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Masters on "Irrigation Problems in Developing Countries"

THESIS ON

Design of a Drip Irrigation System for the Production of Bananas on the Plain of Bagré (Burkina Faso)

By

YIRA Yacouba

Supervised by:

Dott. Agr. Ivan SOLINAS

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DEDICATION

To my parents and my "wife" for their eternal support

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ABSTRACT

Burkina Faso is a country in the dynamic of development of its irrigated agriculture in order to reduce the dependence on the climate conditions. The results achieved so far with surface irrigation are not quite satisfactory and suggest an evolution towards more efficient systems.

It's with this objective that this study proposes to design a drip irrigation system appropriate for the plain of Bagré, one of the largest irrigated agricultural schemes of the country.

First of all, the bananas water requirement has been determined with the software Cropwat based on the local climatic and field conditions.

Having identified and ranked the drip lines available in the study area with the software Ve.Pro.LG, the drip line Python proved to be one that provides the best uniformity (93.7%) at the plot level, according to the field feature.

Then a pipe line system has been designed with EPANET to convey water from the canal (water intake) to the plot. The pipe line system was fully designed with pipe of 147.6 mm of diameter that makes it possible to supply water with a discharge of 76.32 m^3/hour and a flow velocity of 1.24 m/s at a pressure of 5.22 m.w.c. These features ensure proper operation of Python.

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INTRODUCTION

Burkina Faso is a Sahelian country primarily agricultural. Agriculture occupies over 80% of the population and contributes for 30% of Gross Domestic Product. It is extensive rainfed agriculture, thus subject to weather conditions. Among these risks is noted especially the spatial and temporal variability in rainfall. The orientation towards irrigated agriculture, less dependent on rainfall, therefore aims to provide a response to this climatic variability.

Since the droughts of the 1970s, strategies involving the control of water have been developed to secure and improve agricultural production. A National Policy for Development of Irrigation and recently a National Strategy for Sustainable Development of Irrigated Agriculture have been developed to boost irrigated agriculture. The control of water has become a national priority and justifies the development of large schemes such as the scheme of Bagré.

The hydro agricultural plain of Bagré is one of the first "large hydro-agricultural" scheme of Burkina. It has a potential developable land of 30,000 ha including 7,400 ha irrigated by gravity. But its performances, like the seven other major hydro-agricultural schemes in the country have often been below expectations. These poor results are due to the centralization of management by the State, the low technical skills of operators, and a social exploitation of the scheme.

The criticisms of the relatively disappointing performance of existing schemes, however, preclude the need to boost irrigated agriculture in order to mitigate the influence of climate variability, reduce imports and enhance food security. Hence the need to move toward a more optimal type of scheme management, i.e., a management involving more responsibility of the producer and also market-oriented. This concept is much better known under the term “agro-business” or “agricultural entrepreneurship”.

This mode of exploitation, currently promoted by the Burkina Faso government requires optimal management of the triple resource ground-water-human resource. That means in the field of irrigation an efficient irrigation system.

The drip irrigation is nowadays the most efficient irrigation method, it offers efficiency above 90% in terms of water management, is adapted to any landscape and suited to most of the crops.

This thesis is part of the Master "Irrigation Problems in Developing Countries" and aims to propose a design of a drip irrigation system for the production of bananas on the plain of Bagré. It consists of tree (3) chapters: a literature review on drip irrigation, the presentation of the study environment and the methodology, and finally presenting the results.

CHAPTER I: LITERATURE REVIEW

I.1. DRIP IRRIGATION

Drip irrigation is a controlled method of irrigation, consisting of tubes with emitters. It allows increasing water use efficiencies by providing precise amounts of water directly to the root zone of individual plants (Burt and Styles, 2007).

I.1.1. Advantages of Drip irrigation

Many claims as to the advantages of Drip irrigation have been and are still being made. Currently, the following advantages are recognized:

- The evaporative component of evapotranspiration is reduced, as only a limited area of the soil is wetted. This is more prevalent with young trees;
- The higher degree of inbuilt management that localized irrigation offers reduces substantially deep percolation and runoff losses, thus attaining higher irrigation efficiencies. Consequently, localized irrigation is considered as a water-saving technology;
- The limited wetted area results in reduced weed growth;
- Applicable to all forms of plots;
- Unaffected by wind;
- Reduced operating costs and labor. Human intervention is reduced to the periodic inspection of equipment for filtering and control, and the proper operation of drippers;
- Reduced risk of fungal diseases;
- Reduced sensitivity to the use of salt water. The salts are leached to each application and trained at the periphery of the bulb humidifying outside the scope of the active root zone. No risk of damage to the aerial parts of plants by spraying of saline water.

I.1.2. Disadvantages of Drip irrigation

The major disadvantages of localized irrigation are:

- Localized systems are prone to clogging because of the very small aperture of the water emitting devices hence the need for proper filtration and, at times, chemigation;

- The movement of salts to the fringes of the wetted area of the soil may cause salinity problems through the leaching of salts by rain to the 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 salts beyond the root zone depth;

- Rodents, dogs and other animals 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 laterals and emitters required;

- The relatively high investment cost of the system;

- The spatial development of the root zone is limited and concentrated in the vicinity of the dripper making plants more susceptible to wind throw.

I.1.3. Crop water requirements under drip irrigation

Evapotranspiration is composed of the evaporation from the soil and the transpiration of the plant. Since under localized irrigation only a portion of the soil is wetted, the evaporation component of evapotranspiration can be reduced accordingly, using the appropriate ground cover reduction factor *Kr*.

For the design of localized irrigation systems:

$$ET_{crop\text{-}loc} = ET_o \times K_c \times K_r$$

Where:

ETo = Reference crop evapotranspiration using the Penman-Monteith method;

Kc = Crop factor Kc

Kr = Ground cover reduction factor Kr.

FAO (1984) provides the reduction factors suggested by various researchers in order to account for the reduction in evapotranspiration (Table 1).

Table 1: Values of Kr suggested by different authors (Source: FAO, 1984)

Ground cover (%)	Crop factor Kr according to		
	Keller & Karmeli	Freeman & Garzoli	Decroix CTG REF
10	0.12	0.10	0.20
20	0.24	0.20	0.30
30	0.35	0.30	0.40
40	0.47	0.40	0.50
50	0.59	0.75	0.60
60	0.70	0.80	0.70
70	0.82	0.85	0.80
80	0.94	0.90	0.90
90	1.00	0.95	1.00
100	1.00	1.00	1.00

I.1.4. Irrigation requirements

FAO (1984) defines the net irrigation requirements (IRn) as the depth or volume of water required for normal crop production over the whole cropped area, excluding contribution from other sources. The following equation is used:

$$\mathbf{IRn = ETcrop \times Kr - R + LR}$$

By incorporating the irrigation efficiency in the calculations, we obtain the gross irrigation requirements (IRg)

$$\mathbf{IRg = \frac{(ETcrop \times Kr)}{Ea} - R + LR}$$

Where:

IRn = net irrigation requirement

ETo crop = crop evapotranspiration

Kr = ground cover reduction factor

R = water received by plant from sources other than irrigation (for example rainfall)

LR = amount of water required for the leaching of salts

Ea = field application efficiency

According to Rainbird International (1980), the following efficiencies should be used when the surface area wetted by one emitter does not exceed 60 cm in diameter:

Hot dry climate: Ea = 0.85

Moderate climate: Ea = 0.90

Humid climate: Ea = 0.95

I.1.5. Percentage wetted area

The percentage wetted area (Pw) is the average horizontal area wetted within the top 30 cm of the crop root zone depth in relation to the total cropped area. This number depends on the desirable percentage wetted area and the area wetted by one emitter.

