Conceptual Study and Sizing of a Drip Irrigation Fruit Arboretum in the Djarmaya Plain, Hadjer Lamis Province, Chad

Abstract

The objective of this study was to design and size a drip-irrigated arboretum in the Djarmaya Plain. To achieve this, a topographic survey and the use of hydraulic formulations were used to design and size the drip irrigation system. Plant requirements were estimated based on data recorded by meteorological stations in the city of N'Djamena and the use of CropWat software. The results show that 7,346,025 CFA francs are required to develop one hectare of arboretum, for a total cost of 27,547,580 CFA francs. Topographic studies show that the site is relatively flat, although it has some low-lying areas (ponds) and large mounds. The elevations are between 290 and 297.50 m in the general leveling system of Chad. This result, in addition to the high temperatures recorded in the area causing a high need for water, trees are major indicators of the choice of drip irrigation which aims to save water.

Keywords: Arboretum, Drip Irrigation, Djarmaya, water requirements, sizing and design

INTRODUCTION

Chad, a Sahelian country, is located between 7° and 24° North latitude and between 13° and 24° East longitude. It covers an area of 1,284,000 km² and has an estimated population of 14,650,152, of which 56.1% are under 18 years of age and 46.2% are employed (RGPH, 2009). The Chadian economy remains dominated by agro-forestry-pastoral and fishing activities, which contribute 43.5% of the national GDP, including 21% for agriculture, 18% for livestock farming, and 4.5% for fishing (PND 2017-2021). Chad's agricultural potential is estimated at 39 million hectares of arable land, including 5.6 million hectares of irrigable land. The country also has a large livestock population, including: 27,604,000 heads of cattle, 30,791,242 heads of sheep, 34,408,208 heads of goats and 7,285,609 heads of camels, of which approximately 75% are in the Sahelian zone where livestock farming is of the pastoral type, 2,0993,492 heads of pigs, 1,067,006 heads of pigs and 35,295,545 heads of poultry with 87 million ha of pasture (MPIEA, 2019). Despite this potential, Chadian production systems face a challenging environment that is rife with several factors including: (i) the extreme vulnerability of production systems due to climate change (droughts, floods, erratic rains, attacks by crop pests, recurrent animal diseases, etc.); (ii) the degradation of productive natural resources; (iii) insufficient investment and land and institutional reforms; (iv) the weakness of support and advisory systems and the provision of economic services to producers; (v) post-harvest and post-capture losses. This situation plunges the country into recurring, even chronic, food and nutritional insecurity. Faced with this challenge, water management becomes imperative to secure agricultural production through irrigation techniques. In this wake, the Djarmaya plain, a sanctuary of agro-sylvo-pastoral production, presents itself as an opportunity in terms of food security. Its geographical location between the city of Massakory, capital of the province of Hadjer Lamis and the city of N'Djamena makes it possible to supply these Chadian megalopolises with food and fruit products. It is with this in mind that the Rural Engineering Department initiated the installation of a fruit arboretum irrigated by drip irrigation in this plain. Drip irrigation has the advantage of bringing water close to the roots, reducing losses by direct evaporation, runoff and deep percolation (Hanson and May, 2007). Payero et al. (2005) estimates the water use efficiency of the drip system to be greater than 95%; which makes this system adaptable in arid and semi-arid areas. The Djarmaya Plain, located in this climatic zone, is ideal for this system in a context of climate change.

The overall objective of this study is to design and size a drip irrigation system to irrigate this fruit arboretum. More specifically, this involves:

- Proposing a development plan;
- Establishing micro-irrigation parameters;
- Performing hydraulic sizing;

II. Materials and Methods

II.1 Materials

II.1.1 Plant Materials

The study involves two types of plant material, namely lemon trees, of the clementine variety (Citrus clementina), originating from the French West Indies. This early variety is prized for its sweet, juicy fruit and its ease of peeling. The tree ranges from 2 to 4 m in height. It has a compact, well-branched habit with evergreen, dark green, and glossy leaves (photo 1). The second plant material is the Julie variety mango tree, of Caribbean origin, whose fruit has pale green and red skin and a delicious flavor.

Photo 1 : *Citrus clementina*

Photo 2 : Mango tree -Julie

II.1.2 Data Processing

Two Ashtech differential GPS systems were used to conduct topographic surveys at a scale of 1:2000, adhering to accuracy standards of ± 2 cm for planimetric and altimetric measurements.

1-Total Station, 2- Level

Software Used: Covadis version 9.1, Auto CAD 2013, and Microsoft Office

II.2 Methods

II.2.1 Study Site Location

The study area, the Djermaya plain, is located in the department of Haraz-al-biyaar, province of Hadjer-Lamis, between 12.06° and 13.20° North latitude and 14.50° and 15.90° East longitude. Access to the plain is provided by the paved road linking the city of Ndjamena and that of Massaguette over a distance of 90 km. Figure 1 shows the location of the province and the Djermaya plain respectively. Dominated by a Sahelian climate, the study area is densely populated and has 562,957 inhabitants according to the 2009 general census of population and housing. The Djermaya plain is a sanctuary of socioeconomic activities based on agriculture, livestock, fishing and trade. It is also an industrial zone where a refinery has been located for ten years, which works in the transformation of petroleum products.

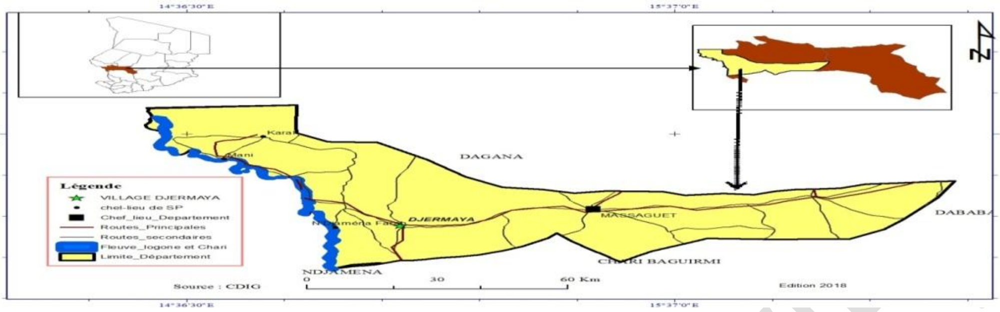
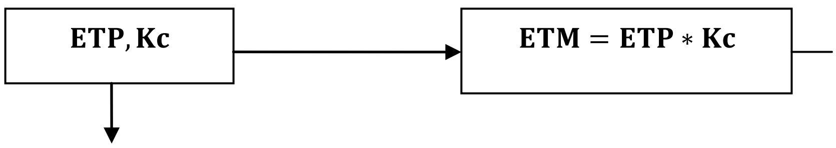


Figure 1. Location map of the Djermaya plain

II.2.2 Layout Design

The arboretum is divided into two blocks, its structure depending on the crops planned, taking into account the adopted irrigation system. 1.7 ha for lemon trees of the Clementine variety, originally from the French Antilles, with a planting density of 6 m × 4 m. 2.05 ha for mango trees of the Julie variety, originally from the French Antilles, with a planting density of 8 m × 8 m. The topographic work at the Djermaya site used two Ashtech differential GPS systems to carry out topographic surveys at a scale of 1/2000, respecting the accuracy standards of ± 2 cm in planimetric and altimetric measurement. The surveys were linked to UTM zone 33 coordinates, in the absence of geodetic points in the vicinity of the study area. The leveling of the markers was linked to the general leveling of Chad. The study area is a vast plain, currently exploited in a summary manner. The topographic surface is relatively flat, but with some low areas (ponds) and large mounds. The elevations are between 290 and 297.50 m in the general leveling system of Chad. The slope of the study area is approximately 15 cm/km and oriented south-north and a slight slope (5 to 10 cm/km) from east to west. The area not being covered by benchmarks in the general leveling of Chad, the major constraint was the attachment of the site to the general leveling over a distance of approximately 45 km.

