight against desertification and food security.

The Institute’s mission is: “To conceive and implement, on behalf of the Italian Development Cooperation, in partnership with local people, research, studies, technical assistance and training initiatives with the aim of reducing hunger and poverty, developing and managing agricultural and environmental resources in a sustainable way”. Among the facilities offered by IAO, this Institute holds master’s Degree courses in Geomantic and Irrigation at the location of participants from developing countries. It is within this context that the fourth edition of the Master in Irrigation, with the participation of fifteen people from Burkina Faso, Ethiopia, Ghana, Mauritania, Mozambique, Niger, and Senegal was held.

Moreover, as in any academic diploma training, after the theoretical and lecture phase, each student must conduct a study on a given thesis to enable him to understand and experiment the field realities. Thus, for the conduction of our thesis, we chose a scenario on irrigated agriculture in Burkina Faso.

Burkina Faso’s economy is predominantly agricultural. Indeed, the agricultural sector represents about 40% of GDP (25% agriculture, 12% livestock, forestry and fishing 3%) and provides employment and income for the vast majority of the population. It provides over 80% of export earnings and its ripple effects support secondary and tertiary sectors, thereby strengthening the overall dynamics of the national economy. It is an extensive farming and low productivity.

Potential irrigable low exploited: The potential irrigable land resources of the country are estimated at 233,500 ha. In 2004, the Ministry of Agriculture, Hydraulic and Fishery Resources (MAHRH) estimated at 32 258 ha of irrigation schemes with 12 058 ha for large irrigated areas, 3 000 ha for medium schemes, 10,000 ha for small irrigation schemes and 7200 ha for lowland. According to 2004 estimations of
MAHRH, the average used is around 20 000 ha with 42.5% operated in total control of water, 30% and 22.5% respectively operated in lowland and small irrigation schemes (Rapport de formulation du programme regional de développement durable de l’agriculture irriguée dans le plateau central, Decembre 2010=Report of diagnostic for the formulation of regional sustainable development program for irrigated agriculture in the Region of Central plateau, December 2010).

Strategies have been developed with the droughts of the 1970s involving the control of irrigation water in order to improve agricultural productivity. Indeed several types of irrigation schemes were then created, including the large schemes and the construction of many small dams and associated perimeters, but the results so far have been mixed with inadequate infrastructure valued and whose management is largely in deficit. Learning from these shortcomings and limitations of these different types of irrigation schemes in a context of poverty and about the persistence of weather conditions and low productivity of rainfed agriculture, the Government decided to review its options and guidelines and defined a national strategy for sustainable irrigated agriculture, underpinned by three key ideas:

- The dynamism of individual initiatives to develop an informal irrigation sector oriented towards the production of high value crop. It is in this context that the Government has initiated with support from the World Bank, the Pilot Project of Private Irrigation Development and Related Activities (DIPAC);
- Development of the Small Villagers Irrigation, idea from the Sixth National Farmer's Day (JNP) held in Banfora in May 2001. The Program for the Development of Small Irrigation (PPIV), supported by Highly Indebted Poor Countries resources, the Special Program for Food Security (PSSA), supported by FAO and actions developed by local NGOs, are the major elements;
- The Government's willingness to undertake actions to promote medium and large irrigation schemes with active promoters, private investors, local communities and farmer organizations. Many technical and financial partners (ADB, BOAD, IDB, Kuwait Fund and Saudis, Bilateral Cooperation, EU ...) have contributed so these various types of development.

In view of these successful experiments, the existence of potential in ground, water and irrigation schemes insufficiently valued, the Government has decided on a
rereading of these options and these guidelines, which led to the development with support from Development Partners (World Bank, FAO, ADB ...), of the document "National Policy for Development of Irrigated Agriculture."

However, irrigated agriculture has many problems among which we have:

- Tenure persistent insecurity linked to difficulties in applying the legislation governing the land until the last moments: the RAF (Agrarian Reform and Land), the cooperative Act and specifications on the occupation and exploitation of irrigation schemes were inapplicable;
- Weakness of famers organizations with the consequent of inability to solve the problems upstream (acquisition of inputs ...), at level (management of infrastructure facilities of irrigation ...) and downstream (marketing, access to market, storage and processing ...) of production;
- The problem of shortage of irrigation water due to silting of dams and channels of irrigation, mismanagement of water added to evaporation and infiltration excess.
- Degradation of several hydro agricultural schemes due to their obsolescence, poor execution, poor maintenance and piracy of some irrigation systems.

1.2 Aim and objective of the study
The aim of the study is to recover twelve (12) hectares non-functional and contribute to improve irrigation water management on the site in order to increase yield of seeds production in the context of the fight against food insecurity and poverty. Local production and availability of improved seeds is necessary in the context of increased climate change.

1.3 Statement of research problem
Given the problems facing irrigated agriculture in Burkina Faso in general, and particularly those of the site subject to our study, we proposed this study to recover 12 hectares, totally not in use. To conduct the study, we have chosen the following topic: “Design proposal of Drip Irrigation system for an efficient management of irrigation water for maize improved seeds production in a part of seeds farm of Loumbila”. For the study of the design, the total area is divided into 06 blocks of 02
hectares each and each hectare has four (4) plots of 0.25 ha. The design of the drip irrigation system has been conducted only on a single plot of 0.25 ha. However in the implementation of the project on all 12 ha of site, the technical data of the studied plot will be reproduced on 47 other plots and height (8) plots (02 ha) will be irrigated per in the same time.

This study will also allow us to compare in many levels the two systems of irrigation practiced in the site, the surface irrigation and the new drip irrigation scheme. It is an opportunity to contribute to popularize the drip irrigation system in to famers in Burkina Faso.

Our study is divided into five main parts that are: literature review, irrigation practice in Burkina Faso, method and materials, design and computations, results and discussions.
II- LITERATURE REVIEW AND DESCRIPTION OF DRIP IRRIGATION SYSTEM

2.1 Some concepts

2.1.1 General definitions of Irrigation
A technique that involves artificially providing crops with water to enable them to grow. This technique is used in farming to enable plants to grow when there is not enough rain, particularly in arid areas. It is also used in less arid regions to provide plants with the water they need when seed setting.

When using irrigation due to insufficiency of rainfall to allow crop growing, irrigation is said to be supplementary; which is the process of distribution additional water to the crop with the objective of stabilizing and increasing yield, in environments where the given crop is usually grown under rainfed agriculture.

In arid and semi arid areas, irrigation is used for production during the dry season in the absence of rain, irrigation is said full. Related to full irrigation, one can use sometime deficit irrigation to save water. Indeed deficit irrigation is an optimization strategy in which irrigation is applied during drought-sensitive growth stages of a crop (Water report 22: Deficit Irrigation Practices, FAO).

2.1.2 Definition, principles and objectives of Drip irrigation system
Localized or drip irrigation is the slow application of water to the soil through mechanical devices called emitters, located at selected points along the water delivery line.

The different types of localized irrigation comprise: drip, micro-jet, also known as jet spray, and micro-sprinkler irrigation. All localized irrigation systems consist of a pumping unit, a control head, main and sub-main pipes, lateral and emitters (Irrigation Manual: Planning, Development, Monitoring and Evaluation of Irrigated Agriculture with farmer Participation, Developed by Andres P. SAWA, Karen FREKEN, Volume IV).

The filtrated water, at times mixed with nutrients move through the system losing its pressure in the emitters from where it’s discharged in small volumes. The movement of the water through the soil is mostly by unsaturated flow.
In drip irrigation, also called trickle irrigation or localized irrigation, the water is led to the field through a pipe system. On the field, next to the row of plants or trees, a tube is installed. At regular intervals, near the plants or trees, a hole is made in the tube and equipped with an emitter. The water is supplied slowly, drop by drop, to the plants through these emitters.

According to FAO (1984), drip irrigation was first used in glass houses in England in the late 1940s, the importance of drip irrigation grew with the development of cheap plastic pipes and fittings. It be mentioned that buried clay pots, which can be considered as a form of localized irrigation, were used in Iran for the irrigation of trees long before the development of modern localized irrigation systems (Irrigation Manual: Planning, Development, Monitoring and Evaluation of Irrigated Agriculture with farmer Participation, Developed by Andres P. SAWA, Karen FREKEN, Volume IV).

