# Approach using the Internet of Things in the Sahel for Smart Irrigation

Fatoumata Thiam[1] and Cheikhou Thiam[2]
[1]*Université Gaston Berger Saint-Louis, Senegal*
[2]*Université de Thiés, Thiés, Senegal*

Keywords: Internet of Things, Irrigation, Artificial Intelligence.

Abstract: Nowadays the Internet of Things (IoT) is used in many sectors such as health, military, industry, agriculture and so on. This technology is considered as a special type of ad hoc network and one of these promising areas is precision farming where it can provide important support that will facilitate agricultural practices and that can modernize and replace some of the traditional techniques. In Sahelian area, water is a critical resource due to short rainy seasons and waste of water in gross irrigation. The main activity in the Niayes area is market gardening. Urgent measures must be taken to save water reserves during the long dry season. Smart irrigation can be a solution for water wastage problem. Many techniques have been developed to solve these problems. In this paper, we can find techniques based on evapotranspiration (ET), Soil Water Assessment Tool (SWAT) and Internet of Things (IoT). This paper aims to propose a solution of smart irrigation based on IoT.

## 1 INTRODUCTION

In recent years, with the evolution of technology, the emergence of a new internet of things information network called the Internet of Things , which is considered as a special type of ad hoc network whose nodes are sensors able to harvest and transmit environmental data in an autonomous way. The nodes are randomly dispersed across a geographic area, called the catchment field, which defines the area of interest for the captured phenomenon. The captured data is routed to a node considered a data collection place, called sink node. The latter can be connected to the network user via the Internet or a satellite. Thus, the user can address requests to the other nodes of the network, specifying the type of data required and harvest the environmental data captured through the well node. Internet applications of objects are numerous. They include different fields: agricultural, health, ... etc. The intelligent irrigation system is an IoT-based device that is able to automatically deactivate the motor pump once the soil moisture sensor has reached the required threshold value. There is a growth in agricultural products via the Internet of Things. This solution is a response to the problems of environmental change in the Sahel and has a significant impact on the agricultural economy.

Population grows at an exponential rate and feeding people is progressively being problematic. Extra food needs to be produced. People are building more and agricultural land are being occupied also, the use of water has significantly increased. Valuable land and water resources required for food production have become critical.

An urgent need of regulating water utilization is required. In fact, decreasing water, drying of rivers, unpredictable environment is very common. In Sahelian area, water is a critical resource due to short rainy seasons and waste of water in gross irrigation. The main activity in the Niayes area is market gardening. To solve that, in agriculture domain, sensors are deployed at suitable locations to monitor crop growth and water use.

In this article we propose an approach that consists of setting up a network of sensors for intelligent irrigation and thus an efficient use of water. This study will be discussing on how the precision irrigation is implementing via many technicals. We will next see those technicals and present some example of works. This article is organized like following: we will introduce first this study, secondly. The section 2 presents some background concepts. Section 3 presents several studies in the domain. In the section 4 we present our approach for optimizing irrigation. The section 5 presents results which are the comparison of different approaches. Finally, the last section summarizes the contributions.



Thiam, F. and Thiam, C.
Approach using the Internet of Things in the Sahel for Smart Irrigation.
DOI: 10.5220/0009800601690174
In *Proceedings of the 9th International Conference on Smart Cities and Green ICT Systems (SMARTGREENS 2020)*, pages 169-174
ISBN: 978-989-758-418-3

# 2 BACKGROUND CONCEPTS

## 2.1 Irrigation Paradigm in the Niayes Area

The world's population is expected to exceed nine billion by 2050, three times more than in 1950 (Angus and Butler, 2014)(Bricas and Seck, 2004). The problem of global food security is growing. The rural exodus leads to an agglomeration form in the urban areas, which have become in a few years the place of life, of more than half of the population. The planet is facing a problem of meeting the food needs of its population.

Food security in urban areas is even more worrying in the cities of the South, already facing a high rate of poverty. In this context, urban and peri-urban agriculture (UPA) is developing, occupying an essential place in the urban food supply.

In Senegal, UPA activities are concentrated in the Niayes area Figure 1. The Niayes is a series of small valleys between dunes along the northern coastline of Senegal. Since its appearance in Senegal in 1937, market gardening has generally evolved both in terms of surfaces used and yields. Nevertheless, the demand is not satisfied, and Senegal continues to import vegetables.