II.2.3 Formulation of basic parameters



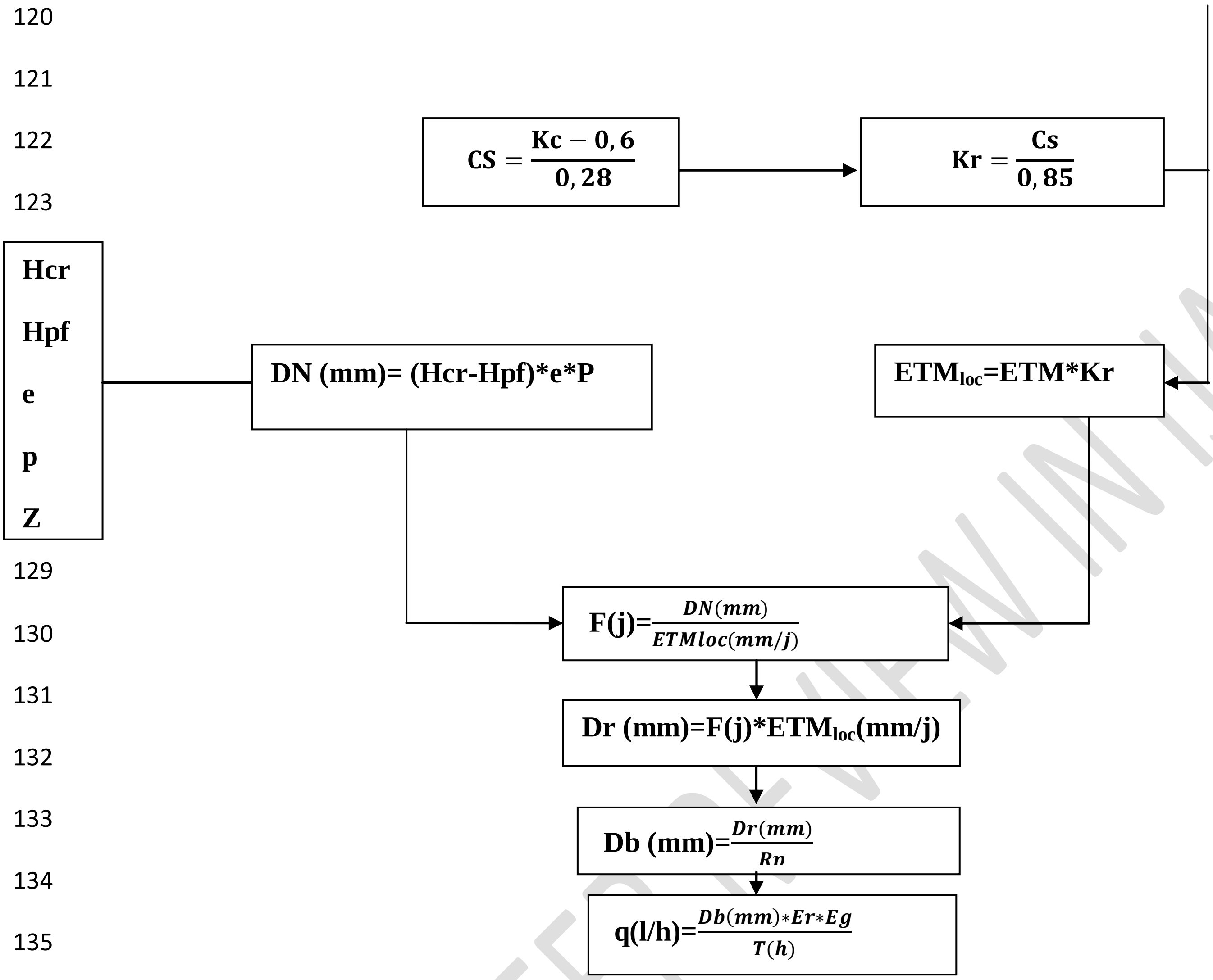


Figure 1: flowchart for determining basic parameters

II.2.4 Sizing of the irrigation Network (Ramps)