The early field work on modern drip irrigation system was carried out under desert conditions and sandy soil, where superior performance was demonstrated in relation to surface and sprinkler irrigation under these extreme conditions. After more than 20 years of research, trials and field used world wide, localized irrigation systems have proven to be the most efficient means of water distribution and application and an ideal way of supplying the plants with nutrients.

The objectives of drip irrigation are:

- Bring water and locally in the root zone;
- Ensure the supply in a high frequency;
- Low-flow supplying to permit a low variation of moisture.

### 2.1.3 Advantages and Disadvantages of Drip irrigation

#### 2.1.3.1 Advantages of localized irrigation

Many claims as to the advantages of localized irrigation have been and are still being made. Currently the following advantages are recognized (Irrigation Manual:
The evaporative component of evapotranspiration is reduced, as only a limited area of the soil wetted. This is more prevalent for young trees;

- The limited wetted area in reduced weed growth;

- The slow rate of water application improves the penetration of into problematic soil;

- The higher degree of inbuilt management that localized irrigation offers reduces substantially deep percolation and runoff losses, thus attaining higher irrigation efficiencies. Consequently localized irrigations is considered as water-saving technology;

- The very frequent irrigation attainable through localized irrigation system results in more diluted salts in the soil moisture solution and pushes (leaches) these salts to the sides of wetted volume of the soil. Hence, water of higher salt can be used with this system;

- The moisture availability to the plant at low tension results in faster growth, higher yield and better quality;

- Since fertilizers can be injected into the system in a controlled manner, fertilizer losses substantially reduced under localized irrigation;

- The controlled water and fertilizer application, attainable with localized irrigation, makes this system more environmentally and health friendly

### 2.1.3.2 Disadvantages of localized irrigation

The major disadvantages of drip irrigation are:

- Localized systems are prone clogging because of the very small aperture of the water emitting devices. Hence the need for proper filtration and, at time, chemigation;
The movement of the salts to the fringes of wetted area of the soil may cause salinity problems through the leaching of the salts by the rain to main root volume. This can be avoided if the system is turned on when it rains, especially when the amount of rain is not enough to leach the salt beyond the root zone depth;

- Rodents, dogs and other in search of water can damage the lateral lines;
- For crops of very high population density, the system may be uneconomic because of the large number of lateral and emitters required.
This part of our thesis report is about the practice of irrigation in Burkina Faso. It focuses indeed on different existing schemes, irrigation systems and irrigation facilities. It is also the place to discuss of different kinds of the mobilization of water resources for irrigation.

3.1 Typology of irrigation systems
The definition of types of facilities is based on the most important criteria are: size, management style, crops and the status of ownership. In Burkina Faso there are essentially four (4) types of irrigation schemes that are: large schemes (major perimeters), medium schemes, small irrigation facilities and lowland.

3.1.1 Large irrigated schemes (large-scale public irrigation schemes)
Great irrigated perimeters (or great irrigation schemes) cover several hundred of ha or a few thousand of ha in one piece. These schemes are mostly run by public management agencies and are the perimeters as the Kou valley, Karfiguela, sugar perimeter of Banfora and perimeters of Sourou and Bagre. The water supply is from rivers or streams, and great dams. These irrigated perimeters are fully realized by the government of Burkina Faso with support of its development partners. One finds among these types of schemes large-scale public paddy irrigation systems.

3.1.2 Medium irrigated perimeters
The medium irrigation schemes have an area between twenty and one hundred hectares. They are mostly perimeters in downstream of dams or around natural lakes. These schemes are also mostly run by public management agencies. The main schemes of this type are for example Mogteto (142 ha), Zoungou (150 ha) and Sandogo (250 ha). The average unit area per farmer is not more than 0.25 ha. As great perimeters they are also fully realized by the government of Burkina Faso with support of its development partners.

3.1.3 Small irrigation schemes
These irrigated areas correspond to small irrigation schemes of a few acres to twenty acres. The State has construct many but some of these perimeters are private and
are developed following the perimeters of state in response to domestic and external increased demand for agricultural products including fruits and vegetables. One finds among these types of schemes commercial privately managed systems, producing for local and export markets and farm-scale individually managed systems, producing for local often around cities.

3.1.4 Lowlands schemes
The technologies of approach is based on two main options: lowlands with simple dikes and earthen bunds overhanging protected by riprap or concrete thresholds according to the contours (PSSA type, PAFR, PRP), lowland improved by the introduction of a small reservoir combined with overhanging ridges with or without central manifold. Some lowlands are equipped with small irrigation systems. Techniques models of irrigation schemes adopted are essentially the schemes of type PSSA, PAFR and those of type PRP (Rapport de formulation du programme régional de développement durable de l’agriculture irriguée dans le plateau central, Décembre 2010).

3.2 Systems of irrigation
One meets all irrigation systems in Burkina Faso. It is surface irrigation that comes first, followed by sprinkler irrigation and drip irrigation. The system the most practiced in terms of area irrigated and people involved, is surface irrigation.

3.2.1 Surface irrigation and means of water pumping
Surface irrigation is the oldest and most common method of applying water to crops. It involves moving water over the soil in order to wet it completely or partially. The water flows over or ponds on the soil surface and gradually infiltrates to the desired depth. Surface irrigation methods are best suited to soils with low to moderate infiltration capacities and to lands with relatively uniform terrain with slopes less than 2-3\% (FAO, 1974).

Surface irrigation is the most common method of irrigation and can be the most inefficient. This is not because it is poor technology, it is because it is difficult to manage properly (Irrigation Water Management: Training Manual No. 8, Structures for water control and distribution).
Like in Burkina Faso, this method is the most common in the practice of irrigated agriculture worldwide. It is often chosen for its simplicity but it success relies entirely on the skill of the farmer irrigating. It occurs in all regions of the country and individual farmers or grouped may themselves without necessarily technical assistance design their furrows, basins and boards.

It is generally practiced by farmers organized on irrigation schemes built by the State in downstream of the dams or by individual farmers installed around dams or other water sources. More and more farmers organized into groups or associations, have the support of projects, NGOs or other partners for constructing of private irrigation schemes.

The means of water supply are scooping manual (sump, watering can), motor pumps, Intake of downstream of dams and pedal pumps.

**a) Principle of Surface irrigation**

![Diagram](image)

*Figure 1: Principle of surface irrigation*

**b) Furrow irrigation**

Furrows are narrow ditches dug on the field between the rows of crops. The water runs along them as it moves down the slope of the field.

The water flows from the field ditch into the furrows by opening up the bank or dyke of the ditch or by means of syphons or spiles. Siphons are small curved pipes that deliver water over the ditch bank. Spiles are small pipes buried in the ditch bank.
In Burkina Faso this method is used for row crops such as cereals (maize), and vegetables (onions, tomatoes, eggplant, okra, etc).

c) Border irrigation

The borderstrip width depends on the topography of the field, which determines the possible width that can be obtained while keeping a horizontal cross-section without requiring too much soil movement, and on the stream size. The stream size also restricts strip width, as it should be sufficient to allow complete lateral spreading throughout the borderstrip width and length. The strip width also depends on the cultivation practices, mechanized or non mechanized for example. Borderstrips should not be wider than 9 m on 1% cross-slopes (James, 1988).

In border irrigation, the field to be irrigated is divided into strips (also called borders or borderstrips) by parallel dykes or border ridges. The water is released from the field ditch into the border through gate structures called outlets. The water can also be released by means of siphons or spiles. The sheet of flowing water moves down the slope of the border, guided by the border ridges.

In Burkina Faso this method is generally used for onion and carrots.

d) Basin irrigation

Basins are horizontal, flat plots of land, surrounded by small dykes or bunds. The banks prevent the water from flowing to the surrounding fields. Basin irrigation is commonly used for rice grown in Burkina Faso. Trees are also grown in basins, where one tree usually is located in the centre of a small basin.

