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AUTOMATION OF IRRIGATION SYSTEMS AND DESIGN OF AUTOMATED IRRIGATION SYSTEMS

Uroromu Ighrakpata[2], Mohamed Chouikha[2], O'tega A. Ejofodomi[1,2] and Godswill Ofualagba[1,2]

[1] Racett Canada Inc, 404 St George Street, Moncton, New Brunswick, Canada E1C 1X0.
[2] Racett Nigeria Ltd., Zone 8, FCT, Abuja, Nigeria,

ABSTRACT: *Canada is a world leader in the production of many agricultural crops, especially wheat and other cereal grains and irrigation necessary to compensate for insufficient precipitation during the critical portions of the growing season in order to avoid a decrease in productivity. Current irrigation systems are unable to determine when the crops have received sufficient water during and even after irrigation, are not easy to use, require user input, manual connection to the water supply and some level of technical expertise before they can be used successfully, and they are not automated. This paper presents a novel automated irrigation system that does not have any of these limitations. The automated irrigation system works by continuously monitoring the soil moisture content and wirelessly activating the pipeline valves to open when the moisture level drops below the minimum threshold for the cultivated crop, causing the land to be irrigated. When the moisture level rises above the maximum threshold, the system deactivates the irrigation pipeline valves, causing them to close and ceasing land irrigation. This automated irrigation system is customizable and can also be used to upgrade existing drip irrigation systems, surface irrigation systems, and sprinkler irrigation systems to overcome their existing limitations.*

KEYWORDS: automated irrigation system, irrigation, crop moisture requirement.

INTRODUCTION

Irrigation is the artificial application of a controlled amount of water to the soil through various systems of tubes, pumps, and sprays [1]. Irrigation is used to assist in the growing of agricultural crops, watering livestock, maintenance of landscapes, revegetation of disturbed soils in dry areas and during periods of inadequate rainfall, protecting plants against frost, suppressing weed growth, preventing soil consolidation, dust suppression, disposal of sewage, and mining. Canada is a world leader in the production of many agricultural crops, especially wheat and other cereal grains. A crop is defined as any terrestrial plant grown for economic profit or personal use. Within many regions of Canada, however, insufficient precipitation during the critical portions of the growing season (April 1 to October 1) may decrease productivity. In these areas, irrigation of agricultural crops is required to maintain high growth rates and yields [2].

In 2010, 7,685 farms irrigated their crops, 838 million m^3 of water were used for irrigation, and the total area of irrigated land in Canada was 528,570 hectares. Irrigation intensity (the volume of water used for irrigation per unit area) varied widely by crop type. Fruit crops received 3,123 m^3/ha of irrigation. Hay (includes any cultivated grass or legume crop which has been (or will be) cut and dried principally for hay or ensilage) received 2,180 m^3/ha. Field Crops (includes annual field crops and tame forages, including barley and potatoes) received 1,334 m^3/ha of irrigation, while

Vegetable crops received only 867 m^3/ha of irrigation [3]. Some common sources of irrigation water include groundwater, springs, wells, rivers, lakes, reservoirs, and other sources such as treated wastewater or desalinated water [1]. In Canada, 3,260 farms obtained at least some of their water for irrigation from on-farm lakes and rivers while 1,555 drew at least some of their water from an underground well and 3,705 farms procured at least some of their irrigation water from off-farm sources (ranging from tap water to provincial water sources such as irrigation districts) [3].

There are various types of irrigation techniques, depending on how the water from the source is distributed within the field. Typically, the goal is to supply the entire field uniformly with water, so that each plant has the amount of water it needs, neither too much nor too little. Four common types of irrigation are surface or flood irrigation, localized irrigation, Drip or micro irrigation and sprinkler irrigation. For surface irrigation, water is distributed over and across land by gravity without the use of mechanical pumps. The field water efficiency of surface irrigation is typically lower than other forms of irrigation but has the potential for efficiencies in the range of 70% - 90%. For localized irrigation, the water is distributed under low pressure through a piped network in a pre-determined pattern and applied to each plant or adjacent to it. For drip irrigation, drops of water are delivered at or near the root of the plants to minimize evaporation and runoff. The field water efficiency of drip irrigation is typically in the range of 80 to 90 percent. For sprinkler irrigation, the water is piped to one or more central locations within the field and distributed in a high-velocity, high-volume spray by overhead high-pressure sprinklers or guns that may or may not be on moving platforms. In 2010, sprinkler irrigation was by far the most popular irrigation in Canada, with it being used on just over 6,000 farms, while 1,540 and 1,480 farms used surface irrigation and drip irrigation respectively. One reason for the popularity of sprinkler irrigation is that it is well suited for irrigating large areas. It is the most common irrigation method for all crop types [1,3].