Keller and Bliesner (1990) present a relationship that may exist between the potential production and Pw. They suggest that Pw often approaches 100% for closely spaced crops with rows and drip laterals spaced less than 1.8 m apart

Taking this, and experience from elsewhere, into consideration, a Pw of 50-60% for low rainfall areas and 40% for high rainfall areas is proposed for widely spaced crops (F.A.O; 2007)

I.1.6. Area wetted by an emitter

The area wetted by an emitter, along a horizontal plane (30 cm below the soil surface), depends on the soil and topography, on the flow rate of the emitter and on the volume of irrigation water. It is therefore advisable to carry out simple field tests in order to establish the area wetted by an emitter.

In the absence of locally available data, Rainbird International (1980) recommends the use of the data presented in table 2.

Table 2: Area wetted by one emitter depending on soil type (Source: Rainbird International, 1980)

Soil type	Area wetted by one emiter (m2)
Sandy soils	0.5 - 2
Loamy soil	2 - 6
Clay	6 - 15

I.1.7. Number of emitters per plant and emitter spacing

The number of the emitters required per plant is established as follows

$$\textbf{Emitters per plant} = \frac{\textbf{Area per plant x Pw}}{\textbf{Aw}}$$

Area per plant (m2)
Pw = Percentage wetted area/100 (%/100)
Aw = Area wetted by one emitter (m2)

I.1.8. Emitter selection

The following are some of the major emitter characteristics that affect the system efficiency and should all be taken into consideration during the emitter selection process:

- ❖ Emitter discharge exponent
- ❖ Discharge-pressure relationship to design specification

$$\mathbf{q = Kd \cdot H^x}$$

Where: q = emitter discharge (lph)
Kd = discharge coefficient that characterizes each emitter
H = emitter operating pressure (m)
x = emitter discharge exponent

- ❖ Stability of discharge-pressure relationship over a long time
- ❖ Manufacturer coefficient of variation
- ❖ Range of operating pressure
- ❖ Susceptibility to clogging
- ❖ Type of emitter connection to lateral and head losses

I.2. BANANA CULTIVATION

Banana (Musa spp.) is one of the most important tropical fruits. Ripe banana fruits are sugary and eaten raw; unripe fruits, called plantains, are cooked and provide a starchy food with nutritional value similar to potato.

I.2.1. Climate

A mean temperature of about 27°C is optimal for growth. Minimum temperature for adequate growth is about 16°C, below which growth is checked and shooting delayed. Temperatures below 8°C for long periods cause serious damage. Maximum temperature for adequate growth is about 38°C, depending on humidity and the radiation intensity. Bananas are day-neutral in their response to daylength.

A humidity of at least 60 percent or more is preferable. Strong winds, greater than 4 m/sec, area major cause of crop loss due to the pseudostems being blown down. Under high wind conditions windbreaks are desirable.

I.2.2. Soils and Fertilizer dose

Bananas can be grown on a wide range of soils provided they are fertile and well-drained. Stagnant water will cause diseases. The best soils are deep, well-drained loams with a high water holding capacity and humus content. Optimum pH is between 5 and 7. The demands for nitrogen and especially potash are high. Since the early stages of growth are critical for later development, nutrients must be ample at the time of planting and at the start of a ratoon crop. Short intervals between fertilizer applications, especially nitrogen, are recommended. Fertilizer requirements are 200 to 400 kg/ha N, 45 to 60 kg/ha P and 240 to 480 kg/ha K per year

Banana is very sensitive to salinity and soils with an ECe of less than 1 mmho/ cm are required for good growth

I.2.3. Crop duration

Banana is normally multiplied vegetatively. Several types of suckers can be used. The development of the plant can be divided into three periods: vegetative, flowering and yield formation. The time from planting to shooting (vegetative) is about 7 to 9 months, but with lower temperatures at higher altitudes or in the subtropics, up to 18 months. The time from shooting to harvest (flowering and yield formation) is about 90 days. In tropical lowlands the time to harvest of the next ratoon crop is about 6 months. The number of ratoons varies. The average life of a commercial plantation can be from 3 to 20 years; with mechanical cultivation the economic life is often 4 to 6 years. Some varieties are replanted after each harvest.

I.2.4. Plant density

Planting distances vary according to variety, climate, soil and management and are between 2 x 2 m and 5 x 5 m, corresponding to a density of 400 to 2500 plants/ha

I.2.5. Water Requirements

Being a long duration crop, the total water requirements of banana are high. Water requirements-per year vary between 1200 mm in the humid tropics to 2200 in the dry tropics. For rainfed production, average rainfall of 2000 to 2500 mm per year, well-distributed, is desirable, but banana often grows under less rainfall. The crop coefficients for banana water requirement calculation are given in the table 3.

Table 3: Crop coefficient (Kc) values of Banana

Crop	**Zone**	**Crop development stages**					**Total growing period**
		Initial	**Crop Development**	**Middle season**	**Late season**	**At harvest**	
Banana	tropical	0,4-0,5	0,7-0,85	1-1,1	0,9-0,1	0,75-0,85	0,7-0,8
	Subtropical	0,5-0,65	0,8-0,9	1-1,2	1-1,15	1,0-1,15	0,85-0,95

From: FAO Irrigation and drainage Paper 33, Table 18

CHAPTER II: STUDY AREA AND METHODOLOGY

II.1. Presentation of the hydro-agricultural plain of Bagre

The plain Bagre hydro agricultural concerns Nakanbé river middle valley about 90 km long. The plain is located primarily in the East Central region and partly in the South Central region of Burkina Faso between parallels 11 ° 12 'and 11 ° 53' North latitude and meridians 0 ° 14 'and 0 ° 50’ West longitude.

The project of Bagré initiated in the 1970s, originally consisting of an electric cover and an agricultural component. On this basis, a dam with a capacity of 1.7 billion m3 was constructed. Under the electric component, a hydroelectric plant with a rated output of 16 MW has been achieved

The overall objective of the Project of Bagré is intensifying, security and increased agro-pastoral-forestry, fisheries, tourism and energy by exploiting natural resources for sustainable socio-economic development of the Project area.

Plain of Bagré has a potential developable land of 30,000 ha including 7,400 ha irrigated by gravity. The fact that it provides a guaranteed production, less subject to climatic hazards, gives to the potential a particular importance.

The hydro agricultural plain of Bagré has specific advantages for the agribusiness plots mainly:

- Surface irrigation system to irrigate 7,400 ha smoothly, greatly reducing production costs;

- The relative fertility of the land area of Bagre. Approximately 80-90% of soils have a depth capacity of over 80 cm, making them suitable for rice cultivation, market gardening and fruit growing;

- The position bordering with coastal countries like Togo, Ghana or Benin and Niger, giving it an advantage in the marketing of agro-pastoral and fisheries;

- The presence of a large hydroelectric facilitating access to energy investors;