3.2.2 Sprinkler irrigation system

This is the second irrigation system practiced in Burkina Faso in terms of technique and irrigated areas. It is used for irrigating gardens concessions. But it is especially used in large areas for crop production. Originally for agriculture, the State had installed this system to absorb a little bit the problem of unemployment by encouraging the return to land of students. Unfortunately, this project has not been conclusive and the plots are redistributed to farmers for the production of maize, rice and wheat.
The National Society of sugar production also uses this technique for the production of sugarcane.

A sprinkler irrigation system generally includes sprinklers, laterals, submains, main pipelines, pumping plants and boosters, operational control equipment and other accessories required for efficient water application.

3.2.3 Drip irrigation system
The drip irrigation is very weakly practiced in Burkina Faso because of its technical progress and the unavailability of equipment on site. Its introduction is being phased by Individuals (agro-businessmen) and NGOs. The latter offer some kits to women in certain regions (Est of Burkina Faso) in the context of fighting against food insecurity. Moreover one of the objectives of this study is to contribute to popularize this technique for good management of water and increasing of yield in an arid country like ours.

3.3 Mobilization of water resources for irrigation
The mobilization of water resources in Burkina Faso is made through rivers or streams, dams, water impoundments, pool of water, borrow areas and groundwater (wells).

3.3.1 Dams or water impoundment
The country abounds of many reservoirs to mobilize the potential of surface water. Indeed, several dams of various sizes have been constructed throughout the country for irrigation development.

However, many of these dams are damaged (cracks in the dikes or embankment washed away by floods, silting) and require rehabilitation.

3.3.2 Pool of water
The need of water for irrigation is also expressed by famers mainly through the exploitation of ponds. They are generally natural water reservoirs but more and more constructed with local materials in favor of the topography of the ground.
3.3.3 Borrow areas
Borrow pits are very numerous and the filling is ensured by the drainage of roads. They are created thanks to the many careers in the construction of roads, and mark out the main national roads. They can be valued by increasing their capacity and through the maintenance of their banks.
Vegetable crops are grown up from the late rains. Borrow pits dry out very early (three months or less).

3.3.4 Mobilization of groundwater
In Burkina Faso, the mobilization of groundwater remains low despite the existence of many garden wells. Wells made for the mobilization of groundwater are often deep and the flow is generally very low. It is difficult to develop performed irrigated agriculture from this groundwater. Groundwater in the country can be mobilized only for gardening, supplementary irrigation and especially for livestock.
IV METHODS AND MATERIALS

The methods and materials chapter illustrates which methodology is used, the overall description of the area of study, the climatic data used and other important parameters of the study site.

4.1 Methodology
The methodology used for the study comprises four (4) phases.

4.1.1 Choice of the topic of the thesis and the site of study
The topic of the thesis is “Design proposal of Drip Irrigation system for an efficient management of irrigation water for maize improved seeds production in a part of seeds farm of Loumbila”. The site is a part of the seed farm of Loumbila which is no more functional. This portion of the irrigation system of 12 ha which is completely degraded was chosen as the study site.

4.1.2 Subdivision of the study site in blocks and plot
Which helped to design the system to a plot and then verify its functionality on a ha on each block.

4.1.3 Literature review
Literature review was to search and read a number of papers and books dealing with irrigation issues in general, but also drip irrigation purposes particularly. This literature including internet research allowed us to have information and understand the topic, subject of our study in all edges.

4.1.4 Choice of working tools and collection of data
The literature review and software really helped us to collect data and general information about irrigation. It has also helped to give an overview of irrigation in Burkina Faso. As for the technical data, they were supplied by different software used in the study.

4.1.5 Writing the thesis
This point has involved the putting together of information, data and writing the thesis report.
This part focused also on results and discussions of the study. This is the place where all the technical data necessary for the irrigation scheme designing have been summarized.

4.2 Overall description of the area

4.2.1 Location of the site
The site is located in the rural commune of Loumbila. The rural commune of Loumbila is in the province of Oubritenga and in the region of Central Plateau in Burkina Faso. This part of the site of twelve (12) ha of which the irrigation scheme is completely degraded, had been constructed since the 1970s. It was a surface irrigation system. The site is located at 16 km from Ouagadougou, the capital of Burkina Faso and 17 km from Ziniaré, the Center of the Region of Central Plateau.

![Map 1: Location of Loumbila /Oubritenga](image)

4.2.2 Climatic conditions
The rural commune of Loumbila has a type of Sudano Sahelian climate as well as the climate of the province of Oubritenga where Loumbila is located. This climate is marked by a long dry season (October to May) and rainy season (June-September). Rainfall is irregular and insufficient. The annual average is between 600 and 800 mm.
4.2.3 Soil description
Generally, soils in the rural commune of Loumbila are shallow and infertile. They are characterized by a phosphorus deficiency. Their organic matter content and nitrogen are low. Their structure is weakly developed, making them susceptible to water erosion.
One could estimate the percentage of sand and clay of the site, respectively 60% and 15%. The area of the study is characterized by sandy loam soil texture.

4.2.4 Irrigation water resources
The water which will be used for irrigation in the new scheme of Loumbila is coming from a dam. The capacity of this dam is 42 000 000 m³. Availability of water should not be a problem for the project.

4.2.5 Cropping pattern
There are two types of agriculture in the site: rainfed agriculture and irrigated agriculture. During all the year there is a production of improved seeds on the site to satisfy the growing need of farmers. Crops generally grown are maize, sorghum, groundnuts and been seeds.
Five years ago the production of improved seeds has been done at the request of FAO, which provided basic seeds to farmers of the site. At harvest, FAO bought these seeds to redistribute to the poorest farmers of the country.
But for purposes of the study, improved seeds of maize will be produced on the new scheme.

4.3 Climatic data used
3.3.1 Precipitation
The annual average of rainfall received in the commune is between 600 and 800 mm. According to the estimation of local climatic data by the software New LocClim, precipitations are as follows:
Table 1: Data of precipitation of the study area

<table>
<thead>
<tr>
<th></th>
<th>Rain [mm]</th>
<th>Effective rain [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>February</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>March</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>April</td>
<td>25.0</td>
<td>24.0</td>
</tr>
<tr>
<td>May</td>
<td>55.0</td>
<td>50.2</td>
</tr>
<tr>
<td>June</td>
<td>100.0</td>
<td>84.0</td>
</tr>
<tr>
<td>July</td>
<td>167.0</td>
<td>122.4</td>
</tr>
<tr>
<td>August</td>
<td>212.0</td>
<td>140.1</td>
</tr>
<tr>
<td>September</td>
<td>123.0</td>
<td>98.8</td>
</tr>
<tr>
<td>October</td>
<td>28.0</td>
<td>26.7</td>
</tr>
<tr>
<td>November</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>December</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Total</td>
<td>717.0</td>
<td>553.1</td>
</tr>
</tbody>
</table>

4.3.2 Temperature
The solar radiation absorbed by the atmosphere and the heat emitted by the earth increase the air temperature. The sensible heat of the surrounding air transfers energy to the crop and exerts as such a controlling influence on the rate of evapotranspiration. In sunny, warm weather the loss of water by evapotranspiration is greater than in cloudy and cool weather.