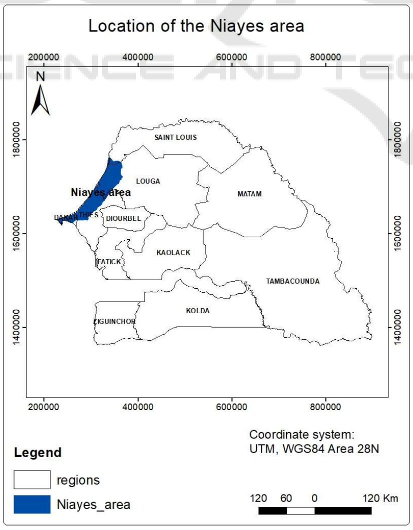


Figure 1: Niaye area in Senegal (translation).

Indeed with the scarcity of rain, the main source of water supply that constituted the semi-superficial aquifers Niayes has shown its limits. As a result, wastewater has become an attractive alternative for market gardeners. However, at the bacteriological level, the coliform and Powerful streptococci concentrations are well above the WHO (World Health Organization) guideline (Niang, 1996).

There are three main constraints identified by farmers (Ba and Cantoreggi, 2018):

- land insecurity (74%);
- lack of water for irrigation (62%);
- and salinization of water and soil (27%).

In view of all these problems, a water saving solution is needed

## 2.2 Mathematical Models

It is important to optimize water utilization in agriculture to avoid water stress in the future. The scheduling and management of irrigation water are used to prevent over-irrigation and water wastage. Many techniques are based on studying the plant water requirement and other on mathematical model, algorithms, etc.

Optimized-irrigation can be defined as applying the right amount of water to the plant, to allow it to grow without over-irrigating or under-irrigating. Indeed, over-irrigation can lead to leaching of soil nutrients, while under-irrigation prevents the plant from growing properly.

Smart-irrigation is a set of hardware and software to automate and optimize irrigation for a good evolution of the crop. For an optimized irrigation schedule, there are two components to consider (George, 2017):

1. Determine the crop water requirements (CWR);
2. Estimate the right time to water the plants.

To determine the CWR, there is a parameter called ET standing for evapotranspiration. The ET is the sum of crop transpiration and evaporation of soil water content. The CWR is the same as ET. To determine ET, the FAO (Food and Agriculture Organization of the United Nations) have stood two methods (Savva and Frenken, 2002) :

- Fao Penman-Monteith method is an equation that require climate parameters to determine the $ET_0$ ;
- Pan evapotranspiration is a measurement that uses a pan evaporimeter and parameters like wind speed, humidity, temperature and the sunshine to calculate the $ET_0$.

$ET_0$ is the evapotranspiration used as reference to calculate other crops ET wich is $ET_c$ equation 1. The reference crop used for $ET_0$ is grass.

Fao Penman-Monteith equation.

$$ET_0 = \frac{0.408\delta(R_n - G) + \gamma\frac{900}{T+273}u_2(e_s - e_a)}{\delta + \gamma(1 + 0.34u_2)} \quad (1)$$

$ET_0$ = Reference evapotranspiration (mm/day)
$R_n$ = Net radistion atr the crop surface (MJ/$m^2$)

$G$ = Soil flux density (MJ/$m^2$)
$T$ = Mean daily air temperature at 2m height (° C)
$u_2$ = Wind speed at 2m hieghr (m/sec)
$e_s$ = Saturation vapour pressure (kPa)
$e_a$ = Actual vapour pressure (kPa)

The FAO Penman-monteith (Savva and Frenken, 2002) is used to determine the $ET_c$ and then the IR, Irrigation requirement equation 2.

$$IR = ET_c - (Pe - Ge + Wb) + LR \quad (2)$$

$IR$= Irrigation Requirement (mm)
$ET_c$= Crop Evapotranspiration (mm)
$Pe$= effective dependable rainfall (mm)
$Ge$= Groundwater contribution from water table (mm)
$Wb$ = Water stored in the soil at the beginning of each period (mm)
$LR$ = Leaching Requirement (mm)

It is important to distinct CWR and IR. In fact, for an effective irrigation, more parameters like the climate, the crop type and the growth stage of the crops, need to be taken into consideration to attain plant water need.