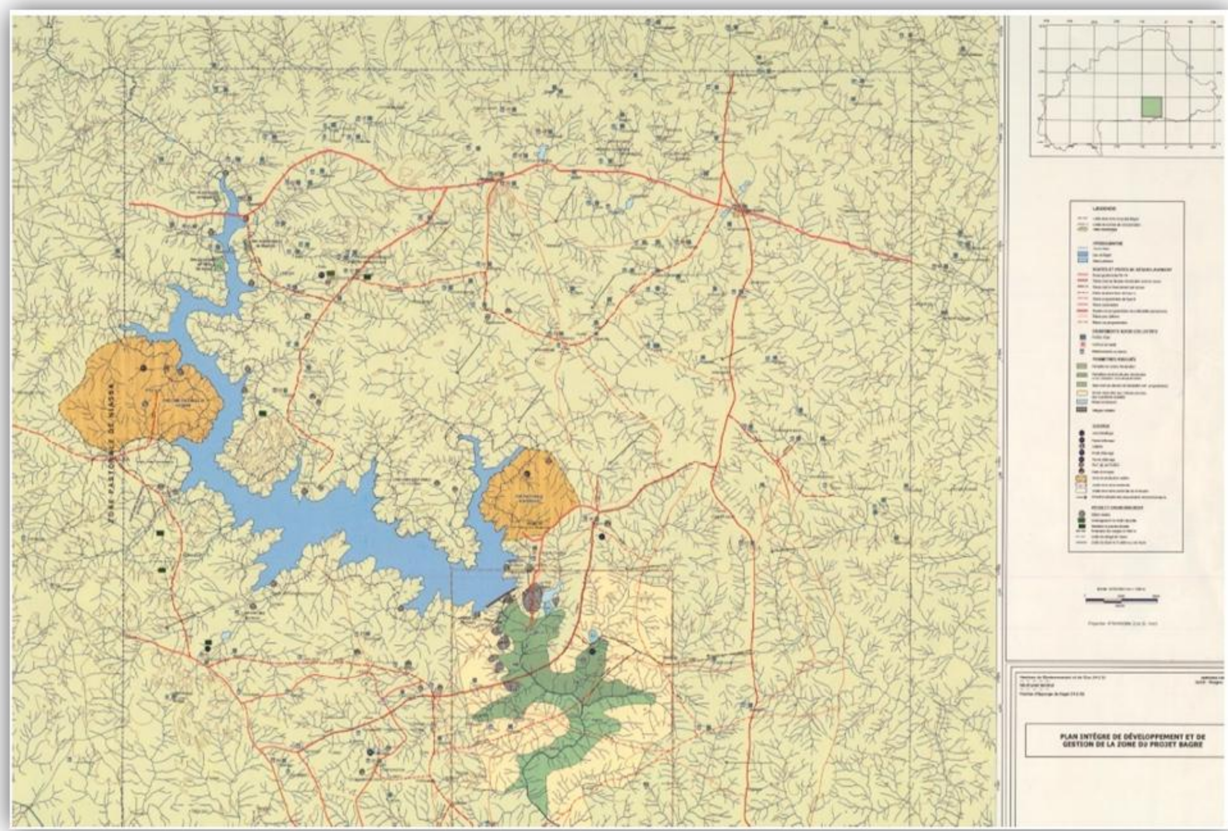
- The existence of important social infrastructure including several primary and secondary schools, shops, storage products and / or equipment, health centers and social advancement;

- The presence of large hotels and tourist facilities including the Centre Ecotourism, etc. ...;

- The presence of all mobile operators and fixed

- The conditions of the roads giving access at any time, in the plain.

Figure 1: Map of the Plain of Bagré



II.1.1. Agro-climatic data of the plain of Bagré

Climate of the plain is subject to a Sudanese tropical climate characterized by two type seasons: (i) a dry season from November to May, influenced by the dry harmattan winds and (ii) a wet season from June October, influenced by the monsoon winds from the southwest.

Rainfall: Rainfall is unevenly distributed in time and space. The rainfall recorded during the last decades shows that the plain is in the range from 800 to 9000 mm isohyets.

Temperatures*:* The plain is subjected to strong sunlight because of its latitude between 1112 and 1153 North. The observed data (Table 4) indicate that the average monthly temperatures vary between a minimum of 16.1°C in December-January and a maximum of 38.9°C in April. The average annual temperature is around 28°C

Wind: The wind speeds that are sweeping the region are irregular and vary between periods of calm (0.8 m / s) and gusts (28 m / s). Harmattan winds (hot and dry) are stronger and blow from December to February in the direction North-northeast. The monsoon, which blows from May, is humid and faces south / southwest.

Evaporation and potential evapotranspiration: The loss by evaporation and evapotranspiration reach very high values. They vary, in fact, between 2600 and 3000 mm per year for evaporation and between 1800 and 2200 mm for evapotranspiration.

Humidity: Overall, the mean relative humidity varies between 59 and 96% from 0 to 6 o'clock and between 31 and 70% at 12 o'clock.

Table 4: Agro-climatic data of Bagré

Month	**Min Temp**	**Max Temp**	**Humidity**	**Wind**	**Sun**	**Rad**	**Eto**	**Rain**	**Eff. Rain**
	°C	°C	%	Km/Day	Hours	MJ/m2/Day	mm/Day	mm	mm
January	16.1	33.2	39	190	8.2	18.8	5.43	0	0
February	19.1	36.2	40	190	8.1	20.1	6.02	0	0
March	23.1	38.2	41	207	8	21.3	6.85	8	7.9
April	25.8	38.9	49	233	7.1	20.5	7.02	34	32.2
May	25.6	37.2	68	259	7.9	21.5	6.32	76	66.8
June	23.7	34.2	81	251	7.6	20.7	5.1	95	80.6
July	22.3	31.7	99	216	6.8	19.6	3.75	179	127.7
August	21.8	30.7	97	190	6.1	18.7	3.59	174	125.6
September	21.8	32	91	156	6.6	19.2	3.94	123	98.8
October	22.6	35.2	74	156	8.2	20.5	4.92	26	24.9
November	19.2	35.7	59	147	8.5	19.5	5.01	0	0
December	16.7	33.5	51	173	8.2	18.3	4.94	0	0
Eff. Rain USDA S.C. Method									

From: New_LocClim_1.10

II.1.2. Soils of the plain

The main existing soils on the plain of Bagré are the Hydromorphic soils. They are characterized by the predominance of silt in the first 60 centimeters of soil. Clay then became predominant. The bulk density increases slightly from the surface to the deep layers (Table 5).

Table 5: Hydrodynamic properties of Hydromorphic soils of Burkina

Depth (cm).	Texture			Bulk density	Cumulative Available water (mm)
	Clay (%)	Silt (%)	Sand (%)		
0 – 20	24.5	40.5	34.9	1.6	23.0
20 – 40	26.2	41.1	32.6	1.6	42.8
40 – 60	29.2	37.4	33.4	1.7	60.5
60 – 80	45.1	23.9	31.0	1.8	77.4
80 - 100	44.9	23.2	31.9	1.7	94.0

From: Propriétés hydrodynamiques des principaux types de sols du Burkina Faso

II.2. METHODOLOGY

II.2.1. Collection of agro-climatic data

The annual rainfall data were obtained directly with the Management Service of the plain (M.O.B), and some supplementary meteorological data were generated by the software **New_LocClim_1.10** from the interpolation done on the basis of data from meteorological stations nearby.

II.2.2. Determination of the bananas water requirement

Bananas water requirement was determined using the software **CROPWAT 8.0** developed by FAO. The crop coefficient Kc, however, was adjusted to bring them closer to subtropical conditions.

II.2.3. Design Software

Two programs were used to design the irrigation system:

A) - EPANET 2.0 for the design and dimensioning of pipes (pipeline system), from the water intake to the head of each of the four sub-plots, namely, main and secondary pipes.

EPANET performs extended period simulation of hydraulic and water quality behavior within pressurized pipe networks. EPANET tracks the flow of water in each pipe, the pressure at each node, the height of water in each tank, and the concentration of a chemical species throughout the network during a simulation period comprised of kmultiple time steps.

EPANET was developed by the Water Supply and Water Resources Division (formerly the Drinking Water Research Division) of the U.S. Environmental Protection Agency's National Risk Management Research Laboratory.