4.3.3 Solar radiation
The evapotranspiration process is determined by the amount of energy available to vaporize water. Solar radiation is the largest energy source and is able to change large quantities of liquid water into water vapour. The potential amount of radiation that can reach the evaporating surface is determined by its location and time of the year. Due to differences in the position of the sun, the potential radiation differs at various latitudes and in different seasons. The actual solar radiation reaching the evaporating surface depends on the turbidity of the atmosphere and the presence of clouds which reflect and absorb major parts of the radiation. When assessing the effect of solar radiation on evapotranspiration, one should also bear in mind that not all available energy is used to vaporize water. Part of the solar energy is used to heat up the atmosphere and the soil profile.
All climatic data are recorded in the following table

Table 2: Climatic data of the study area

<table>
<thead>
<tr>
<th>Month</th>
<th>Min Temp</th>
<th>Max Temp</th>
<th>Humidity</th>
<th>Wind Km/day</th>
<th>Sunshine Hours</th>
<th>Radiation MJ/m^2/day</th>
<th>ETO Mm/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>16.1</td>
<td>33.2</td>
<td>39</td>
<td>190</td>
<td>8.2</td>
<td>18.8</td>
<td>4.94</td>
</tr>
<tr>
<td>February</td>
<td>19.1</td>
<td>36.2</td>
<td>40</td>
<td>190</td>
<td>8.1</td>
<td>20.1</td>
<td>5.52</td>
</tr>
<tr>
<td>March</td>
<td>23.1</td>
<td>38.2</td>
<td>41</td>
<td>207</td>
<td>8.0</td>
<td>21.3</td>
<td>6.42</td>
</tr>
<tr>
<td>April</td>
<td>25.8</td>
<td>38.9</td>
<td>49</td>
<td>233</td>
<td>7.1</td>
<td>20.5</td>
<td>6.66</td>
</tr>
<tr>
<td>May</td>
<td>25.6</td>
<td>37.2</td>
<td>68</td>
<td>259</td>
<td>7.9</td>
<td>21.5</td>
<td>6.01</td>
</tr>
<tr>
<td>June</td>
<td>23.7</td>
<td>34.2</td>
<td>81</td>
<td>251</td>
<td>7.6</td>
<td>20.7</td>
<td>4.86</td>
</tr>
<tr>
<td>July</td>
<td>22.3</td>
<td>31.7</td>
<td>99</td>
<td>216</td>
<td>6.8</td>
<td>19.6</td>
<td>3.58</td>
</tr>
<tr>
<td>August</td>
<td>21.8</td>
<td>30.7</td>
<td>97</td>
<td>190</td>
<td>6.1</td>
<td>18.7</td>
<td>3.45</td>
</tr>
<tr>
<td>September</td>
<td>21.8</td>
<td>32.0</td>
<td>91</td>
<td>156</td>
<td>6.6</td>
<td>19.2</td>
<td>3.79</td>
</tr>
<tr>
<td>October</td>
<td>22.6</td>
<td>35.2</td>
<td>74</td>
<td>156</td>
<td>8.1</td>
<td>20.5</td>
<td>4.69</td>
</tr>
<tr>
<td>November</td>
<td>19.2</td>
<td>35.7</td>
<td>59</td>
<td>147</td>
<td>8.5</td>
<td>19.4</td>
<td>4.63</td>
</tr>
<tr>
<td>December</td>
<td>16.7</td>
<td>33.5</td>
<td>51</td>
<td>173</td>
<td>8.2</td>
<td>18.3</td>
<td>4.50</td>
</tr>
<tr>
<td>Average</td>
<td>21.5</td>
<td>34.7</td>
<td>66</td>
<td>197</td>
<td>7.6</td>
<td>19.9</td>
<td>4.92</td>
</tr>
</tbody>
</table>

4.4 Land tenure and Farmer's organization
The seed farm of Loumbila belongs to the State of Burkina Faso. Indeed, this site is managed by the Ministry of Agriculture, Hydraulic and Fisheries Resources, through the Regional Direction of Agriculture, Hydraulic and Fisheries Resources of Central Plateau. The operation of the site is made by farmers from the village of Loumbila organized in Group with the support of an agriculture technician assigned to this effect. The programming of each crop production is generally at a meeting of the group of farmers under the supervision of technicians. The group has 150 farmers including 48 women.

4.5 Physical infrastructure
This is a perimeter with a total area of 60 hectares, constructed in the 1970s. But today, only half of the site is operated due to a complete degradation of the other part. It is a surface irrigation system with a pump station located about 1 km from the site. The irrigation system that works has been rehabilitated and the other part remained intact and unworkable.
It is to restore operation of 12 ha that we have chosen to propose the design of drip irrigation system.

4.6 Constraints
The real constraint is the high operating costs due to pumping water for irrigation with electrical energy.
Indeed, we know that, surface irrigation is a major consumer of water due to evaporation and infiltration rate, very high.
The implementation of drip irrigation system could help to compare operating costs with the existing system. In the case of satisfactory results for all, the other part (surface irrigation) could be converted to drip irrigation.

4.7 Impacts of the study
The assessment of environmental, economic and social impacts of the study on the area of the project can be three orders:

4.7.1 Economic impacts
The demand for seed of good quality is very high in Burkina Faso. The market remains available and seed farmers earn much money. The money earned by selling a portion of seed allows families to:

- Solve health problems by paying medical prescriptions;
- Children’s schooling;
- Construction of the housing with solid materials;
- Purchase of means of transport (motorbikes) and equipments.
Also yields are improved for farmers who use these seeds.

4.7.2 Environmental impacts
From an environmental perspective the establishment of twelve hectares under irrigation within the area could have positive impacts on the environment.

- From a positive perspective, irrigation would reduce the erosion risk within the perimeter and also increase the opportunities for enhancing biodiversity values.
One of the most significant impacts of further irrigation in this area would be a reduction in the amount of bare ground and corresponding reduction in wind erosion risk.

4.7.3 Social impacts
It is generally accepted that irrigation can transform society as well as land and landscapes. As land use intensifies through the irrigated perimeter and land use changes occurred, it is expected that significant, mostly positive, social changes will also occur.

- The rural exodus will be reduced and youth will be settled;
- The design and operation of schemes will allow famers to grow crop (maize) during the dry season. With the drip irrigation, they can do two cycles of production (improved seeds of maize and vegetables for consumption) during this period;
- The use of improved seeds produced during the rainy season will increase yields. The food security of these populations may be absorbed a little bit and even that of the surrounding populations because some of the seeds would be sold;
- Time availability to do other activities because the duration of irrigation will be reduced.
V- COMPUTATIONS AND DESIGN

This part describes and presents software and tools used for data collection, data processing and analysis.

5.1 Google earth and the site dimensions determination

5.1.1 Description of Google earth

Google Earth is software owned by Google, allowing visualization of the Earth with an assembly of aerial photographs or satellite. Google Earth allows you to travel the world through a virtual globe and view satellite imagery, maps, terrain, 3D buildings, and much more. With Google Earth's rich, geographical content, you are able to experience a more realistic view of the world. You can fly to your favorite place, search for businesses and even navigate through directions.

Google Earth is special multifunctional software.

Here, for the sake of our study, we used it to locate our site subject to the study. Indeed, it permitted us to delimit our site and measure its size, geographic coordinates, the slope and latitude.

5.1.2 Dimension of the site determination

Dimensions and coordinates of the site subject to the study are presented in the following table.

Table 3: Data of the study site

<table>
<thead>
<tr>
<th>Characteristics of site</th>
<th>Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total area</td>
</tr>
<tr>
<td>Length</td>
<td>620</td>
</tr>
<tr>
<td>Width</td>
<td>220</td>
</tr>
<tr>
<td>Latitude</td>
<td>12°28'45,52&quot;N</td>
</tr>
<tr>
<td>Longitude</td>
<td>1°25'13,26&quot;W</td>
</tr>
<tr>
<td>Altitude</td>
<td>1470 m</td>
</tr>
<tr>
<td>Elevation1</td>
<td>282</td>
</tr>
<tr>
<td>Elevation2</td>
<td>288</td>
</tr>
<tr>
<td>Slope</td>
<td>0.9</td>
</tr>
</tbody>
</table>
5.2 New-LocClim_1.10 and climatic data

5.2.1 Description of New-LocClim_1.10

New LocClim is a tool for spatial interpolation of agroclimatic data. Since quite a variety of tools for spatial interpolation of any data already exist, one might question whether a new one is necessary. New LocClim is especially designed for the interpolation of agroclimatic data, offering the possibility of producing climate maps from user provided station data.

However, where such station data is unavailable, New LocClim is also capable of producing climate maps of the average monthly climate conditions (8 variables) taken from the agroclimatic database of the Agromet Group of the Food and Agriculture Organisation of the United Nations.