### 2.3 Computer Simulation Model for Natural Water Resources

Computer science helps to model efficient water use in crop field. Powerful evaluation and simulation tools are made to help water usage planning. To reflect actual values of field parameters, these models have to fit in real time system to avoid ineffective performance of irrigation schedule. In addition, crop growth, depend closely to irrigation frequency and amount of water supplied to the plants. So, it is crucial to have a model to produce a good watering plan. There are many tools used to model water use in crop field, for example (Chen et al., 2018):

- The Soil Water Assessment Tool (SWAT) for watershed scale model, used to simulate the quality and quantity of surface and ground water and predict the environmental impact of land use, land management practices, and climate change.
- MODFLOW wich is a program used by hydrogeologists to simulate the flow of groundwater through aquifers.
- Decision Support System for Agrotechnology Transfer (DSSAT) is software application program that comprises dynamic crop growth simulation models for over 40 crops.

SWAT model is widely used for managing water resources.

### 2.4 Internet of Things - IoT

ICTs has a significant impact on the concept of smart agriculture. Smart-agriculture is the use of computer devices, in the farming process to optimize usage of natural resources, limit human labor and have a good profitability.

The Internet of Things (IoT), in particular Wireless Sensor Networks (WSN) is commonly used in Smart-agriculture. WSN is a collection of physical modules called sensors to capture, process and transmit information in the environment in which they are deployed. Sensors are deployed at different soil depth to sense water flow and help to determine proper time for water supply. Based on IoT, SMART-Irrigation can help for water wastage problems, over-irrigation that can lead to the leaching of nutrients and slowing down crop growth (George, 2017). Precise irrigation is a concept of saving water supply to use exactly the exact amount of water for the plant to develop correctly. Many parameters are taken in account to define a precise irrigation. Some of them are meteorological data like temperature, humidity, the wind, etc. Some of those can be obtained by using sensing elements like soil moisture sensors.

## 3 RELATED WORK

SMART-Irrigation is the use of technology in the farming process to automatize certain procedures and increase yields. Sensor devices are linked by wireless communication technology to monitor data from the agricultural field. Many studies are focused on using soil moisture sensors to determinate water supply or to determine when to irrigate. In the following we will see some work on Smart-irrigation.

CROPWAT(Savva and Frenken, 2002) is a software that can calculate CWR and IR from climatic and crop data in a particular area. Various tables are given to estimate the exact value of each parameter of the Penman-Monteith equation. Meteorological stations are distributed all through a given country making it possible to prepare reference crop evapotranspiration maps for a country. Those meteorological stations are contained in CLIMWAT wich is a software that help to obtain value of each parameter of the Penman-Monteith equation. I

In (Chen et al., 2018), authors created a SWAT based algorithm. The algorithm simulates management allowed depletion (MAD) irrigation scheduling by taking in an allowable depletion percentage of plant available water (PAW). The algorithm also suspends irrigation events after harvest. Weather data are acquired from the nearby meteorological observation post. They are then compiled into daily values and formatted for model input.

In (Myers et al., 2017), the developed system uses real-time sensor data, weather forecasts, geological and environmental information to infer the precise amount of water needed to minimize wastage without compromising the health and wellbeing of the lawn or garden. The water supply in the yard is automatically managed by sensor-actuator nodes, based on semantic inference. The combination of data from multiple sources with a sensor-actuator system helps to provide precise irrigation.

In (Mohanraj et al., 2017), the proposed system automates the irrigation and fertigation using WSN to detect rainfall intensity. The system is integrated with irrigation module which uses Penman-Monteith FAO-56 equation for calculating crop water need. There are four functionalities carried out by end nodes: estimation of CWR, calculation of irrigation period, detection of water discontinuity and monitoring the remaining energy of the battery.

Studies have identified insufficiencies in the auto-irrigation algorithms in the Soil and Water Assessment Tool (SWAT). It is noted a continuation of irrigation during the non-growing period and incapability to simulate growth stage specific irrigation. The CROPWAT program produces a watering calendar for all the growing season of the crops once. That type of configuration may not take in account some climatic change like rain, slopes or unexpected dryness.

In the following part we are aiming to present our solution of smart-irrigation wich will consider evapotranspiration and real time monitoring plant water need for a precise irrigation.

# 4 APPROACH

In our proposal, a set of soil moisture sensors are deployed over the land to monitor soil water content. Then based on defined thresholds, IR (Irrigation Requirement) will be calculated to determine water supply, in addition of a set of external data sources. The system should be able to adapt watering plan through artificial intelligence function. Parameters like effective dependable rainfall (Pe) and groundwater contribution (Ge) (Figure 2) will be acquired from external data sources (OpenWeatherMap.org, ) (wea, ).