EPANET contains a state-of-the-art hydraulic analysis engine that includes the following capabilities:

- places no limit on the size of network that can be analyzed;
- computes friction head loss using either Hazen-Williams, Darcy-Weisbach, or Chezy-Manning equations;
- includes minor head losses for bends, fittings, etc;
- models constant or variable speed pumps;

- computes pumping energy and cost;

- models various types of valves including shutoff, check, pressure regulating, and flow control valves;

- allows storage tanks to have any shape (i.e., diameter can vary with height);

- considers multiple demand categories at nodes, each with its own pattern of time variation;

- models pressure-dependent flow issuing from emitters (sprinkler heads);

- can base system operation on both simple tank level or timer controls and on complex rule-based controls.

B) - Ve.pro.LG. s for the design of the distribution network at the sub-plot level, namely driplines system.

The software Ve.Pro.L.G. s., name derived from the initials of "Verification and Design of drip lines and areas of plant stems from Ve.Pro.LG. s first version, released in 2003 and represents a substantial evolution, being able to assess the functioning of entire planting areas and also extend the application range of the horticultural industry and tree crops, even when grown on sloping ground, with changes in elevation along the line.

Ve.Pro.L.G. s. is an application that, taking into account specific conditions of use, performs audits of project scope and operation of drip lines and areas of irrigation by drop, with the aim of increasing the uniformity of water delivery, water savings and reduces energy consumption. For this purpose, with operational tools needed to verify the operation of equipment already installed, identifying any changes to improve performance and provide reliable and unbiased information to guide design choices in construction of new facilities.

The software is already equipped with the operating characteristics of a large number of drip lines full tested by the National Laboratory of Irrigation within a Convention between ARSIA and University of Pisa and is a direct reference to these, after choosing from a menu pull-down. "However, also allows you to check the operation of any other kind of line dripping, provided we know the parameters of functional skills.

To use the full potential of Ve.Pro.LG s. must first provide details on the specific situation in which we act. Having this information, software, through its operational instruments, produces a complete picture of technical and economic evaluations. In particular, on existing systems, specifying the model used drip line, the slope of the terrain, the length and pressure lines, the operational tools "test lines on the header of unilateral (l / h.m) and verify lines bilaterally on the head (l / h.m) reconstruct the operation in terms of proper maintenance and adequate water filtration, and provide for individual lines or optionally the entire industry, the value of the following parameters:

- Index to estimate the uniformity of delivery EU (%);
- Energy input required for water delivery (Wh / m³);
- Minimum, maximum and average in liters per hour per meter of line (l / h.m);
- Pressure minimum, maximum and average, expressed as water column height H (**m w.c**);
- Average intensity of irrigation (mm/h);
- Waste water or water that is lost in seepage, deep, to avoid excessive portions of crops are irrigated in a deficit, expressed both in percentage terms than in m³ / ha or even in m³ / year on the sector;
- Annual energy consumption in kWh / ha or optionally in kWh for the entire industry;
- Annual energy cost in € / ha or optionally in € for the whole industry, both in the case of pumps coupled to electric motors, which powered by a diesel internal combustion engines;
- Annual incidence of the purchase cost of the drip lines in € / ha or optionally in € for the entire industry.

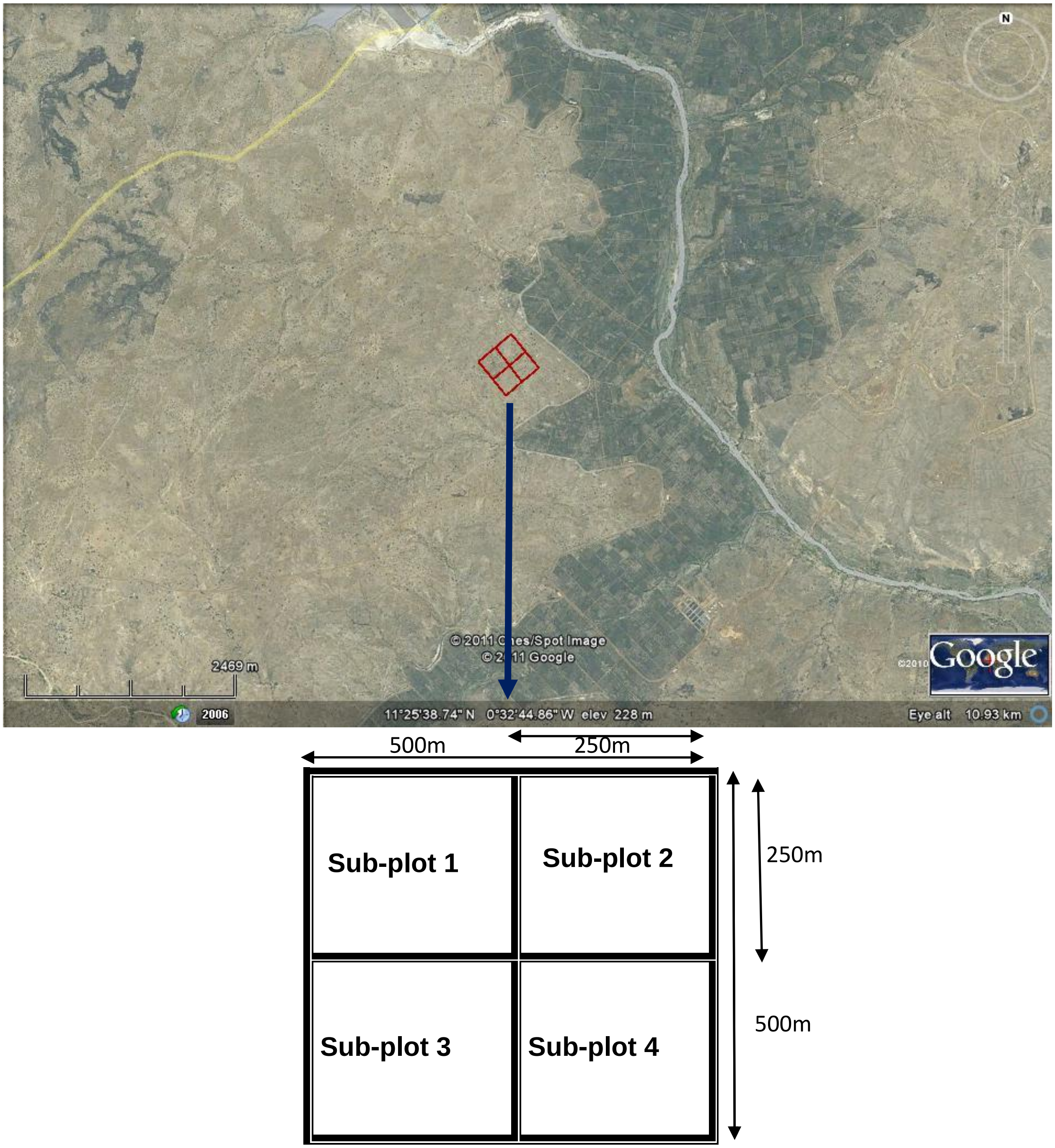
II.2.4. Choice of Plot

An area of 25 ha square shape was arbitrarily defined on the undeveloped area of the plain of Bagré and served as plot type. The choice was made on the agricultural area witch could potentially be attributed to agro-businessmen.

II.2.5. Plot division

To give some flexibility to the scheme, the plot of 25ha has been divided into four (4) sub-plots of 6.25 ha each. This division is designed to enable simultaneous operation or not of these four sub-plots, Allowing to vary the crop pattern.

Figure 2: Plot location on the plain



II.2.6. Choice of irrigation equipment

A census of all irrigation equipments (pipe and pipeline) available in the study area and surrounding countries has been conducted. Only identified equipments have been used in the modeling of irrigation system.