Finally, to learn about the properties of different interpolation methods with respect to different spatial fields, the nine methods provided by New LocClim can be compared with respect to pre-given spatial fields.

New LocClim allows for an extensive investigation of interpolation errors and the influence of different settings on the results. This allows optimising the interpolation with respect to the data analysed.
Furthermore, statistical analysis of the interpolated spatial fields is provided and detailed analysis for single geographic points can be drawn.

Thus, for our case, the software allowed us to determine the climatic data necessary for the study. It appears in its entirety as follows:

**Figure 3**: View of New LocClim

### 5.2.2 Climatic data determination

The precipitation and the Potential Evapotranspiration (PET) coming from New LocClim (and the meteorogical station of Ouagadougou) are shown in the following table 4.

**Table 4**: Precipitation and ETo data from New LocClima

<table>
<thead>
<tr>
<th></th>
<th>Best estimate</th>
<th>Low estimate</th>
<th>High estimate</th>
<th>Standard error</th>
<th>Bias</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prec</td>
<td>(mm)</td>
<td>(mm)</td>
<td>(mm)</td>
<td>(mm)</td>
<td>(mm)</td>
</tr>
<tr>
<td>January</td>
<td>00.0</td>
<td>00.0</td>
<td>00.0</td>
<td>00.0</td>
<td>00.0</td>
</tr>
<tr>
<td>February</td>
<td>1.00</td>
<td>1.17</td>
<td>1.83</td>
<td>0.83</td>
<td>-0.44</td>
</tr>
<tr>
<td>March</td>
<td>3.00</td>
<td>0.33</td>
<td>5.67</td>
<td>2.67</td>
<td>0.67</td>
</tr>
<tr>
<td>April</td>
<td>25.00</td>
<td>16.86</td>
<td>33.14</td>
<td>8.14</td>
<td>1.44</td>
</tr>
<tr>
<td>May</td>
<td>55.00</td>
<td>38.68</td>
<td>71.32</td>
<td>16.32</td>
<td>0.33</td>
</tr>
<tr>
<td>June</td>
<td>100.0</td>
<td>92.56</td>
<td>107.44</td>
<td>7.44</td>
<td>-2.33</td>
</tr>
<tr>
<td>July</td>
<td>167.00</td>
<td>156.72</td>
<td>177.28</td>
<td>10.28</td>
<td>3.56</td>
</tr>
<tr>
<td>August</td>
<td>212.00</td>
<td>172.41</td>
<td>251.59</td>
<td>39.59</td>
<td>-2.00</td>
</tr>
<tr>
<td>September</td>
<td>123.00</td>
<td>116.21</td>
<td>129.79</td>
<td>6.79</td>
<td>-1.89</td>
</tr>
<tr>
<td>October</td>
<td>28.00</td>
<td>22.56</td>
<td>33.44</td>
<td>5.44</td>
<td>-2.33</td>
</tr>
<tr>
<td>November</td>
<td>2.00</td>
<td>1.06</td>
<td>2.94</td>
<td>0.94</td>
<td>-0.33</td>
</tr>
<tr>
<td>December</td>
<td>1.00</td>
<td>0.58</td>
<td>1.42</td>
<td>0.42</td>
<td>-0.22</td>
</tr>
<tr>
<td>Mean</td>
<td>59.75</td>
<td>51.51</td>
<td>67.99</td>
<td>8.24</td>
<td>-0.30</td>
</tr>
<tr>
<td></td>
<td>PET (mm)</td>
<td>(mm)</td>
<td>(mm)</td>
<td>(mm)</td>
<td>(mm)</td>
</tr>
<tr>
<td>-------</td>
<td>----------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>January</td>
<td>173.60</td>
<td>153.93</td>
<td>193.27</td>
<td>19.67</td>
<td>9.66</td>
</tr>
<tr>
<td>February</td>
<td>182.00</td>
<td>154.92</td>
<td>209.08</td>
<td>27.08</td>
<td>6.03</td>
</tr>
<tr>
<td>March</td>
<td>235.60</td>
<td>202.20</td>
<td>269.00</td>
<td>33.40</td>
<td>8.92</td>
</tr>
<tr>
<td>April</td>
<td>255.00</td>
<td>199.82</td>
<td>250.18</td>
<td>25.18</td>
<td>9.59</td>
</tr>
<tr>
<td>May</td>
<td>223.10</td>
<td>197.00</td>
<td>249.20</td>
<td>26.10</td>
<td>2.76</td>
</tr>
<tr>
<td>June</td>
<td>180.00</td>
<td>155.29</td>
<td>204.71</td>
<td>24.71</td>
<td>-4.94</td>
</tr>
<tr>
<td>July</td>
<td>158.10</td>
<td>136.44</td>
<td>179.76</td>
<td>21.66</td>
<td>-8.58</td>
</tr>
<tr>
<td>August</td>
<td>139.50</td>
<td>124.77</td>
<td>154.23</td>
<td>14.73</td>
<td>-3.18</td>
</tr>
<tr>
<td>September</td>
<td>138.00</td>
<td>122.06</td>
<td>153.94</td>
<td>15.94</td>
<td>-2.90</td>
</tr>
<tr>
<td>October</td>
<td>170.50</td>
<td>155.19</td>
<td>185.81</td>
<td>15.31</td>
<td>3.62</td>
</tr>
<tr>
<td>November</td>
<td>174.00</td>
<td>154.89</td>
<td>193.11</td>
<td>19.11</td>
<td>7.89</td>
</tr>
<tr>
<td>December</td>
<td>182.80</td>
<td>155.99</td>
<td>209.61</td>
<td>26.81</td>
<td>9.50</td>
</tr>
<tr>
<td>Mean</td>
<td>181.85</td>
<td>159.38</td>
<td>204.32</td>
<td>22.47</td>
<td>3.20</td>
</tr>
</tbody>
</table>

These data from New LocClim will be used in Cropwat 8.0 to estimate Crop Water Requirement.

5.3 SPAW and soil data determination

5.3.1 Description of SPAW
The SPAW (Soil-Plant-Air-Water) computer model simulates the daily hydrologic water budgets of agricultural landscapes by two connected routines, one for farm fields and a second for impoundments such as wetland ponds, lagoons or reservoirs. Climate, soil and vegetation data files for field and pond projects are selected from those prepared and stored with a system of interactive screens. Various combinations of the data files readily represent multiple landscape and ponding variations.

The objective of the SPAW model was to understand and predict agricultural hydrology and its interactions with soils and crop production without undue burden of computation time or input details. This required continual vigilance of the many choices required for the representation of each physical, chemical and biological process to achieve a "reasonable" and "balanced" approximation of the real world with numerical solutions. In our case we used the software to determine soil data for Crop water Requirements estimation in Cropwat.

5.3.2 Soil data determination
Data used in the software for soil characteristics determination are: 60% of sand, 15% of clay, 2% of organic matter and 2% of gravel. The figure and the characteristics are shown as follows.
The data below coming from the software are used in Cropwat for Crop Water Requirements estimation.

**Table 5: Data of the study soil**

<table>
<thead>
<tr>
<th>Soil characteristics</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture class</td>
<td>Sandy Loam</td>
</tr>
<tr>
<td>Wilting point</td>
<td>10.9 % Vol</td>
</tr>
<tr>
<td>Field capacity</td>
<td>21.5 % Vol</td>
</tr>
<tr>
<td>Saturation</td>
<td>44.5 % Vol</td>
</tr>
<tr>
<td>Available water</td>
<td>0.11 cm/cm</td>
</tr>
</tbody>
</table>

### 5.4 VeProLGs (1.6.0) and design parameter determination

#### 5.4.1 Description of VeProLGs

Ve.Pro.LGs is a computer program for the verification and design of drip line and areas of planting to save water and energy. Ve.Pro.LGs is a software application that performs operational tests on equipment design and dimensioning of drip irrigation, with the aim of increasing the uniformity of distribution of irrigation to save water and reduce energy consumption. Through the use of Ve.Pro.LG / s is possible to evaluate the functioning of entire sectors of irrigation on field crops, trees, flowers and plants, although grown on slopes and strongly with changes in elevation along the line. In particular, the program has operational tools that allow:
- To verify the operation of equipment already installed, identifying any changes to improve performance
- Guide the design choices in the construction of new facilities according to criteria of high efficiency;
- Provide useful parameters for site management;
- Involve the evaluation of functional performance of the plants the costs of amortization of the purchase of drip lines and energy costs for water delivery.