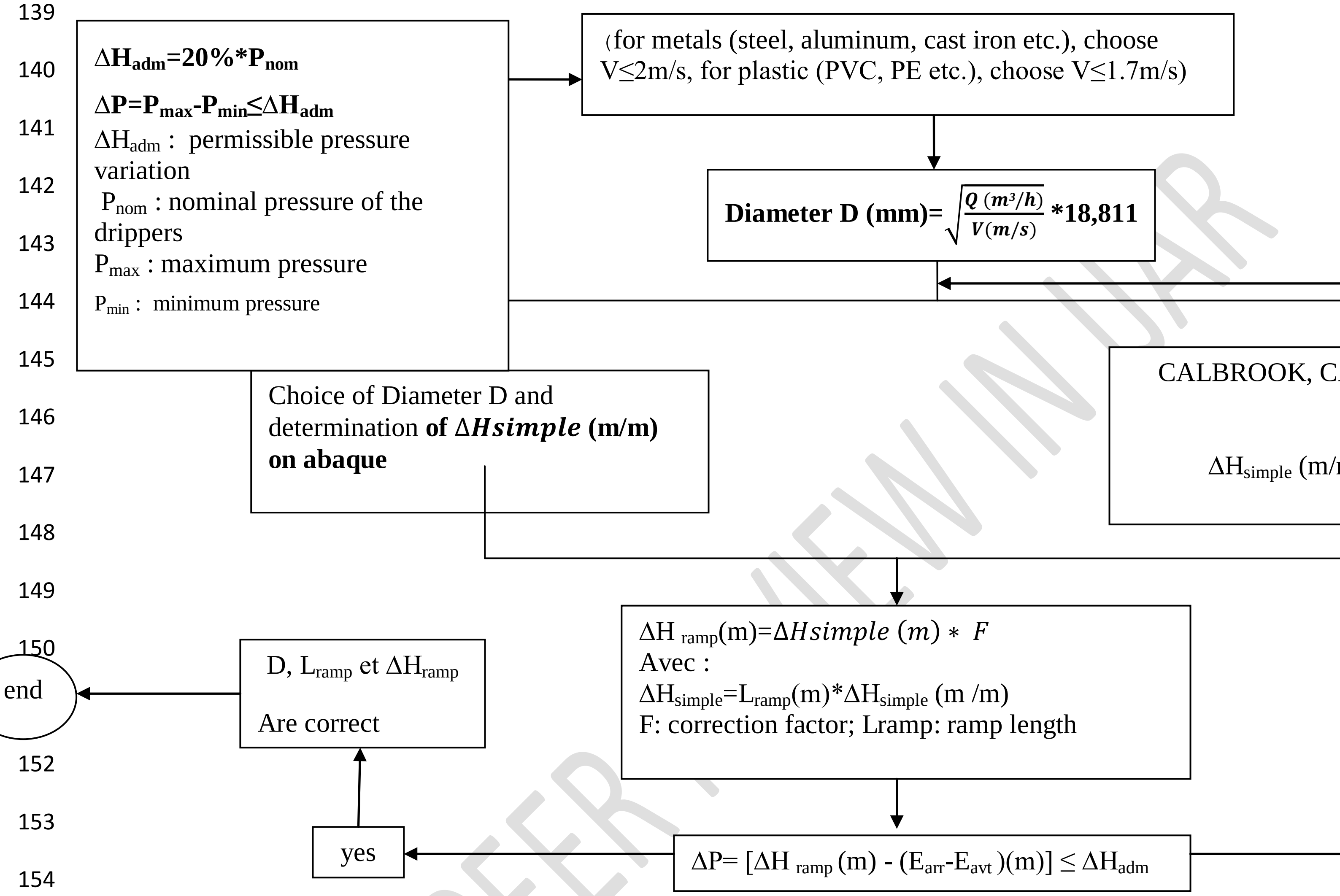


Figure 2 : tube sizing flowchart with en-route service

II.2.5 Main Pipe Sizing

This involves determining the diameter and length of the main pipe. The sizing procedure is shown in Figure 3.

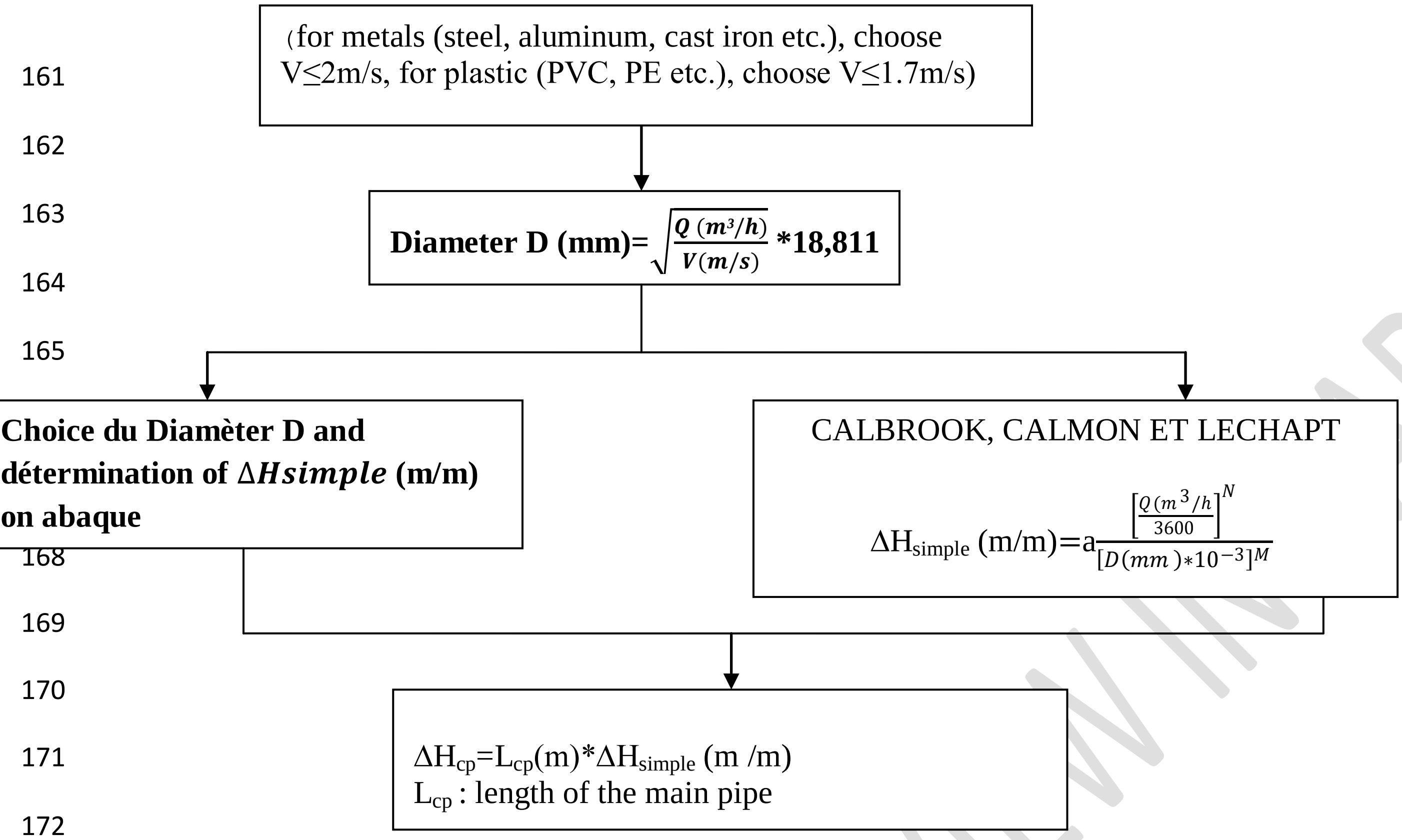


Figure 3 : flowchart for sizing tubes without en-route service

II.2.6 Pumping Station Sizing

The pumping station consists of one or more pumps designed to pump the required water volumes into the irrigation network pipes under flow and pressure conditions appropriate for the proper operation of the system. This pumping station consists of a submersible pump powered by solar panels and a 4 m³ tank connected to the pump. The pumping station is designed to pump water directly into the main pipe supplying the tank. The boom supports are gravity-fed from the tank. The sizing of photovoltaic pumping equipment requires the definition of the following data:

Flow rate (Q): This is the amount of water that the pump can deliver over a given period of time. In pumping, the flow rate is usually given in liters per hour (l/h) or cubic meters per hour (m3/h). In solar pumping, the flow rate (or daily water requirement) is expressed in m3 per day (m3/d);

The total head (THM) of a pump: This is the pressure difference in meters of water column between the suction and discharge ports.

II.2.6.1 Flow Rate Q (m³/h)

The maximum peak total flow rate required at the head of the network is attached as a calculation note.

II.2.6.2 Calculation of the Total Manometric Head: TMH (m)

This includes:

Pump suction pressure losses

$$\Delta H_{suction}(m) = \frac{V^2 (m/s)^2}{2g(m/s^2)}$$

ΔH_{uction}: Linear pressure drop at the suction end;

V: Velocity in the suction pipe;

g: Acceleration due to gravity (g = 9.81 m/s²).