CHAPTER III: RESULTS AND DISCUSSION

III.1. CROP WATER REQUIREMENT

III.1.1.Results

a) First production cycle of banana

Table 6: First production cycle water requirement

Totals					
Total gross irrigation	1172.7	mm	Total rainfall	1139.9	mm
Total net irrigation	1055.4	mm	Effective rainfall	579.0	mm
Total irrigation losses	0.0	mm	Total rain loss	560.9	mm
Actual water use by crop	1538.3	mm	Moist deficit at harvest	29.8	mm
Potential water use by crop	1542.8	mm	Actual irrigation requirement	963.8	mm
Efficiency irrigation schedule	100.0	%	Efficiency rain	50.8	%
Deficiency irrigation schedule	0.3	%			

From: Cropwat analysis

The total net irrigation is equal 1,055.4mm, with a maximum daily water requirement of 6.7mm/day for a planting date of 01 April (Table 6).

b) Second production cycle of banana

Table 7: Second production cycle water requirement

Totals					
Total gross irrigation	1543.0	mm	Total rainfall	482.2	mm
Total net irrigation	1388.7	mm	Effective rainfall	277.3	mm
Total irrigation losses	0.0	mm	Total rain loss	205.0	mm
Actual water use by crop	1539.9	mm	Moist deficit at harvest	0.0	mm
Potential water use by crop	1544.9	mm	Actual irrigation requirement	1267.6	mm
Efficiency irrigation schedule	100.0	%	Efficiency rain	57.5	%
Deficiency irrigation schedule	0.3	%			

From: Cropwat analysis

The total net irrigation is equal 1,388 mm, with a maximum daily requirement of 6.9 mm/day (Table 7).

III.1.2.Discussion

The maximum daily water requirement is 6.9mm/day and is registered in the second production cycle. The irrigation system must be able to fill this need. It will therefore be sized in relation to this need.

III.2. Drip line design

The drip line design is the design of the irrigation system at field level. It is consists in choosing, depending on the characteristics of the field, the drip line that provides better uniformity while having a look at the investment cost

III.2.1. Result

a) Drip line available in the study area and used in the Design

The result of the investigation into the emitters available in the study area gave the following table. This is essentially the Drip lines manufactured by **Netafim**.

Table 8: Drip lines available in the study area

Dripnet PC 16390 d.16 q.1.0 s.0.3 autocomp (2005)	Dripnet PC 16390 d.16 q.1.0 s.0.6 autocomp (2005) areas in	Python 80 d.22 q.0.6 s.0.4 (2001)
Python d.22 q.0.84 s.0.3 (2004)	RAAM d.16 q.2.3 s.0.8 autocomp (2004)	RAAM d.16 q.1.6 s.0.8 autocomp (2004)
RA'AM d.17 q.2.3 s.0.5 autocomp(1997)	RA'AM d.17 q.2.3 s.0.6 autocomp(1997)	Streamline 60 d.16 q.0.87 s.0.3 (2004)
Streamline 60 d.16 q.1.32 s.0.3 (2000)	Streamline 80 d.16 q.1.49 s.0.2 (2000)	Streamline 80 d.16 q.1.49 s.0.3 (2000)
Streamline 80 d.16 q.1.49 s.0.4 (2000)	Streamline SL60 d.16 q.0.87 s.0.4 (2000)	Streamline SL80 d.16 q.0.98 s.0.4 (2000)
Streamline SL80F d.16 q.0.98 s.0.3 (1999)	Typhoon 20 d.16 q.1.75 s.0.4(1998)	Uniram d.16 q.2.3 s0.3 autocomp. (2002)
Uiram CNL d.16 q.2.3 s.0.6 autocomp (2004)	Uiram CNL d.16 q.2.3 s.0.6 autocomp. (2005)	Uniwine d.16 q.2.3 s.0.8 autocomp. (2005)
Uniwine d.16 q.1.6 s.0.8 autocomp. (2004)		

b) Ranking of drip lines according to uniformity

According to the sub plots features i.e. square of side 225m with a slope of 1%, the rank of drip line according to the distribution uniformity gives the result shown in table 9.

Table 9: Ranking of Drip line according to uniformity

RANKING OF DRIP LINE ACCORDING TO UNIFORMITY

INPUTS

Lunghezza 250 m **Slope** 1 %

RESULTS

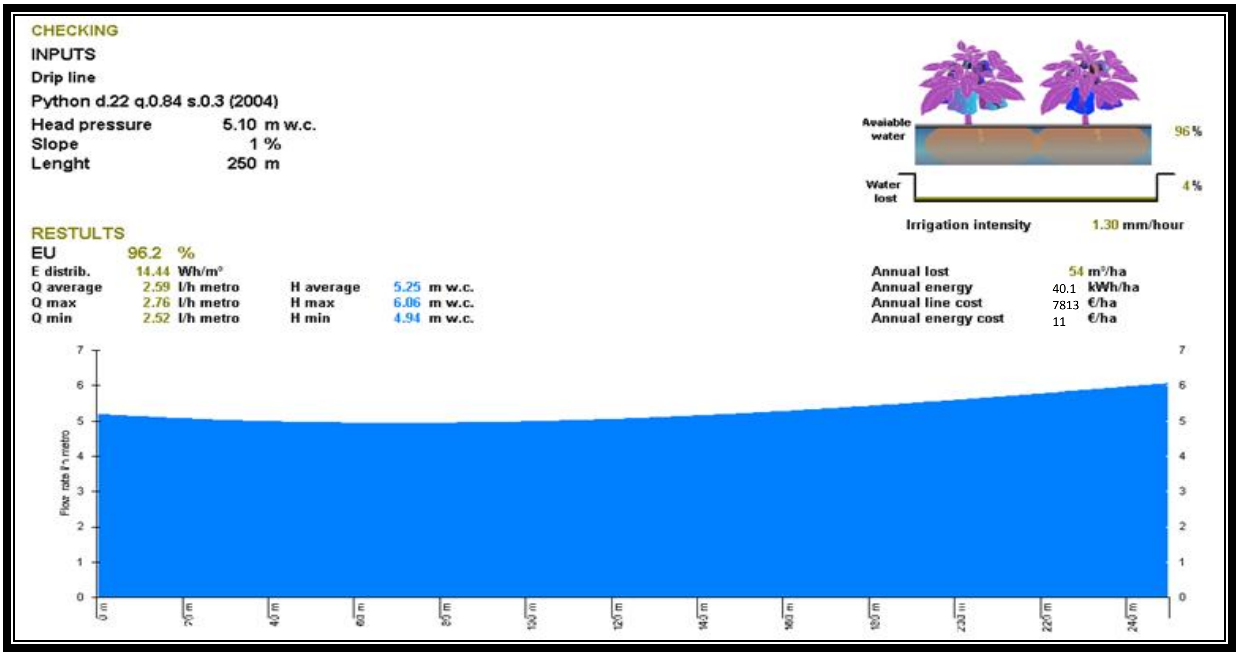
Drip lines model	Spacing. m	Press. head m c.a.	Q ave. l/hm	Intensity mm/hour	E distrib. Wh/m°	EU %
Uniram CNL d.16 q.2.3 s. 0.8 autocomp. (2005)	0.8	26.0	2.90	1.4	72.225	**98.1**
Uniwine d.16 q.1.6 s.0.8 autocomp. (2004)	0.8	16.2	2.12	1.1	45.197	**97.5**
RAAM d.16 q.1.6 s.0.8 autocomp. (2004)	0.8	14.4	2.04	1.0	40.210	**97.4**
Dripnet PC 16390 d.16 q.1.6 s.0.6 autocomp. (2005)	0.6	18.0	2.68	1.3	50.505	**97.0**
RA'AM d.17 q.2,3 s.0,6 autocomp. (1997)	0.6	31.1	3.76	1.9	87.635	**96.6**
Uniwine d.16 q.2,3 s.0.8 autocomp. (2005)	0.8	25.7	2.92	1.5	72.450	**96.5**
Python d.22 q.0.84 s.0.3 (2004)	0.3	5.1	2.57	1.3	14.512	**96.1**
RAAM d.16 q.2.3 s.0.8 autocomp. (2004)	0.8	25.1	3.03	1.5	71.631	**95.6**
Streamline SL80 d.16 q.0,98 s.0,4 (1998)	0.4	6.8	1.85	0.9	19.718	**94.2**
Streamline SL60 d.16 q.0,87 s.0,4 (1998)	0.4	6.4	1.78	0.9	19.073	**90.9**