5.4.2 Data for Irrigation Uniformity distribution Determination
Data useful and chosen in the software for the uniformity of irrigation distribution determination are recorded in following table.

Table 6: Data for uniformity determination

<table>
<thead>
<tr>
<th>Input data</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drip line</td>
<td>Streamline 80 d.16 q.1,49 s. 0,4(2000)</td>
</tr>
<tr>
<td>Head pipe (50 m)</td>
<td>PE BD PFA 4 DN 75</td>
</tr>
<tr>
<td>Head pressure</td>
<td>4.0 m.w.c</td>
</tr>
<tr>
<td>Slop</td>
<td>0.9</td>
</tr>
<tr>
<td>Line side 1</td>
<td>50 m</td>
</tr>
</tbody>
</table>

Using these data in the software, one obtains the figure below.
Figure 5: Uniformity of irrigation determination

The uniformity of irrigation distribution on the plot of 0.25 ha determined is 95.8%, the area flow rate is 2.5 l/s and the irrigation intensity is 3.6 mm/hour. This uniformity is finally used in Cropwat to estimate Crop Water Requirements.

5.5 CROPWAT 8.0 and Crop Water Requirements and irrigation scheduling

5.5.1 Description of CROPWAT 8.0

CROPWAT is a decision support tool developed by the Land and Water Development Division of FAO (http://www.fao.org/nr/water/infores_databases_cropwat.html). CROPWAT 8.0 for Windows is a computer program for the calculation of crop water requirements and irrigation requirements based on soil, climate and crop data. In addition, the program allows the development of irrigation schedules for different management conditions and the calculation of scheme water supply for varying crop patterns. CROPWAT 8.0 can also be used to evaluate farmers’ irrigation practices and to estimate crop performance under both rainfed and irrigated conditions.
All calculation procedures used in CROPWAT 8.0 are based on the two FAO publications of the Irrigation and Drainage Series, namely, No. 56 "Crop Evapotranspiration - Guidelines for computing crop water requirements" and No. 33 titled "Yield response to water".

CROPWAT 8.0 includes standard crop and soil data. When local data are available, these data files can be easily modified or new ones can be created. Likewise, if local climatic data are not available, these can be obtained for over 5,000 stations worldwide from CLIMWAT, the associated climatic database. The development of irrigation schedules in CROPWAT 8.0 is based on a daily soil-water balance using various user-defined options for water supply and irrigation management conditions. Scheme water supply is calculated according to the cropping pattern defined by the user, which can include up to 20 crops.

CROPWAT 8.0 is a Windows program based on the previous DOS versions. Apart from a completely redesigned user interface, CROPWAT 8.0 for Windows includes a host of updated and new features, including:

- Monthly, decade and daily input of climatic data for calculation of reference evapotranspiration (ET0);
- Backward compatibility to allow use of data from CLIMWAT database;
- Possibility to estimate climatic data in the absence of measured values;
- Decade and daily calculation of crop water requirements based on updated calculation algorithms including adjustment of crop-coefficient values;
- Calculation of crop water requirements and irrigation scheduling for paddy & upland rice, using a newly developed procedure to calculate water requirements including the land preparation period;
- Interactive user adjustable irrigation schedules;
- Daily soil water balance output tables;
- Easy saving and retrieval of sessions and of user-defined irrigation schedules;
- Graphical presentations of input data, crop water requirements and irrigation schedules;
- Easy import/export of data and graphics through clipboard or ASCII text files;
- Extensive printing routines, supporting all windows-based printers;
- Context-sensitive help system;
Multilingual interface and help system: English, Spanish, French and Russian.

5.5.2 Determination of crop irrigation schedule

The crop irrigation schedule coming from Cropwat estimation useful for the maize crop irrigation is recorded in the following table.

Table 7: Data of crop irrigation schedule

<table>
<thead>
<tr>
<th>Date</th>
<th>Day</th>
<th>Stage</th>
<th>Rain</th>
<th>Ks</th>
<th>ETa</th>
<th>Depl</th>
<th>Net Irr</th>
<th>Deficit</th>
<th>Loss</th>
<th>Gr. Irr</th>
<th>Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>mm</td>
<td>Fract</td>
<td>%</td>
<td>%</td>
<td>mm</td>
<td>mm</td>
<td>mm</td>
<td>mm</td>
<td>l/s/ha</td>
</tr>
<tr>
<td>03 Nov</td>
<td>1</td>
<td>Init</td>
<td>1.0</td>
<td>0.07</td>
<td>7</td>
<td>97</td>
<td>29.6</td>
<td>0.0</td>
<td>0.0</td>
<td>25.5</td>
<td>3.57</td>
</tr>
<tr>
<td>12 Nov</td>
<td>10</td>
<td>Init</td>
<td>0.0</td>
<td>1.00</td>
<td>100</td>
<td>47</td>
<td>16.5</td>
<td>0.0</td>
<td>0.0</td>
<td>25.8</td>
<td>0.22</td>
</tr>
<tr>
<td>21 Nov</td>
<td>19</td>
<td>Init</td>
<td>0.0</td>
<td>1.00</td>
<td>100</td>
<td>44</td>
<td>17.9</td>
<td>0.0</td>
<td>0.0</td>
<td>29.4</td>
<td>0.24</td>
</tr>
<tr>
<td>30 Nov</td>
<td>28</td>
<td>Dev</td>
<td>0.0</td>
<td>1.00</td>
<td>100</td>
<td>47</td>
<td>21.3</td>
<td>0.0</td>
<td>0.0</td>
<td>30.1</td>
<td>0.28</td>
</tr>
<tr>
<td>7 Dec</td>
<td>35</td>
<td>Dev</td>
<td>0.2</td>
<td>1.00</td>
<td>100</td>
<td>50</td>
<td>24.5</td>
<td>0.0</td>
<td>0.0</td>
<td>29.7</td>
<td>0.41</td>
</tr>
<tr>
<td>13 Dec</td>
<td>41</td>
<td>Dev</td>
<td>0.2</td>
<td>1.00</td>
<td>100</td>
<td>47</td>
<td>24.7</td>
<td>0.0</td>
<td>0.0</td>
<td>30.0</td>
<td>0.49</td>
</tr>
<tr>
<td>19 Dec</td>
<td>47</td>
<td>Dev</td>
<td>00</td>
<td>1.00</td>
<td>100</td>
<td>51</td>
<td>28.2</td>
<td>0.0</td>
<td>0.0</td>
<td>30.8</td>
<td>0.56</td>
</tr>
<tr>
<td>24 Dec</td>
<td>52</td>
<td>Dev</td>
<td>00</td>
<td>1.00</td>
<td>100</td>
<td>49</td>
<td>28.9</td>
<td>0.0</td>
<td>0.0</td>
<td>31.4</td>
<td>0.68</td>
</tr>
<tr>
<td>29 Dec</td>
<td>57</td>
<td>Mid</td>
<td>00</td>
<td>1.00</td>
<td>100</td>
<td>48</td>
<td>28.5</td>
<td>0.0</td>
<td>0.0</td>
<td>31.8</td>
<td>0.67</td>
</tr>
<tr>
<td>03 Jan</td>
<td>62</td>
<td>Mid</td>
<td>00</td>
<td>1.00</td>
<td>100</td>
<td>48</td>
<td>28.8</td>
<td>0.0</td>
<td>0.0</td>
<td>32.5</td>
<td>0.68</td>
</tr>
<tr>
<td>8 Jan</td>
<td>67</td>
<td>Mid</td>
<td>00</td>
<td>1.00</td>
<td>100</td>
<td>49</td>
<td>29.6</td>
<td>0.0</td>
<td>0.0</td>
<td>33.0</td>
<td>0.68</td>
</tr>
<tr>
<td>13 Jan</td>
<td>72</td>
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<td>1.00</td>
<td>100</td>
<td>50</td>
<td>30.2</td>
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<td>0.0</td>
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<td>0.71</td>
</tr>
<tr>
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<td>77</td>
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<td>00</td>
<td>1.00</td>
<td>100</td>
<td>51</td>
<td>30.6</td>
<td>0.0</td>
<td>0.0</td>
<td>33.0</td>
<td>0.72</td>
</tr>
<tr>
<td>23 Jan</td>
<td>82</td>
<td>Mid</td>
<td>00</td>
<td>1.00</td>
<td>100</td>
<td>52</td>
<td>31.2</td>
<td>0.0</td>
<td>0.0</td>
<td>30.5</td>
<td>0.74</td>
</tr>
<tr>
<td>28 Jan</td>
<td>87</td>
<td>Mid</td>
<td>0.2</td>
<td>1.00</td>
<td>100</td>
<td>53</td>
<td>31.7</td>
<td>0.0</td>
<td>0.0</td>
<td>37.1</td>
<td>0.75</td>
</tr>
<tr>
<td>2 Feb</td>
<td>92</td>
<td>Mid</td>
<td>00</td>
<td>1.00</td>
<td>100</td>
<td>53</td>
<td>31.8</td>
<td>0.0</td>
<td>0.0</td>
<td>33.1</td>
<td>0.75</td>
</tr>
<tr>
<td>7 Feb</td>
<td>97</td>
<td>End</td>
<td>00</td>
<td>1.00</td>
<td>0</td>
<td>53</td>
<td>31.7</td>
<td>0.0</td>
<td>0.0</td>
<td>33.0</td>
<td>0.77</td>
</tr>
<tr>
<td>12 Feb</td>
<td>102</td>
<td>End</td>
<td>00</td>
<td>1.00</td>
<td>100</td>
<td>49</td>
<td>29.3</td>
<td>0.0</td>
<td>0.0</td>
<td>30.5</td>
<td>0.76</td>
</tr>
<tr>
<td>19 Feb</td>
<td>109</td>
<td>Ned</td>
<td>00</td>
<td>1.00</td>
<td>0</td>
<td>59</td>
<td>35.7</td>
<td>0.0</td>
<td>0.0</td>
<td>37.1</td>
<td>0.61</td>
</tr>
<tr>
<td>1 Mars</td>
<td>119</td>
<td>End</td>
<td>00</td>
<td>1.00</td>
<td>100</td>
<td>63</td>
<td>38.0</td>
<td>0.0</td>
<td>0.0</td>
<td>39.6</td>
<td>0.46</td>
</tr>
<tr>
<td>7 Mars</td>
<td>125</td>
<td>End</td>
<td>00</td>
<td>1.00</td>
<td>0</td>
<td>22</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td></td>
</tr>
</tbody>
</table>