Pressure drop in the transport pipe (from the source to the reservoir);

Pressure drop in the riser;

The most restrictive geometric discharge height:

This corresponds to the difference in height between the water surface at the station and the highest point where the water to be irrigated is located on the perimeter (the reservoir):

$$Hgéo = Zmax - Zeau$$

Table 1 : Lowest water levels in the river in a dry year

Return period	100 ans	50 ans	20 ans	10 ans	5 ans	Année moy (2 ans)
Water rating (m)	283,09	283,24	283,46	283,76	284,05	284,01

Source : CBLT

total load

It is calculated by

$$H_{total} = \sum_i (\Delta H_{cm} + \Delta H_{cp} + \Delta H_{suction})$$

- Pressure losses in the filters
  They can be estimated between 5 and 7 m in general.

$$\Delta H_{filterd} = 5 \text{ à } 7m$$

Pressure losses in connecting parts (valves, tees, elbows, etc.)

We take 10% of the total calculated pressure losses as a value:

$$\Delta H_{pièces}(m) = 0,10 * H_{total(} m)$$

The total manometric height HMT is then given by:

$$HMT(m) = H_{total} + H_{géo} + \Delta H_{pièces}(m) + \Delta H_{filtered}$$

II.2.7 Sizing the photovoltaic field

Calculation of daily energy requirements:

$$j = \frac{\boldsymbol{\rho} * \mathbf{g} * \mathbf{Q} * \boldsymbol{\Omega} * \mathbf{HMT}}{\mathbf{3600} * \boldsymbol{Rond} * \boldsymbol{Rmp}}$$

Ej : daily energy requirement in kWh/day
ρ: Density of water in (kg/m³)
Ω: Daily sunshine, which is the number of hours per day during which a surface of 1m² will receive a solar power of 1000W. Ω is taken here as equal to 5h
g : acceleration of gravity in (m/s²)
Q : flow rate at operating point in cubic meters per hour (m³/h)
HMT : total manometric height at the operating point in meters (m)
Rond : inverter efficiency = 95%
Rmp : motor-pump efficiency = 75.5%

Calculation of the peak power of the photovoltaic system Pc

$$\mathbf{Pc} = \frac{\mathbf{Ej}}{\mathbf{K} * \mathbf{Ei}}$$

Pc : system peak power in Watts
Ei : average daily sunshine = 6kW/day/m²
K : Conversion factor generally taken equal to 0.65

Calculation of the number of panels

For this project we chose 200W monocrystalline solar panels with the following characteristics:
Power : 200 W

Intensity : 8,05 A

Tension : 30,4 V

The number of panels is given by

$$\mathbf{Np} = \frac{\mathbf{Pc}}{\mathbf{P}}$$

Pc : system peak power in Watts
P : power of a panel in Watts
Np : number of panels

III Results and Discussion

III.1 Development Plan

The study used COVADIS and AUTOCAD software to refine the development plan

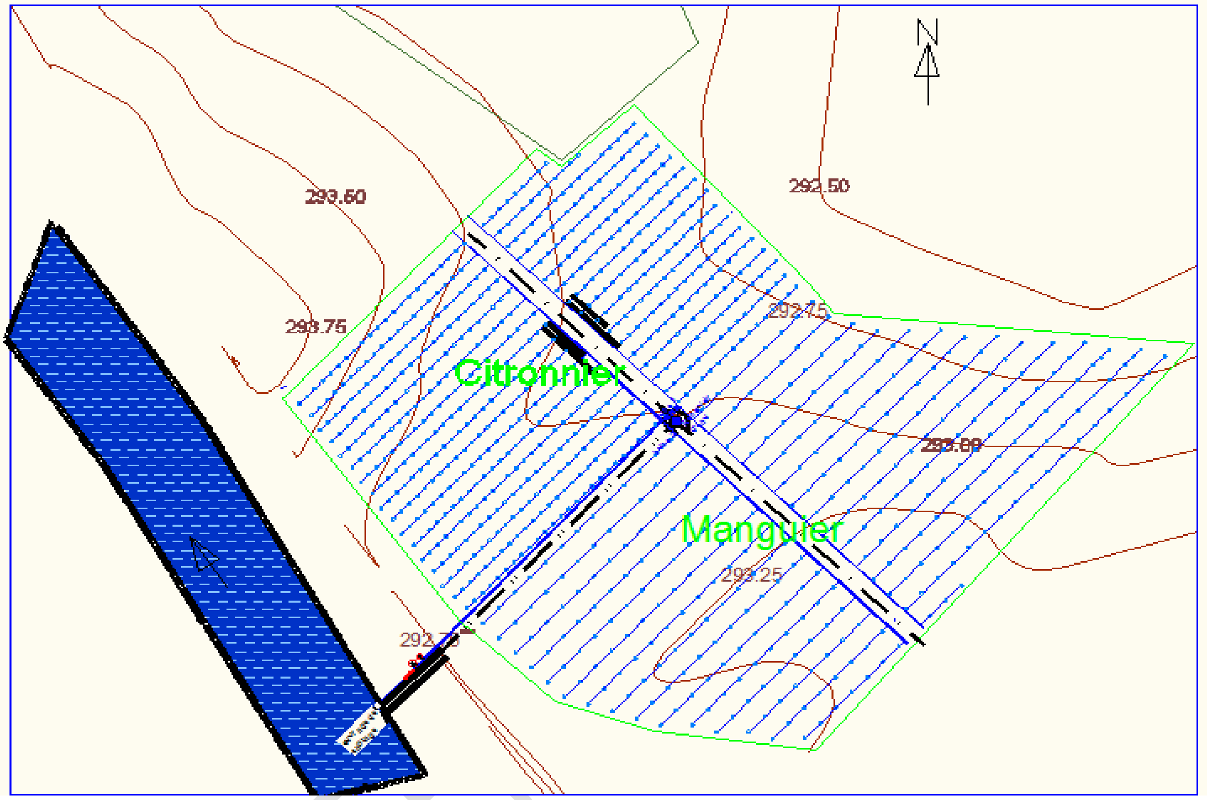


figure 4: Development plan for the irrigated area for the arboretum

Table 2: Results of calculations of irrigation parameters for Citrus clementina

Month	January	Februari	March	April	May	June	Juily	August	Septe
ETP(mm/Month)	221	207	293	270	252	204	195	154	172
P(mm/Month)	0	0	0	6	25	48	160	187	92
Kc	0,7	0,7	0,7	0,7	0,7	0,7	0,85	0,85	0,65
ETM(mm/Month)	154,7	144,9	205,1	189	176,4	142,8	165,75	130,9	111,8
ETMloc(mm/Month)	65,00	60,88	86,18	79,41	74,12	60,00	69,64	55,00	46,97
ETMloc(mm/j)	2,17	2,03	2,87	2,65	2,47	2,00	2,32	1,83	1,57
Peff(mm/Month)	3	3	3	8,1	24,25	43,8	139	161,95	81,2
Hcr-Hpf(%)	0,173	0,173	0,173	0,173	0,173	0,173	0,173	0,173	0,173
da	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2
RU(mm)	24,912	24,912	24,912	24,912	24,912	24,912	24,912	24,912	24,91
RFU(mm)	16,608	16,608	16,608	16,608	16,608	16,608	16,608	16,608	16,60
BN(mm)	45	41	67	55	33	0	-86	-124	-51
BB(mm/Month)	53,09	51,60	81,18	68,17	45,83	9,77	-74,15	-114,23	-42,8