From: VeProLG analysis

Of the 22 drip lines identified, 10 provide uniformity above 90%, which is potentially useful in designing a system of drip irrigation.

c) Operating under Python

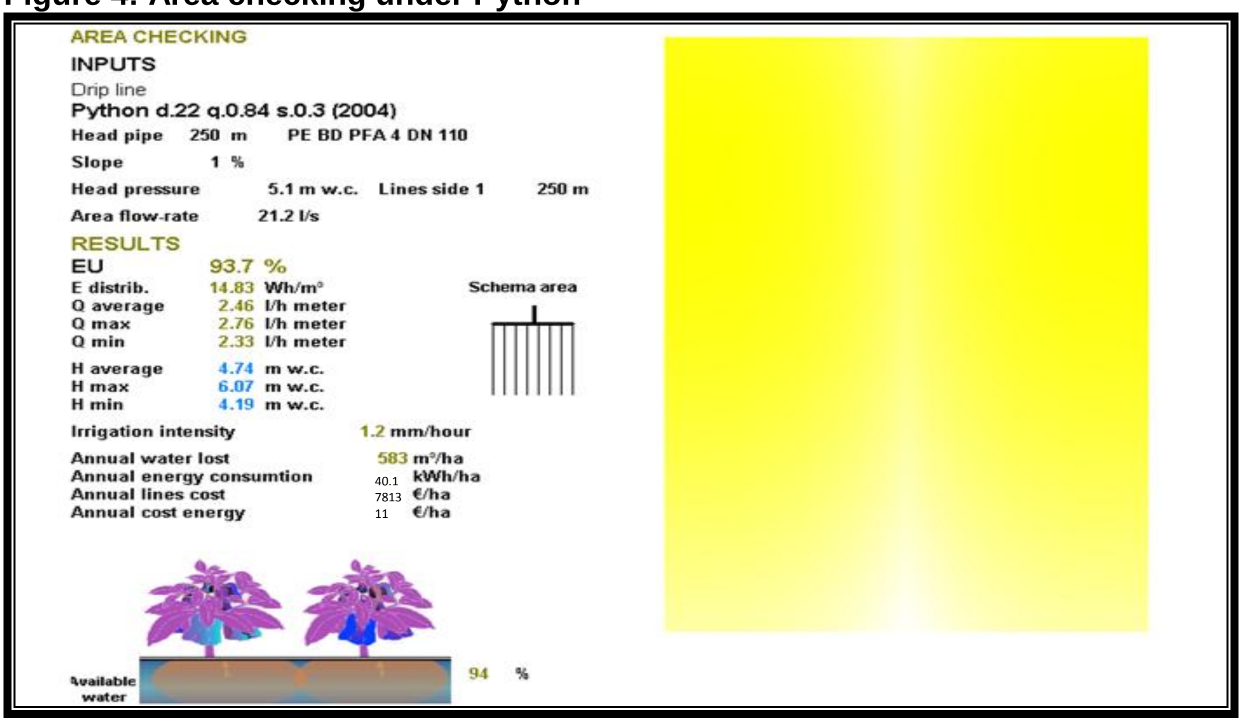
Figure 3: Line checking under Python



From: VeProLG analysis

Python provides uniformity on line of 96.2 %, with an operating pressure of 5.10 m w.c (0.5atm) and an irrigation intensity of 1.3mm/hour (figure **3**).

Figure 4: Area checking under Python



From: VeProLG analysis

The area uniformity is 93.7 % and the area flow rate is 21.2 l/s = 76.32 m^3/hour (figure 4)

III.2.2. Discussion

Among the 22 drip line available in the study area, 10 provide a uniform distribution over 90%. (90% being the acceptable threshold in drip irrigation). The first 6 drip lines ranking are self-compensating, i.e. drip line whose discharge varies very little or not in case of change of pressure (Emitter discharge exponent x close to zero). Another characteristic of self-compensating drip lines is their relatively high cost due to this particular characteristic.

The seventh ranking drip line (Python) is not self-compensating and does provide a very satisfactory uniformity of 96.1% on line and 93.7% on area. Moreover, Python has the advantage of operating under a very low pressure (5 m.w.c) which means a low energy requirement by pumping (Annual cost of energy = 11 €/ha).

Knowing that the cost of non self-compensating drip lines is significantly less than the cost of self-compensating drip line, and also considering that a uniformity of 93.7% is sufficient to ensure proper functioning of the system, it is preferable to choose the drip line Python to design the irrigation system.

Considering that the system operates by rotational distribution of irrigation water within the four (4) sub-plots and the drip line Python delivers a irrigation intensity of 76.32m^3/hour/sub-plot; a pump that provides a flow rate of 76.32m^3/hour is enough to cover the system water needs.

Python has an operating pressure of 5.1m (0.5atm) therefore the choice of the pump's pressure will reflect this operational pressure and should take into account the head losses due to the transport of water inside the pipe lines.

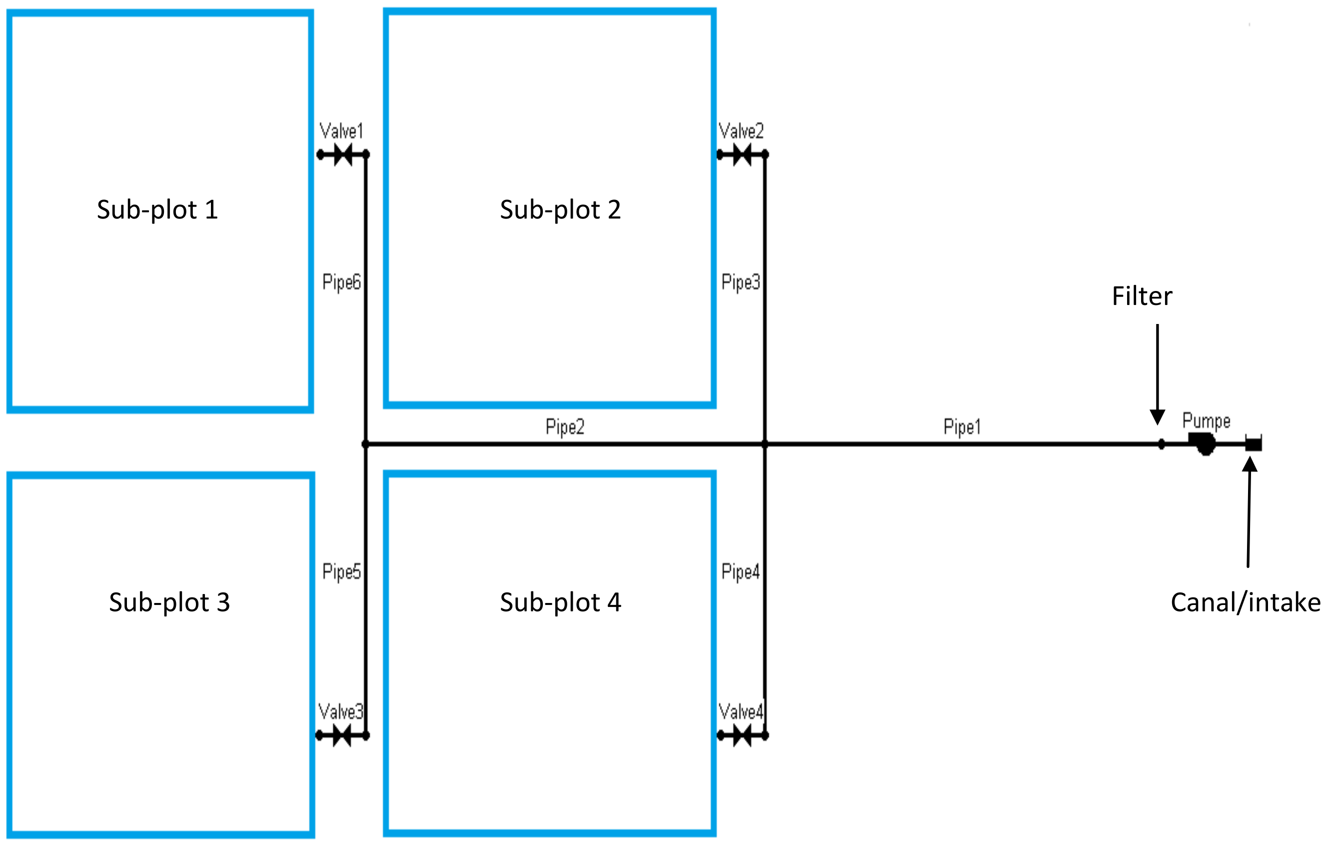
Moreover, the intensity of irrigation issued by Python (1.27mm/hour) is sufficient to meet the maximum daily water requirement of 6.9mm/day in just 5 hours 25 minutes. It implies that in a system of rotational irrigation between the 4 sub plots; it is possible to irrigate the whole sub plots in less than 22 hours.