There are several types of irrigation systems currently used in the agriculture industry and other industries. A system utilizing sprinklers, sprays, or guns mounted overhead on permanently installed risers is often referred to as a solid-set irrigation system. Higher pressure sprinklers that rotate are called rotors and are driven by a ball drive, gear drive, or impact mechanism. Rotors can be designed to rotate in a full or partial circle. Guns are similar to rotors, except that they generally operate at very high pressures of 40 to 130 lbf/in² (275 to 900 kPa) and flows of 50 to 1200 US gal/min (3 to 76 L/s), usually with nozzle diameters in the range of 0.5 to 1.9 inches (10 to 50 mm). Every rotor has its own flow, wetting diameter, spray radius and trajectory. An example of a solid-set irrigation system is the Netafim MegaNet Sprinkler and Netafim PolyNet Polyethelyne Pipe shown in Figure 1. The trajectory angles range from 15-24^0 and the flow rate ranges from 200-750 L/H. Each sprinkler is perfectly balanced with two equal water jets, can be installed on solid sets or removable field stands, and distributes water uniformly [4].

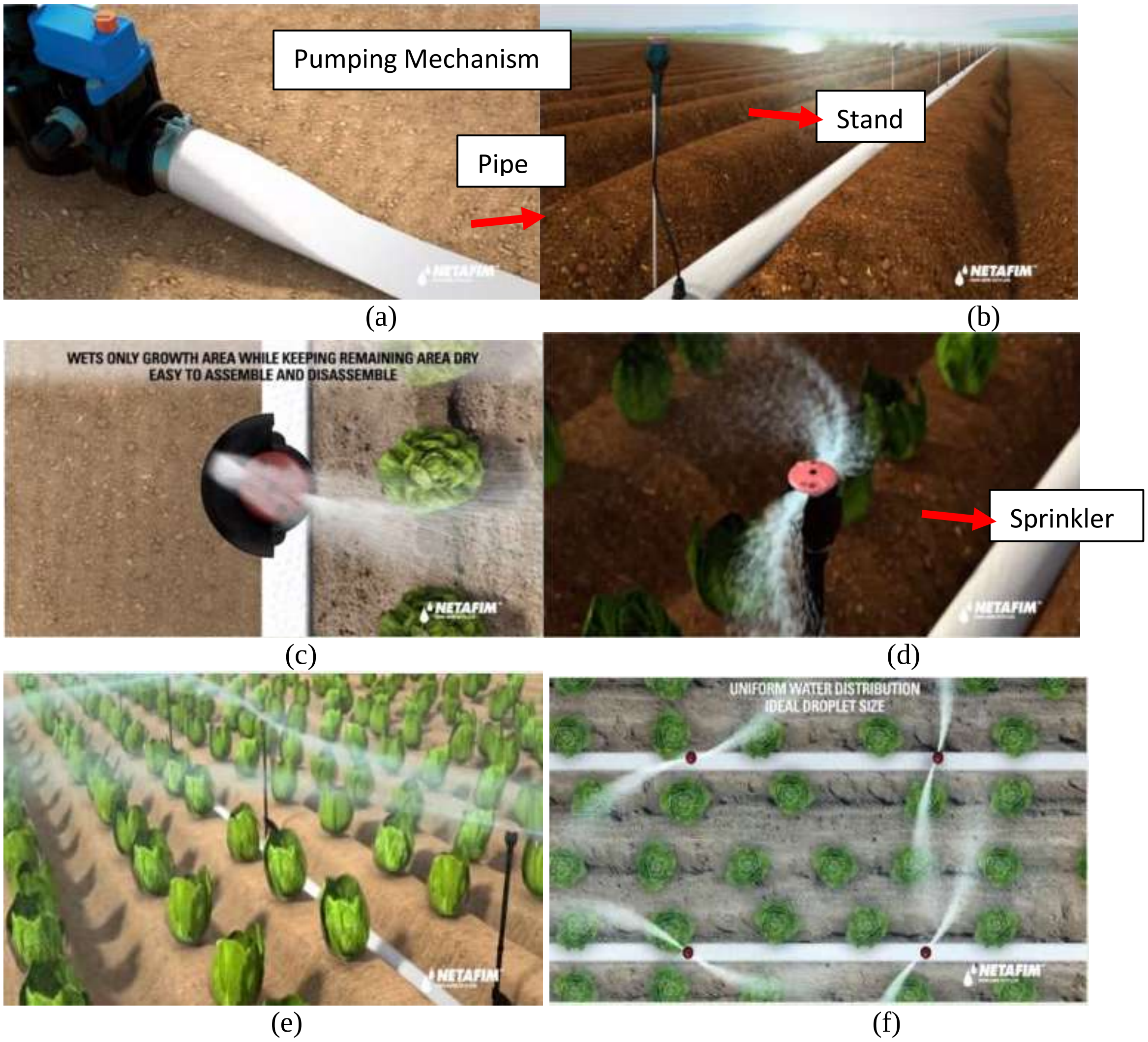
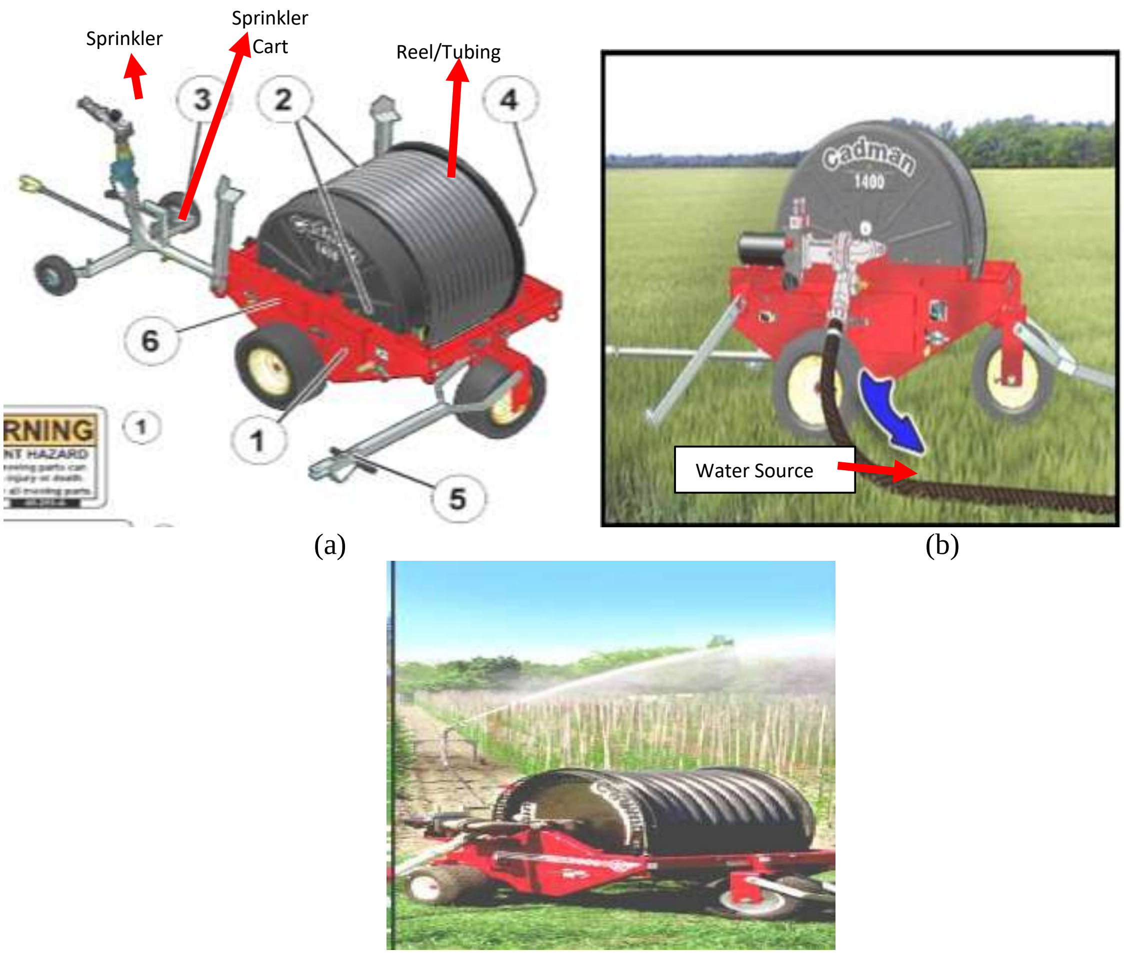


Figure 1. NetaFim MegaNet Sprinkler System [4] (a) Pumping Mechanism with Netafim PolyNet Polyethelyne Pipe (b) Polyethyelyne Pipe connected to Stand and Sprinkler (c) 180^0 spray coverage with NetaFim Sprinkler (d) 360^0 spray coverage with NetaFim Sprinkler (e) NetaFim Sprinkler irrigating Field Crops (f) NetaFim Sprinkler irrigating vegetable crops.