From crop irrigation schedule in Cropwat the total gross irrigation and the total net irrigation are respectively 592.4 mm and 568.7 mm for all the cycle of the maize cultivation. The gross irrigation value (39.6mm) will be used to calculate the duration of irrigation.
5.6 EPANET 2.0 and design of the irrigation scheme

5.6.1 Description of EPANET 2.0

Developed by EPA’s Water Supply and Water Resources Division (www.epa.gov/nrmrl/wswrd/dw/epanet.html) EPANET is software that models water distribution piping systems. It is a Windows 95/98/NT/XP program that performs extended-period simulation of the hydraulic and water quality behavior within pressurized pipe networks.

Pipe networks consist of pipes, nodes (pipe junctions), pumps, valves, and storage tanks or reservoirs. EPANET tracks the flow of water in each pipe, the pressure at each node, the height of the water in each tank, and the concentration of a chemical species throughout the network during a simulation period. Chemical species, water age, source, and tracing can be simulated.

EPANET provides an integrated computer environment for editing network input data, running hydraulic and water quality simulations, and viewing the results in a variety of formats. These include color-coded network maps, data tables, time series graphs, and contour plots.

EPANET provides a fully equipped, extended-period hydraulic analysis package that can:

- Handle systems of any size;
- Compute friction head loss using the Hazen-Williams, the Darcy Weisbach, or the Chezy-Manning head loss formula;
- Include minor head losses for bends, fittings, etc;
- Model constant or variable speed pumps;
- Compute pumping energy and cost;
- Model various types of valves, including shutoff, check, pressure regulating, and flow control;
- Allow storage tanks to have any shape (i.e., surface area can vary with height);
Consider multiple demand categories at nodes, each with its own pattern of time variation;

- Model pressure-dependent flow issuing from emitters (sprinkler heads);
- Base system operation on simple tank level or timer controls as well as on complex rule-based controls.

5.6.2 The plan of irrigation scheme

The whole plan of the irrigation scheme is composed of 48 plots of 0.25 ha each. The source of water (dam) used for irrigation is located at 800 km from the perimeter. The plot (A) at the downstream of the perimeter is chosen to make the design in order to ensure that the pressure and the base demand of the plot is sufficient and satisfactory and may be sufficient to cover any plot at any point on the perimeter. The scheme is as follows:
VI RESULTS AND DISCUSSIONS

The results and discussions of the study present and analyze different parameters of irrigation management and the irrigation network.

6.1 Irrigation requirements

To calculate the volume useful for irrigation we took the greater value of gross irrigation (39.6 mm) from crop irrigation schedule table in Cropwat and divided it by 6 days. The result is 6.6 mm/days. The required volume (in m$^3$) for 0.25 ha is calculating multiplying the result converted in m/day by the area (in m$^2$). Thus the total volume for maize cultivation (cycle of maize is 125 days) for the different areas is calculated and recorded in the table below.

Table 8: Different volume of water

<table>
<thead>
<tr>
<th>Gross irrigation for each area</th>
<th>0.25 ha</th>
<th>01 ha</th>
<th>01 block (2 ha)</th>
<th>Whole area (12 ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>In m$^3$</td>
<td>2 062.5</td>
<td>8 250</td>
<td>16 500</td>
<td>99.000</td>
</tr>
</tbody>
</table>

The volume of water for maize cultivation on 0.25 ha is 2 062.5 m$^3$.

The Irrigation Requirements per day is 2 062.5 m$^3$/125 days = 16.5 m$^3$/days. This value will be used to calculate the duration of irrigation.

6.2 Duration of irrigation

To calculate the duration of irrigation we used the value of gross irrigation (16.5 m$^3$/days) for the plot of 0.25 ha.

The base demand of the plot determined in Ve.Pro.LGs is 9 m$^3$/h. The duration of irrigation obtained is 16.5 m$^3$/day/9 m$^3$/h = 1 h 49.8 mn. This time could be estimated to 1 h 55 mn.
6.3 The irrigation network

Here we present the irrigation network of the 12 hectares even though the design has concerned 0.25 hectare. Indeed, the capacity of the pump selected (Q=80m$^3$/h) for the proper functioning of the network, provides irrigation to both two hectares (one block) in the same duration of irrigation.

The desired flow at the head of the plot is 9 m$^3$ and pressure that can convey this flow is 4 mw.c. The variation of pressure (minimum and maximum pressure) for the proper functioning of the perimeter is between 4 and 4.25 mw.c. Thus, the network is as follows:

![Figure 6: Irrigation network for twelve ha](image)

The figure below presents an overview of the plot (A) with drip lines.
The following figure is an extract from the plot (A) to show visually the lines, spacing between crop lines and drippers.

**Figure 7:** View of a plot with drip lines

**Figure 8:** View of drip lines and spacing
6.4 Different pipe sizes
The different pipes sizes used in the design and that can convey water from the dam to the parcel are recorded in the table below.