III.3. PIPE LINE DESIGN

The Pipe line design concerns the design of the system from the water intake (canal) to the head of each of the four sub-plots. It aims to choose the size of the pipes that ensure to each sub-plot an optimal operating pressure and flow rate.

III.3.1. Results

a) System Overview



b) Characteristics of system components

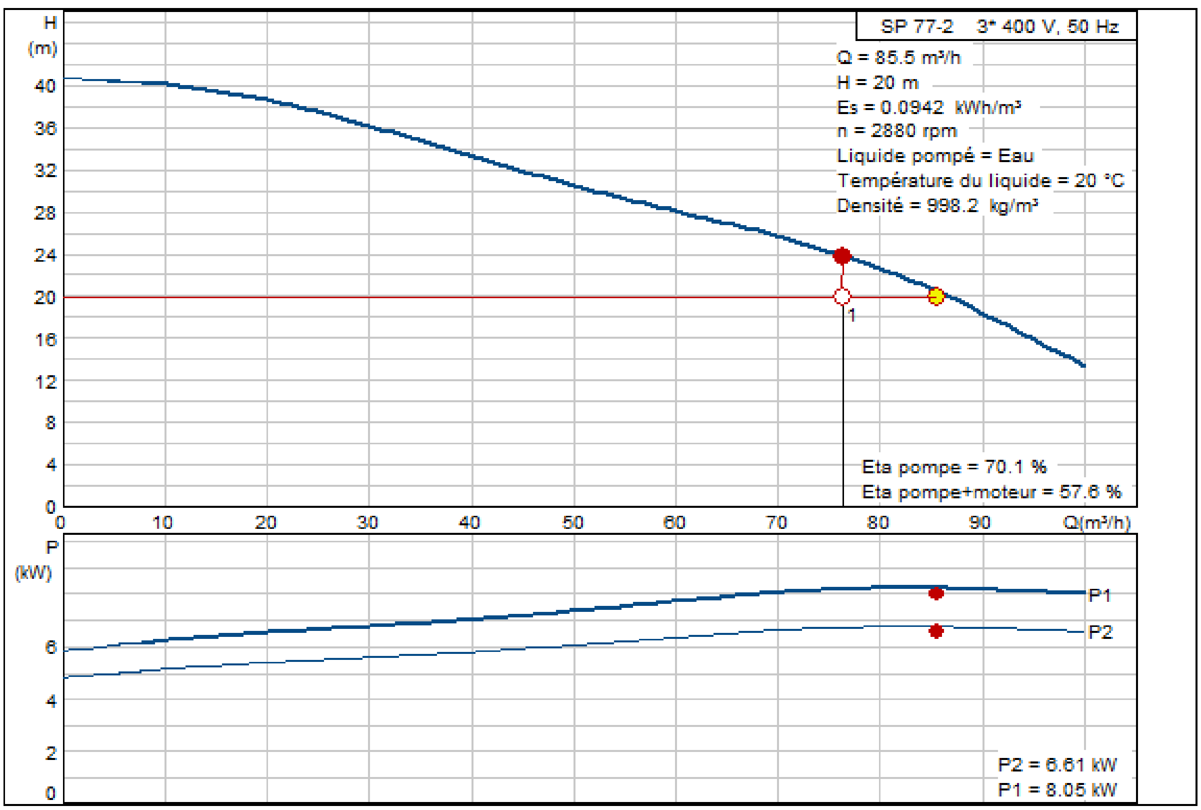
- **Pipes**

Pipe identity	Pipe 1	Pipe 2	Pipes 3 &4	Pipes 5 & 6
Pipe characteristics				
Length (m)	275	250	125	125
Diameter(mm)	147.6	147.6	147.6	147.6
Roughness	140	140	140	140

- **Pump**

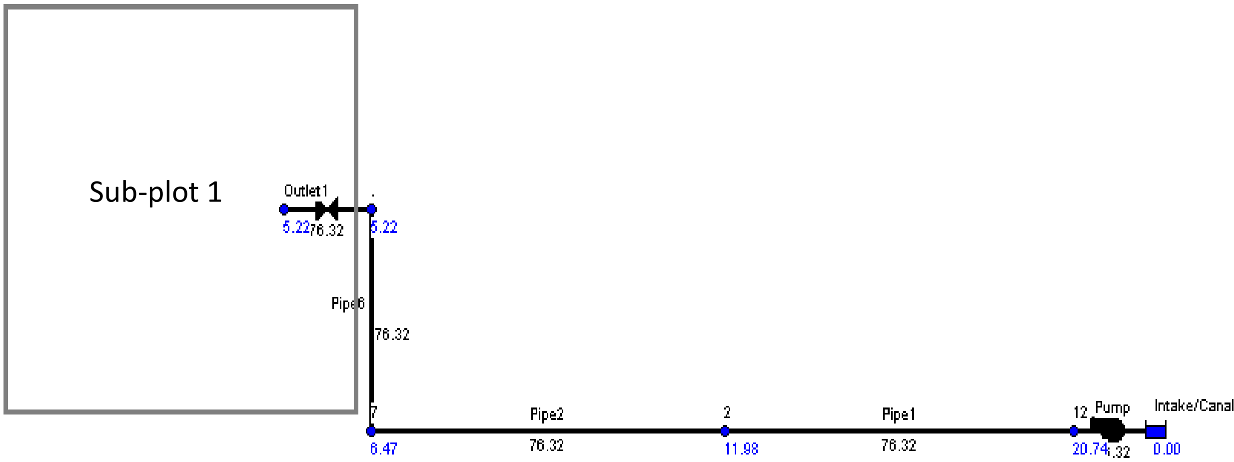
The characteristics of the pump used in the design are given in the figure 5.