Sprinklers can also be mounted on moving platforms connected to the water source by a hose. Automatically moving wheeled systems known as traveling sprinklers may irrigate areas such as small farms, sports fields, parks, and pastures unattended. Most of these utilize a length of polyethylene tubing wound on a steel drum. As the tubing is wound on the drum powered by the irrigation water or a small gas engine, the sprinkler is pulled across the field. When the sprinkler arrives back at the reel the system shuts off. This type of system is known to most people as a "waterreel" traveling irrigation sprinkler and they are used extensively for dust suppression, irrigation, and land application of waste water. An example of a current waterreel traveling irrigation system is the CADMAN Mini Traveler (see Figure 2).



(a) (b) (c)

Figure 2. CADMAN Mini Traveler [5] (a) Mini Traveler with Labeled parts (b) Mini Traveler powered by irrigation water source (c) Mini Traveler irrigating field crop.

Drip irrigation offers several advantages, including strong root development, no evaporation or run off of water, inexpensive and easy installation, and ability to be installed to a basic hose faucet with no need for direct connection to water lines. A drip irrigation system consists of a "head" and a distribution network. The head of the system is composed of the water source, pump, filter system, pressure regulator and necessary pressure gauges. It may also include a water meter or electronic controller. The distribution network includes the mainline and laterals or dripper lines located down the plant rows [6]. An example of a Drip irrigation system is the Netafim Techline CV Drip Line (see Figure 3).

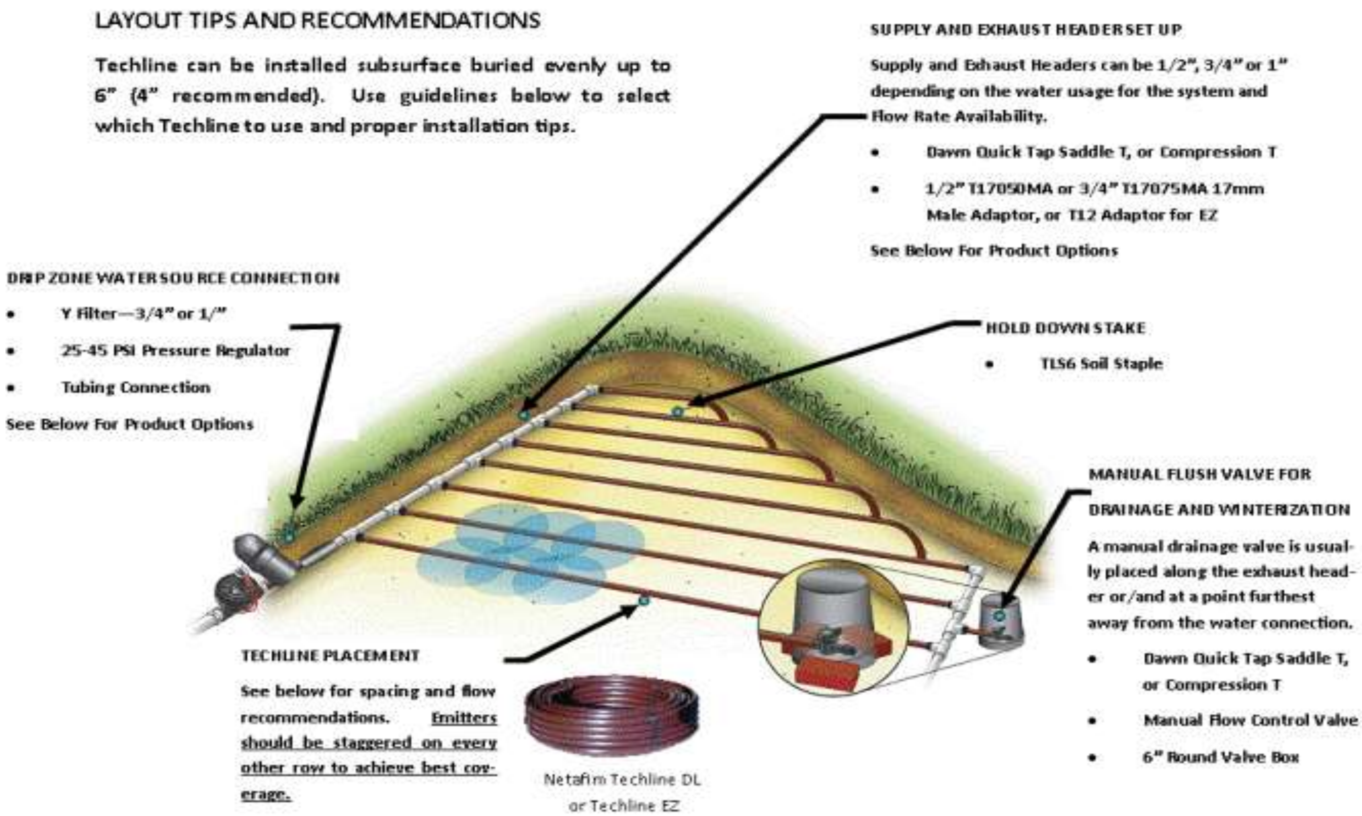


Figure 3. NetaFim Techline CV Drip Line System with four main components: Water source connection , supply and exhaust headers (Poly Tubing supply line), Netafim Drip Line, and a manual flush valve located at furthest point from water source and lowest vertical point of the system [7].