BB(mm/J)	1,77	1,72	2,71	2,27	1,53	0,33	-2,47	-3,81	-1,43
BB(mm/sem)	12,39	12,04	18,94	15,91	10,69	2,28	-17,30	-26,65	-10,0
Zr(cm)	100	100	100	100	100	100	100	100	100
Hcr-Hpf(mm/m)	1,73	1,73	1,73	1,73	1,73	1,73	1,73	1,73	1,73
DN(mm)	15,57	15,57	15,57	15,57	15,57	15,57	15,57	15,57	15,5
F tchéorique(J)	7,2	7,7	5,4	5,9	6,3	7,8	6,7	8,5	9,9
F rétenue(j)	7,0	7,0	5,0	5,0	6,0	7,0	6,0	8,0	9,0
Dr(mm)	15,2	14,2	14,4	13,2	14,8	14,0	13,9	14,7	14,1
Db(mm)	18	17	17	15	17	16	16	17	16
q(l/h)	21	20	20	19	21	20	20	21	20

Table 3: Results of calculations of irrigation parameters for the Mango tree

Month	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**S**
ETP(mm/Month)	221	207	293	270	252	204	195	154	1
P(mm/Month)	0	0	0	6	25	48	160	187	9
Kc	0,7	0,7	0,7	0,7	0,7	0,7	0,7	0,7	0
ETM(mm/Month)	154,7	144,9	205,1	189	176,4	142,8	136,5	107,8	1
ETMloc**(mm/Month)**	65,00	60,88	86,18	79,41	74,12	60,00	57,35	45,29	5
ETMloc(mm/j)	2,17	2,03	2,87	2,65	2,47	2,00	1,91	1,51	1
Peff(mm/Month)	0	0	0	0	24,25	43,8	139	161,95	8
Zr(mm)	150	150	150	150	150	150	150	150	1
Hcr-Hpf(%)	0,173	0,173	0,173	0,173	0,173	0,173	0,173	0,173	0
da	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1
RU(mm)	31,14	31,14	31,14	31,14	31,14	31,14	31,14	31,14	3
RFU(mm)	20,76	20,76	20,76	20,76	20,76	20,76	20,76	20,76	2
BN(mm/Month)	64,35	60,27	85,31	78,62	73,38	59,40	56,78	44,84	5
BB(mm/Month)	75,26	70,50	99,78	91,95	85,82	69,47	66,41	52,45	5
BB(mm/J)	2,51	2,35	3,33	3,07	2,86	2,32	2,21	1,75	1
BB(mm/sem)	17,56	16,45	23,28	21,46	20,02	16,21	15,50	12,24	1
Zr(cm)	150	150	150	150	150	150	150	150	1
Hcr-Hpf(mm/cm)	1,73	1,73	1,73	1,73	1,73	1,73	1,73	1,73	1
DN(mm)	23,36	23,36	23,36	23,36	23,36	23,36	23,36	23,36	2
Fthéorique(J)	10,78	11,5	8,130	8,82	9,5	11,7	12,22	15,5	1
Frétenue(J)	7	8	5	6	6	8	8	11	1
Dr(mm)	15,17	16,24	14,36	15,88	14,82	16,00	15,29	16,61	1
Db(mm)	17,7	19,0	16,8	18,6	17,3	18,7	17,9	19,4	1
q(l/h)	42,6	46	40	45	42	45	43	47	4

NB : - With the flow rate of 40l/h; we recommend drippers with a flow rate of 8 l/h, which gives 5 distributors per tree for the mango tree

- With a flow rate of 20 l/h, we recommend drippers with a flow rate of 4 l/h, which results in 5 distributors per tree.

- The coefficients used to calculate the irrigation parameters are: E = 90%, CU = 95%, CS = 0.36, Kr = 0.42, Rp = 0.855, P = 33%, and e = 0.3.

III.3. Pumping Equipment Plan

The study used AUTOCAD software to create the pumping equipment plan.

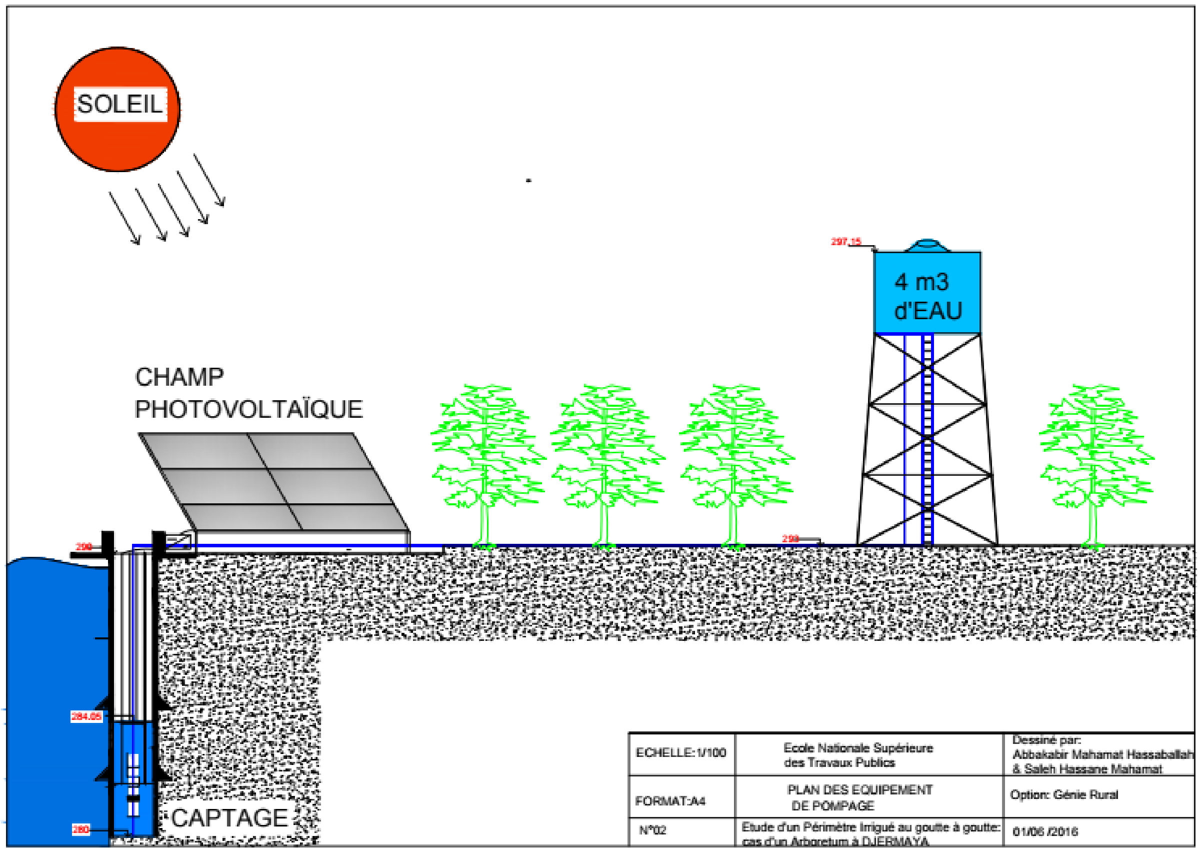


Figure 5: Pumping Station

III.4. Results of Irrigation Network Calculations

For the tube calculations, a velocity V=0.5m/s and coefficients a=1.101x〚10〛^(-3), N=1.84 and M=4.88 are assumed