Our system will consist of soil moisture sensors, actuators and sprinklers nodes. The sensors measure-

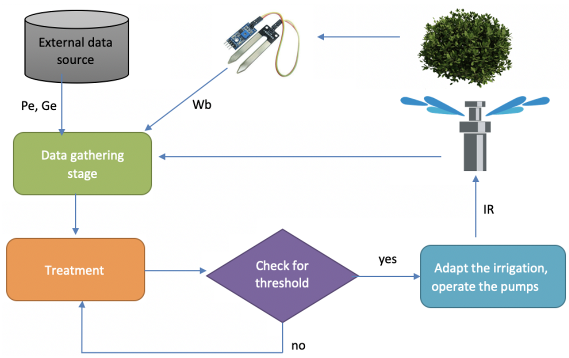


Figure 2: Flow diagram.

Table 1: Crop evapotranspiration for tomato crop in Niayes area, Saint-Louis (coef=coefficient).

| Month | Decade | Stage | Kc coef. | Etc mm/day | Etc mm/decade |
|---|---|---|---|---|---|
| Oct | 3 | Init | 0.60 | 3.11 | 2.8 |
| Nov | 1 | Init | 0.60 | 3.20 | 0.2 |
| Nov | 2 | Init | 0.60 | 3.28 | 0.0 |
| Nov | 3 | Deve | 0.66 | 3.55 | 0.0 |
| Dec | 1 | Deve | 0.81 | 4.34 | 0.2 |
| Dec | 2 | Deve | 0.96 | 5.12 | 0.2 |
| Dec | 3 | Deve | 1.13 | 6.20 | 0.3 |
| Jan | 1 | Mid | 1.22 | 6.95 | 0.4 |
| Jan | 2 | Mid | 1.22 | 7.19 | 0.5 |
| Jan | 3 | Mid | 1.22 | 7.45 | 0.5 |
| Fev | 1 | Mid | 1.22 | 7.71 | 0.6 |
| Fev | 2 | Late | 1.20 | 7.86 | 0.7 |
| Fev | 3 | Late | 1.11 | 7.55 | 0.5 |
| Mar | 1 | Late | 1.01 | 7.18 | 0.2 |
| Mar | 2 | Late | 0.92 | 6.77 | 0.0 |

ments will be sent to the system. These data will then be combined with evapotranspiration data of the actual area to serve as an input to our system.

During data gathering and modelization (Figure 3), the system collects raw data from various sources. The sensor network will measure the water kept in the soil before irrigation (Wb). The modelization part, raw data are annotated then integrated. We will use CROPWAT's generated data tables (Table 1) to have the crop evapotranspiration value ($ET_c$). These data are organized in a model to become a state context of a section of the field. The processing phase will receive the integrated data from the precedent stage. During this phase, reasoning is applied on these integrated data to infer an efficient irrigation schedule for each section of the field. For the reasoning, a rule-based engine can be utilized.

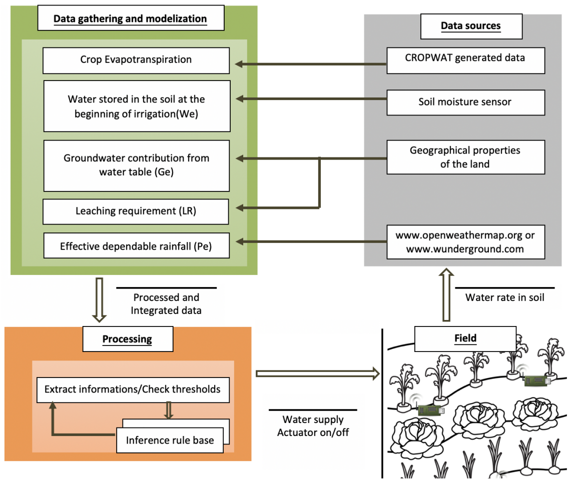


Figure 3: Functioning architecture.