There are several limitations inherently in current irrigation systems used today. Most of these systems are not able to detect when the crops require moisture or water. It is left to the farmers to decide when the crops need to be watered, and their knowledge and experience in determining this crucial factor affecting optimum crop productivity varies. Rigorous scientific experiments have not yet been conducted to ascertain how much water crops need for optimum germination and growth. While it is already known that different crops require different amounts of water, the volume of water required by each crop has not been determined experimentally. The current irrigation systems are unable to determine when the crops have received sufficient water during and even after irrigation. Most farmers simply estimate the volume of water tow be dispersed or distributed during irrigation, but they are unable to determine if and when their crops have received sufficient water. Over–irrigation of crops also has adverse effects on some crops, just as inadequate water also has negative effects on optimum crop productivity.

Another limitation of irrigation systems is that they are not automated. They still require user input before they are able to successfully irrigate the land. And this has to be done every single time the land needs to be irrigated. Moreover, these systems are not easy to use. Most of them require the user to have some level of technical expertise before they can be utilized to successfully irrigate crops. The sprinkler system and the waterreel traveling system discussed above, possess some level of automation, but they both require the user to have some detailed knowledge and expertise about the system and how to use them to properly irrigate the land. Many of these irrigation systems also require manual connection to the water supply, and in most cases, require the user to manually turn on the water supply before irrigation can commence. The irrigation systems currently in use today are not able to automatically vary the volume of water supplied to a land with multi-cropping. So if a farmer has a land in which he/she has planted different crops, with each crop requiring different volumes of water, these irrigation systems are unable to automatically adjust the volume of water supplied to each land section containing a specific crop.

There are many reasons why agricultural process have not yet been fully automated. One of the major reason is that a lot of people have the wrong perception of the agriculture industry. Most people have a backward view of agriculture and their vision of the industry is some form of annual cropping with a lot of physically intensive labor and they fail to see the potential satisfying careers currently available in the industry. As a result, a lot of engineers, who are required and vital for the automation of the agriculture industry, tend to steer away from the industry and go in to more technologically advanced industries. This is one of the key reasons why irrigation systems are not yet fully automated. However, automation of the agriculture industry is vital because this industry provides the food necessary for sustenance of all mankind. Another reason my agricultural processes have not yet been fully automated is that there is still not enough interaction and collaboration with technologically savvy industries on mutually beneficial projects. There are few publications in scientific literature discussing innovative technological products and applications for the agriculture industry.

This paper presents a novel automated irrigation system that does not have any of the limitations discussed above. Soil moisture content is automatically measured every few seconds using moisture sensors. If the moisture in the soil falls below a minimum threshold for the agricultural crop in the land, the system sends a wireless message to the valves in the irrigation pipelines, including the valve controlling access to the main water source, causing the power supply to the valves to be altered, opening them and allowing water to flow into the land for crop irrigation. Soil moisture is continuously measured throughout the entire irrigation process. When the moisture level in the soil rises above a maximum threshold for the crop, the system sends another wireless message to the valves in the irrigation pipelines, altering the power supply to the valves to shut them and cease land irrigation. This automated irrigation system can also be used to upgrade existing drip irrigation systems, surface irrigation systems, and sprinkler irrigation systems to enable them overcome all the limitations they inherently possess.

MATERIALS AND METHODS

MATERIALS

i. Sensors

These are the set of sensors that are used to determine when the automated irrigation system needs to be turned on. A variety of factors can be taken into consideration when determining that the automated irrigation system needs to be switched on, depending on the application of the system.

For water irrigation, the amount of moisture in the soil will be the primary measurement used in determining the threshold for switching on the system, as well as the humidity. For frost protection, the temperature of the soil surface may be the criteria needed in determining when the system needs to be switched on. The automated irrigation system can also be used to ensure livestock have a continuous supply of fresh drinking water. For this particular case, a water level sensor will be needed to determine when the level of water in the drinking trough has fallen below a minimum level. Some of the sensors used in the automated irrigation system are shown in Figure 4.