Table 4 : Results of ramp calculations on ramp door 1

RAIL HOLDER 1									
	Length (m)	**Speed d'un groupe de goutteurs: q (l/h)**	**Number of a group of drippers**	**Speed (m³/h)**	**Diameter (mm)**	**Speed (m³/s)**	**Diameter Choisie (m)**	**Simple pressure drop(m/m)**	**Si pr dr**
RAMP 1	84	20	22	0,44	18	0,00012	0,0200	0,0136	1,1
RAMP 2	84	20	22	0,44	18	0,00012	0,0200	0,0136	1,1
RAMP 3	86	20	22	0,44	18	0,00012	0,0200	0,0136	1,1
RAMP 4	86	20	22	0,44	18	0,00012	0,0200	0,0136	1,1
RAMP 5	88	20	22	0,44	18	0,00012	0,0200	0,0136	1,1
RAMP 6	88	20	22	0,44	18	0,00012	0,0200	0,0136	1,1
RAMP 7	90	20	23	0,46	18	0,00013	0,0200	0,0147	1,3
RAMP 8	90	20	23	0,46	18	0,00013	0,0200	0,0147	1,3

RAMP 9	92	20	24	0,48	18	0,00013	0,0200	0,0159	1,4
RAMP 10	92	20	24	0,48	18	0,00013	0,0200	0,0159	1,4
RAMP 11	94	20	24	0,48	18	0,00013	0,0200	0,0159	1,4
RAMP 12	94	20	24	0,48	18	0,00013	0,0200	0,0159	1,4
RAMP 13	96	20	24	0,48	18	0,00013	0,0200	0,0159	1,5
RAMP 14	96	20	24	0,48	18	0,00013	0,0200	0,0159	1,5
RAMP 15	98	20	25	0,5	19	0,00014	0,0200	0,0172	1,6
RAMP 16	98	20	25	0,5	19	0,00014	0,0200	0,0172	1,6
RAMP 17	98	20	25	0,5	19	0,00014	0,0200	0,0172	1,6
TOTAL				4,04					

The values of Δp are all lower than the ΔHadm, however by adding them to the working pressure of the drippers 10m+15,047<40m=4bars which is the class 4 pressure and it respects the class of 4 bars.

Table 5: Result of ramp calculations on ramp door 2

RAIL HOLDER 2

	Length (m)	**Speed d'un groupe de goutteurs: q(l/h)**	**Number of a group of drippers**	**Speed (m³/h)**	**Diameter (mm)**	**Speed (m³/s)**	**Diameter Choisie (m)**	**Simple pressure drop(m/m)**	**Simple pressure drop(m)**
RAMP 1	36	20	9	0,18	11	5E-05	0,012	0,032	1,142
RAMP 2	44	20	11	0,22	12	6E-05	0,012	0,038	1,670
RAMP 3	65	20	17	0,34	16	9E-05	0,016	0,029	1,900
RAMP 4	65	20	17	0,34	16	9E-05	0,016	0,029	1,900
RAMP 5	65	20	17	0,34	16	9E-05	0,016	0,029	1,900
RAMP 6	65	20	17	0,34	16	9E-05	0,016	0,029	1,900
RAMP 7	65	20	17	0,34	16	9E-05	0,016	0,029	1,900
RAMP 8	65	20	17	0,34	16	9E-05	0,016	0,029	1,900
RAMP 9	65	20	17	0,34	16	9E-05	0,016	0,029	1,900
RAMP 10	61	20	16	0,32	15	9E-05	0,016	0,022	1,371
RAMP 11	61	20	16	0,32	15	9E-05	0,016	0,022	1,371
RAMP 12	61	20	16	0,32	15	9E-05	0,016	0,022	1,371
RAMP 13	61	20	16	0,32	15	9E-05	0,016	0,022	1,371
RAMP 14	61	20	16	0,32	15	9E-05	0,016	0,022	1,371
RAMP 15	61	20	16	0,32	15	9E-05	0,016	0,022	1,371
RAMP 16	61	20	16	0,32	15	9E-05	0,016	0,022	1,371
RAMP 17	61	20	16	0,32	15	9E-05	0,016	0,022	1,371
TOTAL				3,1					

The values of Δp are all lower than the ΔHadm and respect the 4 bar class because 10m+19.045<40m=4bars

RAIL HOLDER 4

Table 6: Summary of ramp calculations on ramp door 3

RAIL HOLDER 3									
	Length (m)	**Speed d'un groupe de goutteurs**	**Number of a group of drippers**	**Speed (m^3/h)**	**Diameter (mm)**	**Speed (m^3/s)**	**Diameter Choisie (m)**	**Simple pressure drop(m/m)**	**Sin pre dro**
RAMP 1	61	40	8	0,32	15	0,00009	0,016	0,022	1,3
RAMP 2	61	40	8	0,32	15	0,00009	0,016	0,022	1,3
RAMP 3	65	40	9	0,36	16	0,00010	0,016	0,028	1,8
RAMP 4	69	40	9	0,36	16	0,00010	0,016	0,028	1,9
RAMP 5	77	40	10	0,4	17	0,00011	0,020	0,011	0,8
RAMP 6	85	40	11	0,44	18	0,00012	0,020	0,014	1,1
RAMP 7	85	40	11	0,44	18	0,00012	0,020	0,014	1,1
RAMP 8	97	40	12	0,48	18	0,00013	0,020	0,016	1,5
RAMP 9	101	40	13	0,52	19	0,00014	0,020	0,018	1,8
RAMP 10	109	40	14	0,56	20	0,00016	0,020	0,021	2,3
RAMP 11	117	40	15	0,6	21	0,00017	0,025	0,008	0,9
RAMP 12	121	40	15	0,6	21	0,00017	0,025	0,008	0,9
RAMP 13	129	40	16	0,64	21	0,00018	0,025	0,009	1,1
RAMP 14	133	40	17	0,68	22	0,00019	0,025	0,010	1,3
RAMP 15	21	40	3	0,12	9	0,00003	0,010	0,037	0,7
TOTAL				6,84					

The values of Δp are all lower than the〚ΔH〛_adm and respect the 4 bar class because 10m+13.415<40m=4bars.