Figure 5: Characteristics of the pump



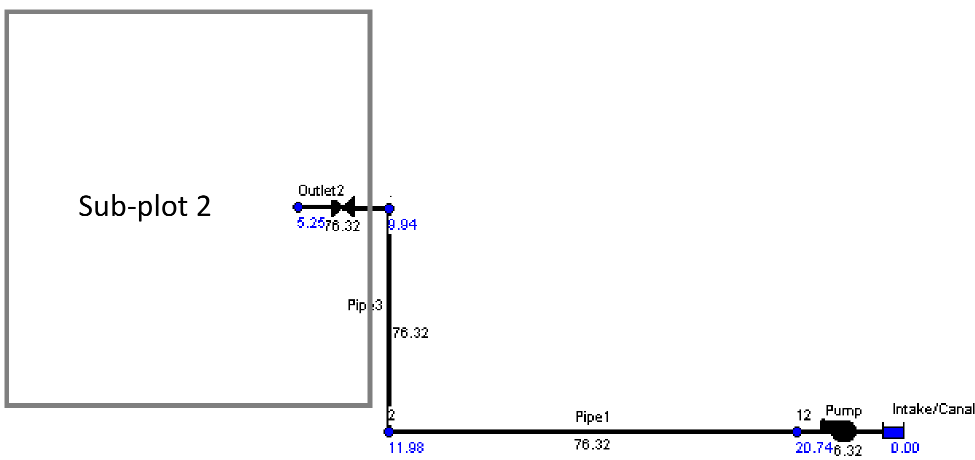
c) **System in operation.**

Figure 6: system watering the sub-plot 1



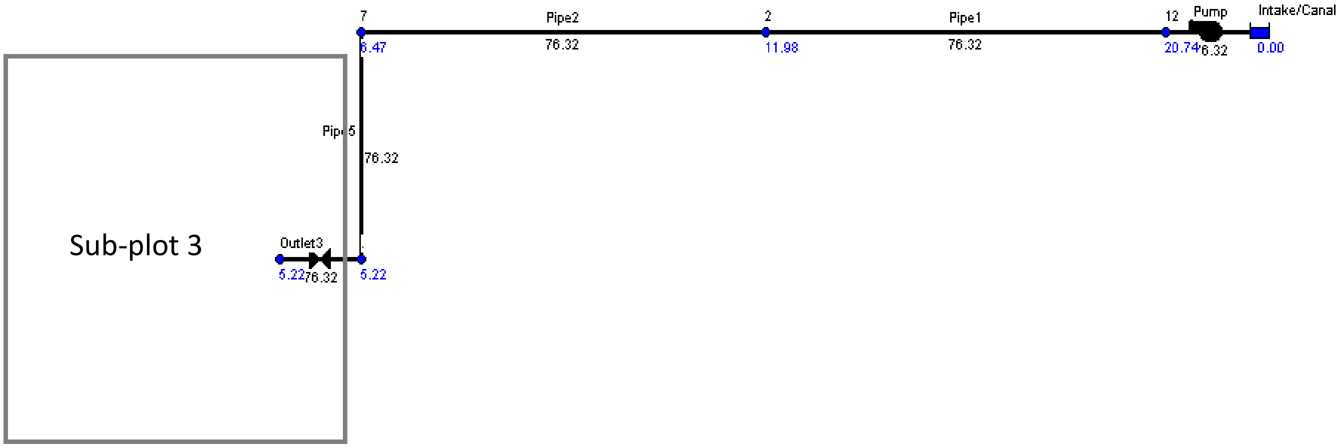
The system delivers to the sub-plot 1 a Flow rate of 76.32 m^3/hour with a Pressure of 5.22 m.w.c and a flow velocity of 1.24 m/s (figure 6).

Figure 7: System watering the sub-plot 2



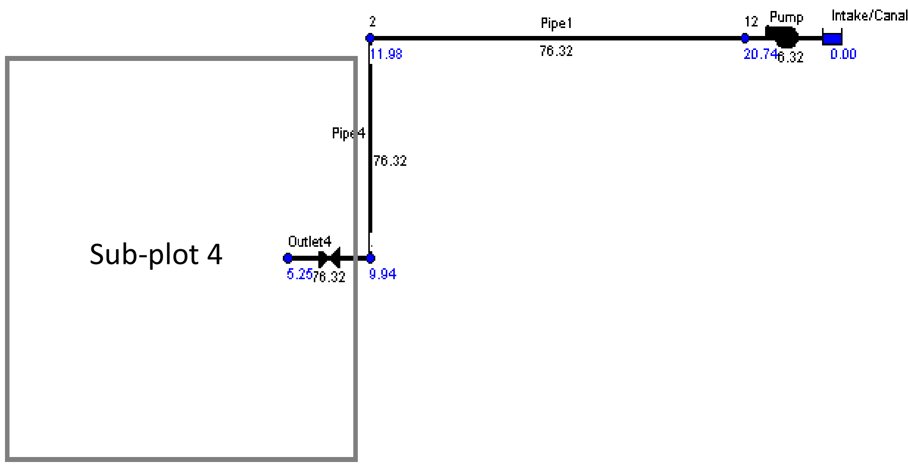
The system delivers to the sub-plot 2 a Flow rate of 76.32 m^3/hour with a Pressure of 5.25 m.w.c and a flow velocity of 1.24 m/s (figure 7).

Figure 8: System watering the sub-plot 3



The system delivers to the sub-plot 3 a Flow rate of 76.32 m^3/hour with a Pressure of 5.22 m.w.c and a velocity of 1.25 m/s (figure 8)

Figure 9: System watering the sub-plot 4



The system delivers to the sub-plot 2 a Flow rate of 76.32 m^3/hour with a Pressure of 5.25 m.w.c and a flow velocity of 1.24 m/s (figure 9)

III.3.2. Discussion

The pipe line system was fully designed with pipe of 147 mm of diameter. This diameter ensures a flow velocity lower than 1.5 m/s while maintaining a pressure close to 5 m.w.c. This corresponds to the operational pressure of Python.

The diameter of the pipe was kept constant because the delivery system will be by rotation among the 4 sub plots. Then all the water from the pump will be used by a single sub-plot at a time. This means that the same discharge (76.32 m^3/hour) will be conveyed from the pump to each sub-plot. Hence the necessity of having a uniform diameter pipe system to ensure a constant flow velocity.

A pump with a low operating pressure of 20 m.w.c has been used for the design. Although Python works with an operating pressure of 5.1mcw, a pump with a pressure of 20 m.c.w was used in order to compensate the loss due to the water transport inside the pipes (friction) and also to overcome the slope of the field.

Valves (TCV) with loss coefficient to obtain the desired pressure head at each sub plot level have been also used. Indeed the 4 sub-plot receive a head pressure a little bit higher than they need then the need to decrease this pressure to the desired pressure.

Has been also integrated a filter to the design although EPANET does not offer this option. But in order to assure to the drip line system good water quality and thereby avoid emitters clogging, the use of filter is required. The choice of this filter could indeed integrate a sand filter and a disc filter as the source of water for irrigation is surface water (dam).

CONCLUSION

The using of tools such as Cropwat, VeProLG and EPANET helped to design a complete drip irrigation system adaptable to the plain of Bagré.

The final system has an efficiency of 93.7% and works with a very low request of energy by pumping, only 5 m.w.c of operating pressure. This performance increases substantially water saving in irrigation, therefore, allows extension of irrigated areas with the same resource and also its sustainable use.

The system also has the advantage of being designed entirely with irrigation facilities available in the study area, which makes its eventual implementation feasible and quite easy.

This design was made for the cultivation of bananas on the plain of Bagré but the same approach might be applied to other crops on different agricultural fields.

This methodological approach and especially the final result provide a guide to Burkina Faso for the future of irrigated agriculture to develop.

LITERATURE

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