(a) (b) (c)

Figure 4. Sensors used in Automated Irrigation System [8] (a) Moisture Level Sensor (b) Humidity and Temperature Sensor (c) Liquid Level Sensor

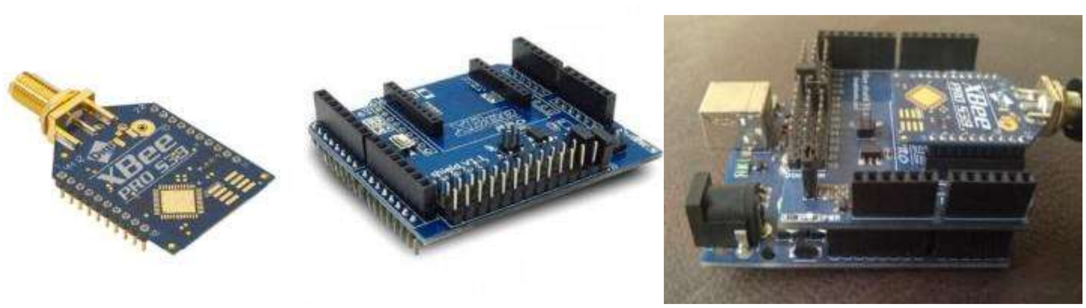
ii. Development Board

A development board will be required for the automated irrigation system to be able to autonomously detect the environmental data necessary to determine when land irrigation should commence or cease. The development board used in this system is the Arudnio Mega.

Figure 5. Arduino Mega [8]

iii. XBee

XBee Pro 900HP wireless modules are used to establish wireless communication between the monitoring unit of the automated irrigation system and the valves in the irrigation pipelines. The XBee Module is shown in Figure 6a. It is mounted on the Arduino Mega using an XBee Shield shown in Figure 6b. The mounted XBee is shown in Figure 6c. With a 2.1 dB antenna, this module can establish a wireless connection between the monitoring unit and the pipeline valves up to a distance of 15.5 km. With a high gain antenna, this distance increases to 45 km. This wireless connection is used to instruct the valves when to open in order to commence land irrigation, and when to close in order to cease land irrigation.



(a) (b) (c)

Figure. 6. Xbee Modlue [8] (a) XBee Pro 900HP Module (b) XBee Shield (C) XBee stacked on XBee Shield Stacked and Arduino.

iv. Irrigation Pipes

There are several types of pipes used for irrigation. The most common is aluminum irrigation pipes (see Figure 7). The diameter of the pipes selected for land irrigation depends on the availability of the water source and the size of the land to be irrigated.

(a) (b)

Figure. 7. Irrigation Pipes (a) [9] Flexible Polyethylene pipeline for drip irrigation systems (b) 8” Aluminum Irrigation Pipes [10].

v. Irrigation Pipeline Valves

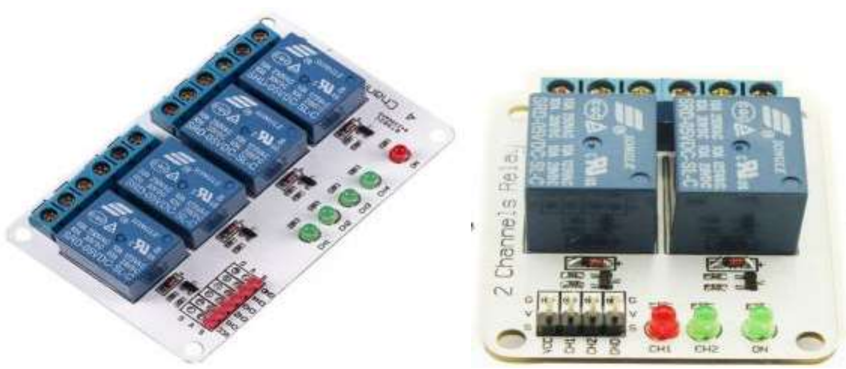
Irrigation valves are placed at strategic locations within irrigation pipes to control the flow of water. By closing or opening these valves, the flow of water to the land can be turned off or on. There are valves available for the different types of irrigation systems (see Figure 8). They usually require a power supply of 12 V or 24 V. The power connection for the valves can be connected to the Arduino mega using relays to automatically alter the power supply to the valves, causing it to either close or open.

(a) (b)

Fig. 8. Irrigation Pipeline Valves [11].

vi. 12V and 24 V Relays

Relays are electrical switches used to establish or break an electrical connection. 12 V and 24 V relays are used in the automated irrigation system to connect and control the power supply to the irrigation pipeline valves using the Arduino Mega.