Table 9: Characteristics of the pipe

<table>
<thead>
<tr>
<th>Different pipes</th>
<th>Description</th>
<th>Diameter of pipes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mainline</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pipe connecting the supply line to the pimping unit</td>
<td>205 mm (800m)</td>
<td></td>
</tr>
<tr>
<td>Supply line</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pipe connecting the mainline to side line</td>
<td>273.05 mm (104m)</td>
<td></td>
</tr>
<tr>
<td>Side lines or laterals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pipe connecting the supply line to the valve</td>
<td>273.05 (587m)</td>
<td></td>
</tr>
<tr>
<td>Valve</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Device used to close or open water between side line and the head pipe</td>
<td>75 mm</td>
<td></td>
</tr>
<tr>
<td>head pipe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pipe connecting the drip line and convey water to the plot</td>
<td>75 mm (50m)</td>
<td></td>
</tr>
<tr>
<td>Drip lines</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Line that contains drippers</td>
<td>16 mm</td>
<td></td>
</tr>
</tbody>
</table>

6.5 Characteristics of the irrigation network at a plot
The type of drip line chosen for the design is Streamline 80 d.16 q.1,49 s. 0,4(2000). The spacing between crop lines is 0.8 m. Therefore we need a total length of 3 125 m of drip line on a surface of 0.25 ha.

The length of the head pipe at the plot is 50 m and the type is PE BD PFA 4 DN 75. These characteristics are summarized in the following table:

Table 10: Characteristics of materials and equipment used

<table>
<thead>
<tr>
<th>Material</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drip line</td>
<td>Streamline 80 d.16 q.1,49 s. 0,4(2000)</td>
</tr>
<tr>
<td>Total length of drip lines for the plot</td>
<td>3 125 m</td>
</tr>
<tr>
<td>Type of Head pipe</td>
<td>PE BD PFA 4 DN 75 (Polietilene BD PFA 4)</td>
</tr>
<tr>
<td>Length of Head pipe</td>
<td>50 m</td>
</tr>
<tr>
<td>Capacity of the pump</td>
<td>80 m³/h</td>
</tr>
<tr>
<td>Pressure at the plot</td>
<td>4 mw.c</td>
</tr>
<tr>
<td>Base demand</td>
<td>9 m³</td>
</tr>
</tbody>
</table>
CONCLUSION

The conduct of the study of the thesis allows us to know the technical feasibility of the project. Indeed, thanks to the methodological approach, the topic, subject of our study was discussed in all its contours.

The existence of positive factors and potential (soil, irrigation water), the availability of technical may allow the execution and the implementation of the project of the irrigation scheme.

The estimation of crop water requirement has been done using software (Cropwat, VeProLGS ...). Combining data from the software allowed us to obtain results and determine the water requirements needed for maize cultivation on an area of 0.25 ha. The uniformity of distribution obtained is 96% indicating a good efficiency. The total gross irrigation for the entire cycle of corn on 0.25 ha are estimated to 1 481 m³.

For the scheme design, strictly speaking, the software EPANET allowed to determine the pressure necessary to convey water from the dam up the parcel, thus ensuring water base demand. The base demand is estimate to 9 m³ for the plot and the variation of the pressure is between 4 and 4.25 mw.c.

For the management the duration of irrigation of the plot of 0.25 ha is 1h 25 mn. The results obtained in this study pointed out that for the proper functioning of the capacity of pump (80m³) chosen may irrigate simultaneously one block (2 ha).

As perspectives, much remains to be done to improve the functioning of the system. Indeed additive work for adding filters is very necessary because first of all, drip irrigation requires clear water to prevent clogging of drippers. Also we could consider fertigation, thing essential for a correct application of fertilizers in order to increase productivity, quality and profitability. In addition it reduces labor and time requirements.
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- Irrigation Water Management: Training Manual No. 8, Structures for water control and distribution


- Irrigation Manual: Planning, Development Monitoring and Evaluation of Irrigated Agriculture with Farmer Participation Volume III Module 8

- Water report 22: Deficit Irrigation Practices, FAO

- Rapport de formulation du programme régional de développement durable de l’agriculture irriguée dans le plateau central, Décembre 2010

ANNEXES

Annexes include Successive steps and data of Crop Water Requirements. They also present the characteristics of the pump.
Table 11: Crop irrigation schedule

<table>
<thead>
<tr>
<th>Date</th>
<th>Day</th>
<th>Stage</th>
<th>Rain</th>
<th>Ks</th>
<th>ETa</th>
<th>Depl</th>
<th>Net In</th>
<th>Deficit</th>
<th>Loss</th>
<th>Gr. In</th>
<th>Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nov 3</td>
<td>1</td>
<td>Init</td>
<td>1.0</td>
<td>0.07</td>
<td>7</td>
<td>57</td>
<td>29.6</td>
<td>0.0</td>
<td>0.0</td>
<td>30.6</td>
<td>3.57</td>
</tr>
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<td>Nov 12</td>
<td>10</td>
<td>Init</td>
<td>0.0</td>
<td>1.00</td>
<td>100</td>
<td>47</td>
<td>16.5</td>
<td>0.0</td>
<td>0.0</td>
<td>17.2</td>
<td>0.22</td>
</tr>
<tr>
<td>Nov 21</td>
<td>19</td>
<td>Init</td>
<td>0.0</td>
<td>1.00</td>
<td>100</td>
<td>44</td>
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<td>0.0</td>
<td>0.0</td>
<td>18.7</td>
<td>0.24</td>
</tr>
<tr>
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<td>28</td>
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<td>1.00</td>
<td>100</td>
<td>47</td>
<td>21.3</td>
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<td>0.0</td>
<td>22.2</td>
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</tr>
<tr>
<td>Dec 7</td>
<td>35</td>
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<td>1.00</td>
<td>100</td>
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<td>47</td>
<td>24.7</td>
<td>0.0</td>
<td>0.0</td>
<td>25.8</td>
<td>0.50</td>
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<tr>
<td>Dec 19</td>
<td>47</td>
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<td>0.0</td>
<td>1.00</td>
<td>100</td>
<td>51</td>
<td>28.2</td>
<td>0.0</td>
<td>0.0</td>
<td>29.4</td>
<td>0.57</td>
</tr>
</tbody>
</table>

Totals

<table>
<thead>
<tr>
<th>Total gross irrigation</th>
<th>592.4 mm</th>
<th>Total rainfall</th>
<th>4.6 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total net irrigation</td>
<td>560.7 mm</td>
<td>Effective rainfall</td>
<td>4.3 mm</td>
</tr>
<tr>
<td>Total irrigation losses</td>
<td>0.0 mm</td>
<td>Total rain loss</td>
<td>0.3 mm</td>
</tr>
<tr>
<td>ACTUAL WATER USE BY CROP</td>
<td>526.3 mm</td>
<td>Moist deficit at harvest</td>
<td>13.2 mm</td>
</tr>
<tr>
<td>Potential water use by crop</td>
<td>527.6 mm</td>
<td>Actual irrigation requirement</td>
<td>523.3 mm</td>
</tr>
</tbody>
</table>

Efficiency irrigation schedule | 100.0 % | Efficiency rain | 93.9 % |
Deficiency irrigation schedule | 0.2 %   |
Table 12: Scheme of supply

<table>
<thead>
<tr>
<th>Precipitation deficit</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. MAI23 (Rain)</td>
<td>19.3</td>
<td>14.5</td>
<td>15.8</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>43.1</td>
<td>13.5</td>
</tr>
<tr>
<td>Net scheme in req.</td>
<td>6.1</td>
<td>5.2</td>
<td>0.6</td>
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<td>0.0</td>
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<td>0.0</td>
<td>0.0</td>
<td>1.4</td>
<td>4.3</td>
</tr>
<tr>
<td>in mm/year</td>
<td>15.3</td>
<td>14.5</td>
<td>15.8</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>43.1</td>
<td>13.5</td>
</tr>
<tr>
<td>in mm/month</td>
<td>0.71</td>
<td>0.56</td>
<td>0.07</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.17</td>
<td>0.49</td>
</tr>
<tr>
<td>Irrigated area</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>0.0</td>
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<td>0.0</td>
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<td>0.0</td>
<td>0.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>% of total area</td>
<td>0.71</td>
<td>0.56</td>
<td>0.07</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.17</td>
<td>0.49</td>
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</tbody>
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Figure 9: Characteristics of the pump