Table 7: Summary of ramp calculations on ramp door 4

	Length (m)	Speed d'un groupe de goutteurs	Number of a group of drippers	Speed (m³/h)	Diameter (mm)	Speed (m³/s)	Diameter Choisie (m)	Simple pressure drop(m/m)	Sim pre dro
RAMP 1	98	40	13	0,52	19	0,00014	0,020	0,018	1,8
RAMP 2	98	40	13	0,52	19	0,00014	0,020	0,018	1,8
RAMP 3	98	40	13	0,52	19	0,00014	0,020	0,018	1,8
RAMP 4	98	40	13	0,52	19	0,00014	0,020	0,018	1,8
RAMP 5	98	40	13	0,52	19	0,00014	0,020	0,018	1,8
RAMP 6	98	40	13	0,52	19	0,00014	0,020	0,018	1,8
RAMP 7	94	40	12	0,48	18	0,00013	0,020	0,016	1,4
RAMP 8	90	40	12	0,48	18	0,00013	0,020	0,016	1,4
RAMP 9	82	40	12	0,48	18	0,00013	0,020	0,016	1,3
RAMP 10	82	40	11	0,44	18	0,00012	0,020	0,014	1,1
RAMP 11	74	40	10	0,40	17	0,00011	0,020	0,011	0,8
RAMP 12	70	40	9	0,36	16	0,00010	0,016	0,028	1,9
RAMP 13	62	40	8	0,32	15	0,00009	0,016	0,022	1,3
RAMP 14	62	40	8	0,32	15	0,00009	0,016	0,022	1,3
RAMP 15	50	40	7	0,28	14	0,00008	0,016	0,018	0,8
TOTAL				6,68					

The values of Δp are all lower than the〚ΔH〛_adm and respect the 4 bar class because 10m+10.244<40m=4bars

Table 8: Summary of the results of the ramp holder calculations

RAIL HOLDERS								
	Length (m)	**Speed (m³/h)**	**Diameter (mm)**	**Speed (m³/s)**	**Diameter Choisie (m)**	**Simple pressure drop(m/m)**	**Simple pressure drop(m)**	**Loss of load(m)**
RAILHOLDER 1	100	4,04	53	0,00112	0,063	0,003	0,297	0,113
RAIL OLDER 2	100	3,1	47	0,00086	0,050	0,006	0,564	0,214
RAIL HOLDER 3	116	6,84	70	0,00190	0,075	0,003	0,388	0,148
RAIL HOLDER 4	116	6,68	69	0,00186	0,075	0,003	0,371	0,142
TOTAL								0,617

The values of Δp are all lower than the ΔHadm, respecting the 4 bar class because 10 m + 3.117 < 40m = 4 bars.

Table 9: Results of calculations of the main pipe ramps

MAIN DRIVE								
Length (m)	**Speed (m³/h)**	**Diameter (mm)**	**Speed (m³/s)**	**Diamèter Choisie (m)**	**Simple pressure drop(m/m)**	**Simple pressure drop(m)**	**Loss of load(m)**	**[Eupst Edown (m)**
150	20,66	121	0,00574	0,125	0,002114	0,317	0,317	-0,75

The values of Δp are all lower than the⟦ΔH⟧_adm, respecting the 4 bar class because 10 m + 1.067 < 40 m = 4 bars.

Determining the diameter of the riser column

$$D(\mathrm{mm}) = \sqrt{\frac{Q(m3/h)}{V(m/s)}} * 18{,}81$$

$$D(\mathrm{mm}) = \sqrt{\frac{20{,}66}{3}} * 18{,}81 = 49{,}36$$

$$\mathbf{D = 50mm}$$

$$\Delta H_{simple}\ (m/m) = a\frac{\left[\frac{Q(m^3/h)}{3600}\right]^N}{[D(mm) * 10^{-3}]^M}$$

$$\Delta H_{simple}\ (m/m) = 0{,}001101\,\frac{[20{,}66]^{1{,}84}}{[50*10^{-3}]^{4{,}88}}$$

$$\mathbf{\Delta H_{simple}(m/m) = 0{,}185}$$

$$\Delta H_{cm}\,(m) = \Delta H_{simple}\ (m/m) * Lcm$$

$$\Delta H_{cm}\,(m) = 0{,}185 * 10$$

$$\mathbf{\Delta H_{cm}(m) = 1{,}85m}$$

Calcul of HMT

$$HMT(m) = H_{totale} + H_{géo} + \Delta H_{pièces}\,(m) + \Delta H_{filter}$$

$$H_{totale} = \sum_i (\Delta H_{cm} + \Delta H_{cp} + \Delta H_{suction})$$

$$\Delta H_{suction}\ (m) = \frac{V^2(m/s)^2}{2g(m/s^2)}$$

$$\Delta H_{suction}\ (m) = \frac{3^2}{2*9{,}81} = \mathbf{0{,}46m}$$

$H_{totale} = 0{,}32 + 1{,}85 + 0{,}46$ $\mathbf{H_{totale}=2{,}6m}$

$Hgéo = Zmax - Zeau$

$H_{géo} = 297{,}15 - 284{,}05 = \mathbf{13{,}10m}$

$\Delta H_{pièces}\,(m) = 0{,}10 * H_{total\ e}(m) = 0{,}10*2{,}6 = 0{,}26m$

$\mathbf{\Delta H_{filtre}=6m}$

HMT(m)= 2,6m+13,10m+0,26m +6m=21,96

HMT(m)= 22m

Choice of Pump

We used Grundfos catalogs to select the pump.

Submersible pump specifications:

Type : SP 30-3 MS 4000

Power : 3 KW

Mass : 25 Kg

Pressure : 350 KPa

Yield: 80%

Diamèter : 95 mm

HMT : 35m

Speed : 24 m³/h

Result of the calculation of the peak power of the photovoltaic system P

$$Ej = \frac{\rho * g * Q * \Omega * HMT}{3600 * Rond * Rmp}$$

$$Ej = \frac{1000 * 9{,}81 * 20{,}66 * 5 * 22{,}4}{3600 * 0{,}95 * 0{,}755} = 8791{,}12$$

$\boldsymbol{Ej} = \mathbf{8791 Wh/jour}$

$$Pc = \frac{Ej}{K * Ei}$$

$$Pc = \frac{8791}{0{,}65 * 6} = 2254{,}12$$

$\mathbf{Pc = 2254W}$

Result of calculating the number of panels

$$Np = \frac{Pc}{P}$$

$$Np = \frac{2254}{200} = 11{,}27$$

$$\mathbf{Np = 12}$$

The photovoltaic field (12 panels) will be arranged in series in two rows.

Table 10: Estimated Quote

N°	**Désignation**	**U**	**Quantity**	**Prix Unitaire**	**Total price**
0	Installation, delivery and removal from the site	FF	1	500 000	500 000
under Total 0					500 000
I	Development works				
1.1	Backfilling and compacting of tracks	ml	366	11 000	4 026 000
1.2	Base of the lemon trees	U	564	1 500	846 000
1.3	Base of the mango trees	U	338	2 000	676 000
under Total I					5 548 000
II	Wire mesh fencing				
2.1	Manual excavation for anchoring the stiffening angles and reinforced posts	m³	14,88	3 000	44 640
2.2	Supply and installation of 1.5m above-ground angles and anchoring at 0.30m	ml	285	3 500	997 500
2.3	Supply and installation of 1.5m high wire mesh (all constraints included)	ml	854	4 500	3 843 000
2.3	Reinforced concrete for corner posts for securing the gates	m³	1	140 000	140 000
2.4	Cyclopean concrete dosed at 250kg/m³ to seal the angles to the posts	m³	12,825	100 000	1 282 500
2.5	Double-leaf access gate, 1.5m high and 2m wide	U	2	150 000	300 000
Under Total II					6 607 640
III	Headworks				
3.1	Volumetric Valve	U	1	15 500	15 500
3.2	Pressure Regulator	U	1	16 000	16 000
3.3	Volumetric Meter	U	1	25 000	25 000
3.4	Pressure Gauge	U	1	3 000	3 000
3.5	Shutoff Valve	U	5	7 000	35 000
3.6	Sand Filter	U	1	165 000	165 000
3.7	Screen Filter	U	1	200 000	200 000
3.8	Suction Cup	U	1	15 500	15 500