(a) (b)

Figure. 9. Relays [8] (a) 12 V Relay (b) 24 V Relay [11]

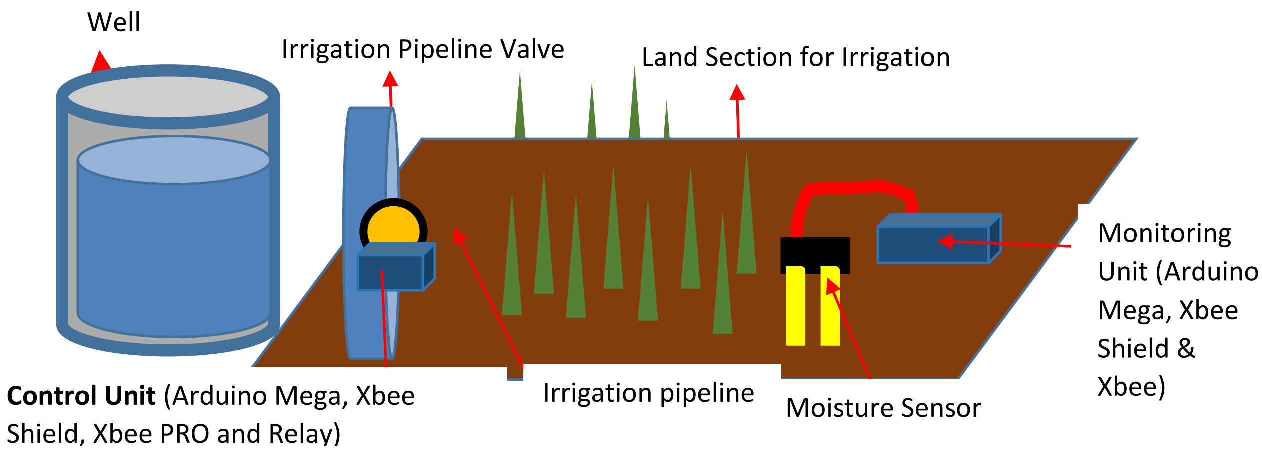
vii. Irrigation Water Pump

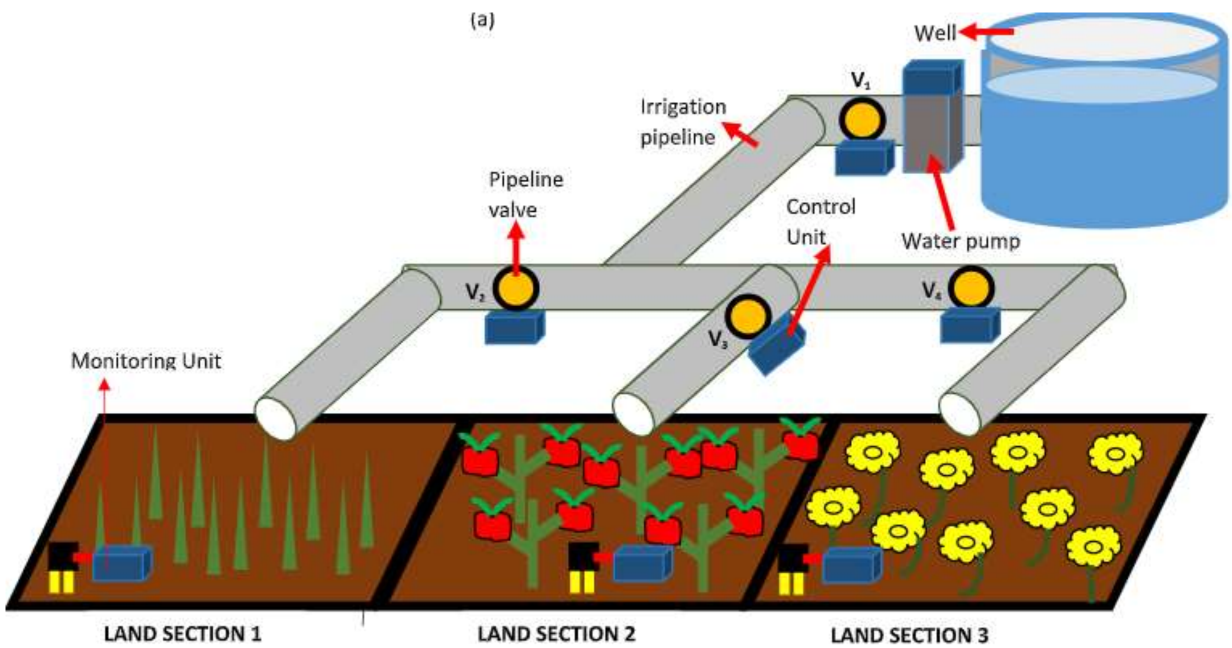
A water pump is required in order to provide enough force to move the water from the water source to the land to be irrigated. This is usually achieved by connecting a water pump to water source and the irrigation pipes.