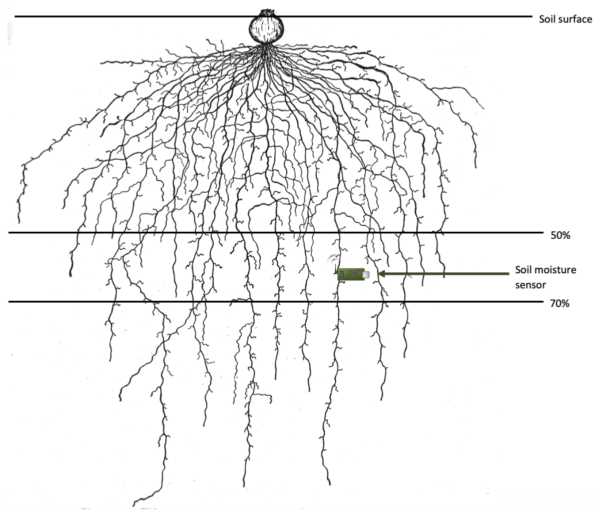


Figure 4: Onion bulb root system.

# 5 RESULT

We develop an adaptive and a contextual system to automate and optimize irrigation. Based on that, an adapted water supply is applied through the irrigation system. As a result, the watering system will use strict water quantity to allow the crop to grow properly. This output will be used to make a set of inference rules to adjust the water supply and optimize it.

In the processing phase, the output of the modelization phase is used to create inference rules for a more effective irrigation that will help predict watering plan when there is a fault in our system. The system monitors the intensity of the rain, the overflow due to a malfunction of the drip setup, to stop the watering pump.

The sensor location in soil will be determinated by the plant root zone. The Management Allowed Depletion or MAD is the highest amount of water in plant root zone that can be taken of. This amount depends on many factors like the plant type, soil properties or exposition of the land toward the sun wich is more surfaces for evaporation. The value is estimated between 50% to 70% in plant root zone. Placing our sensor in that point can contribute in optimization of our irrigation plan Figure 4.

Our proposition is comparative to a real-time system. In fact, the water need depend on actual state of the soil. Rain, overflood, dysfunctioning sprinkler or a continuous watering is automatically detected by sensors and relayed to the system. Each sensor can be located and if any issue, an action is made to cut off actuators in this area.

# 6 CONCLUSIONS

Gross irrigation in Niayes area affects water resources a lot. In addition of climatic changes, rainy seasons are short. That causes water depletion in this area.

In this paper, we tried to show techniques used for smart irrigation. We have looked at some examples that uses mathematical models, application programs and sensing devices to determine water use and water need of crops.

Technology has contributed a lot in solutions of water scarcity problem. In agriculture irrigation systems are progressively controlled by technology. To monitor water use, devices like soil moisture sensors help a lot in that point. Data gathered are integrated to help make decision and adjust watering plans.

We presented a proposition of smart-irrigation. Based on using sensors and exploiting advantages given by FAO Penman-Monteith formula to get certain data like plant evapotranspiration. In the future of our work we'll compare our system with an another that ties up to our work.

# REFERENCES

Weather data packages.

Angus, I. and Butler, S. (2014). *Une planète trop peuplée?. Le mythe populationniste, l'immigration et la crise écologique*. Écosociété (Éditions).

Ba, A. and Cantoreggi, N. L. (2018). Agriculture urbaine et périurbaine (aup) et économie des ménages agriurbains à dakar (sénégal). *International Journal of Environment, Agriculture and Biotechnology*, 3(1):195–207.

Bricas, N. and Seck, P. A. (2004). L'alimentation des villes du sud: les raisons de craindre et d'espérer. *Cahiers Agricultures*, 13(1):10–14.

Chen, Y., Marek, G. W., Marek, T., Brauer, D. K., and Srinivasan, R. (2018). Improving swat auto-irrigation functions for simulating agricultural irrigation management using long-term lysimeter field data. *Environmental Modelling & Software*, 99:25–38.

George, B. A. (2017). Technical manual for "crop water requirements and irrigation scheduling".

Mohanraj, I., Gokul, V., Ezhilarasie, R., and Umamakeswari, A. (2017). Intelligent drip irrigation and fertigation using wireless sensor networks. In *Technological Innovations in ICT for Agriculture and Rural Development (TIAR), 2017 IEEE*, pages 36–41. IEEE.

Myers, T., Mohring, K., and Andersen, T. (2017). Semantic iot: Intelligent water management for efficient urban outdoor water conservation. In *Joint International Semantic Technology Conference*, pages 304–317. Springer.

Niang, S. (1996). Utilisation des eaux usées domestiques en maraîchage périurbain à dakar (sénégal). *Science et changements planétaires/Sécheresse*, 7(3):217–223.

OpenWeatherMap.org. Weather api.

Savva, A. P. and Frenken, K. (2002). *Crop water requirements and irrigation scheduling*. FAO Sub-Regional Office for East and Southern Africa Harare.