3.9	Check Valve	U	1	15 000	15 000
3.10	Intake Collars	U	120	500	60 000
Under Total III					550 000
IV	System Distribution Network				
4.1	Supply and installation of PN10 DN125 PVC pipe (including all suggestions for supplying records: elbows, tees, sleeves)	ml	150	3 500	525 000
4.2	Supply and installation of PN4 DN50 HDPE pipe (including all suggestions for supplying records: elbows, T-pieces, sleeves)	ml	100	750	75 000
4.3	Supply and installation of PEHD PN4 DN63 pipe (including all suggestions for supplying records: elbows, T-pieces, sleeves)	ml	100	1 000	100 000
4.4	Supply and installation of PN4 DN75 HDPE pipe (including all suggestions for supplying records: elbows, T-pieces, sleeves)	ml	232	1 500	348 000
4.5	Supply and installation of PN4 DN10 PEBD pipe (including all suggestions for supplying records: elbows, T-pieces, sleeves)	ml	21	300	6 300
4.6	Supply and installation of PN4 DN12 LDPE pipe (including all suggestions for supplying records: elbows, tees, sleeves)	ml	80	350	28 000
4.7	Supply and installation of PN4 DN16 LDPE pipe (including all suggestions for supplying records: elbows, tees, sleeves)	ml	1443	400	577 200
4.8	Supply and installation of PN4 DN20 LDPE pipe (including all suggestions for supplying records: elbows, tees, sleeves)	ml	3118	425	1 325 150
4.9	Supply and installation of PN4 DN25 LDPE pipe (including all suggestions for supplying records: elbows, tees, sleeves)	ml	500	500	250 000
4.10	Drippers of 8 l/h	U	1690	250	422 500
4.11	Drippers of 4 l/h	U	2820	150	423 000
Under Total IV					4 080 150
V	Pumping Station				
5.1	Supply and Installation of a $4m^3$ pump with a 3m head and all accessories	U	1	1 500 000	1 500 000
5.2	Supply and Installation of a $24m^3/h$ submersible pump and a 35m TDH and accessories	U	1	2 500 000	2 500 000
5.3	Supply and Installation of 200W Solar	U	7	350 000	2 450 000

	Panels				
5.4	Construction of a 15cm thick well in reinforced concrete dosed at 350 kg/m^3 and with an internal diameter of 140cm	ml	10	250 000	2 500 000
Under Total IV					8 950 000
	Total				26 235 790
	unforeseen **5%**				1 311 790
	Général Total				**27 547 580**

The total cost of the project amounts to 27,547,580 CFA francs, or 7,346,025 the cost of development per hectare

Discussion

The Djarmaya Plain is located in the Sahelian zone, where the dry season is marked mainly by a lack of rainfall, and the rainy season (June–October) is characterized by the arrival of the African monsoon (Muller et al. 2010; Salack et al. 2011). Crop water requirements are consistent with temperatures. They vary depending on the crop's development stage and the season. Crops are more water-demanding during periods of active growth and during periods of intense heat. For this project, March is the month of high temperatures, thus increasing water requirements. Temperature changes have a significant impact on crop water requirements. In general, an increase in temperature leads to an increase in evapotranspiration (ETP), which means that plants transpire more water, and soil water evaporates more quickly. This leads to an increase in crop water requirements. Drip irrigation can be considered a recent improvement in water supply through irrigation. The reason given is that it prevents or in most cases significantly reduces losses through direct evaporation, runoff, and deep percolation (Hanson and May 2007; Safi et al., 2007). The precise application of water, particularly fertilizers, contributes significantly to increasing water use efficiency and, consequently, improving crop yields (Singh and Rajput, 2007). In addition, it prevents weed growth around the crop (Ayers et al., 1995). Climatic factors can affect them in several ways, including increased rainfall, rising temperatures, storms, and floods, leading to structural damage, material degradation, and changes in the environment around the booms. Ramps are vulnerable to climatic factors, and it is important to consider these risks in the design, construction and maintenance of infrastructure.

Conclusion

The objective of the study was to design and size a drip-irrigated arboretum in the Djarmaya Plain. The results show that 7,346,025 CFA francs are required to develop one hectare of arboretum, for a total cost of 27,547,580 CFA francs. Topographical studies show that the site is relatively flat, although it has some low-lying areas (ponds) and large mounds. The elevations are between 290 and 297.50 m in Chad's general leveling system. This result justifies the choice of the drip system, which allows for good water distribution under the plants in conditions of low elevation. Furthermore, the high temperatures recorded in the area, resulting in a high water requirement for the trees, are a major factor in favor of drip irrigation, which is intended to save water. It goes without saying that the best management of the system requires local personnel trained in the maintenance and upkeep of the irrigation network. Ultimately, the success of this project would contribute to improving the nutritional status of people in the area as well as the sustainable management of natural resources.

References cited

1. Hanson B, May B.2007. The effect of drip line placementon yield and qualityof drip irrigated processing tomatoes.Irrig Drainage syst21:109-118.(CrossRef).
2. Payero JO,Yonts CD,Irmak S,tarkalson D.2005. Advantages disadvantages of subsurface drip irrigation.Extension. ECO5-776,institute of Agriculture and Natural resources at the university of Nebraska-Lincoln.
3. RGPH, 2009.. General Census of Population and Inhabitants, Directorate of Agricultural Production and Statistics of the Ministry of Agriculture
4. PND 2017-2021, Chad National Development Plan 2017-2021 vision
5. MPIEA, 2019 : inventory of Chad’s agricultural potential, Ministry of Production, Irrigation and Agricultural Equipment.
6. Muller, B. et al., 2010. L’assurance agricole : un outil potentiel d’appui au développement en Afrique de l’Ouest soudano-sahélienne, Colloque "Agir en situation d'incertitude" (Session 4),Montpellier, France, pp.1-17.
7. Salack, S., Muller, B. & Gaye, a. T., 2011. Rain-based factors of high agricultural impacts over Senegal. Part I: Integration of local to sub-regional trends and variability. Theoretical and Applied Climatology, 106(1-2), pp.1–22
8. Hanson B., May D. (2007). The effect of drip line placement on yield and quality of drip irrigated processing tomatoes.Irrig. Drainage Syst. 21:109-118.
9. Singh D.K., Rajput T.B.S. (2007). Response of lateral placement depths of subsurface drip irrigation on okra (Abelmoschus esculentus). International Journal of Plant Production, 1:73-84.

10. Ayars J.E., Phene C.J., Schoneman R.A., Meso B., Dale F., Penland J. (1995). Impact of bed location on the operation of subsurface drip irrigation systems. In: Proc.5th Int. Micro-irrigation Congress, ASAE, p.168-174.