Figure 10. Irrigation Water Pump [7]

METHODS

The automated irrigation system automatically and continuously measures the moisture level in the soil using a monitoring unit that comprises of several sensors, an Arduino Mega, XBee Shield, and XBee Pro Module. It also measures the temperature and humidity. Each valve in the irrigation pipeline is fitted with a control unit consisting of an Arduino Mega, XBee Shield, XBee Pro Module and a Relay to electrically control its power supply using the Arduino Mega. The water pump at the water source is also fitted with a control unit. When the moisture level drops below a certain threshold, the system sends a wireless message to the water pump and the pipeline valves of the irrigation system. Once these valves receive the message, the power supply to the water pump and valves are altered to activate the pump and open the valves, causing water to flow through the system and water the soil in that particular region. When the moisture level rises above a certain level, the system sends a wireless message to the water pump and the pipeline valves in the irrigation system, altering the power supply to the water pump and valves to close them, causing water to stop flowing through the system and the pump to stop allowing water from the water source flow into the irrigation pipelines and into the soil in that particular region. The automated irrigation system can be applied to a single land section requiring irrigation or multiple land sections with differing irrigation requirements. While the system is to be used primarily for land irrigation, it can also be used for automated watering of livestock, and for cooling of plants and livestock. A simple schematic of the automated irrigation system for surface irrigation of a single land section is shown in Figure 11a.





(b)

Figure 11. Automated Irrigation System (a) Surface Irrigation for a Single Land Section (b) Localized Irrigation for Multiple Land Sections.

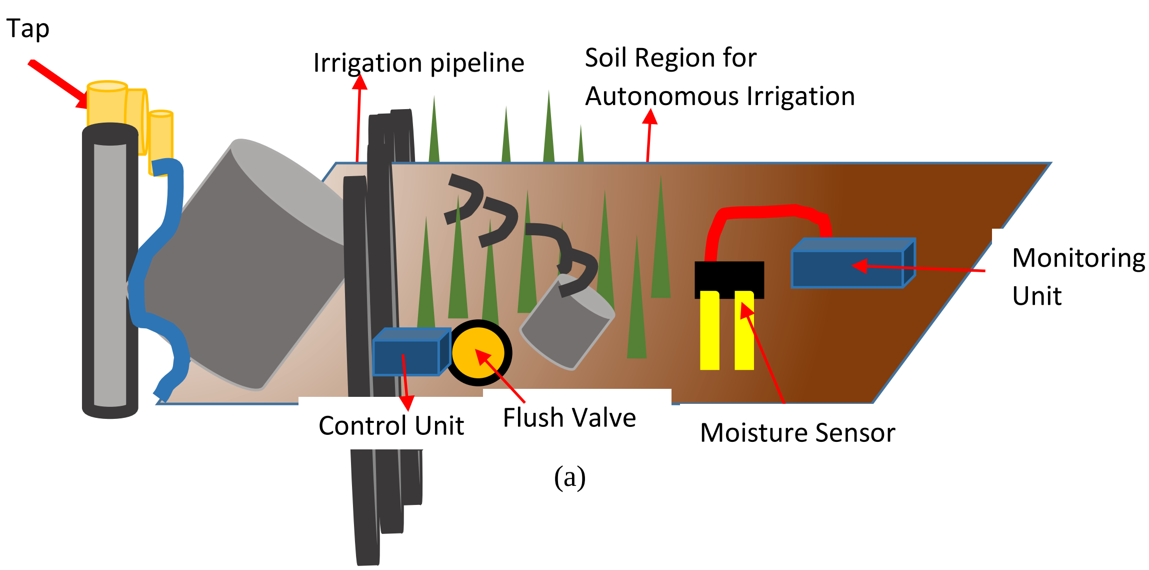
Figure 11b shows the automated irrigation system used for localized irrigation for multiple land sections. As shown in Figure 11b, the automated irrigation system can be used to water grass, agricultural crops, flowers and even trees. The soil moisture content requirement for grass, agricultural crops, flowers and trees vary. In Figure 11b, the water requirements for each of the three land sections will vary because what is being grown in each land section is different. When the measurement of the moisture sensor in Land Section 1 drops below the minimum moisture level for grass, it sends a wireless message to Valves V_1, and V_2, as well as the control unit for the water pump. This message causes the power supply to both valves and the water pump to be altered, switching on the water pump and the valves and allowing water from the well to flow into Land Section 1 only. When the measurement of the moisture sensor in Land Section 1 rises above the maximum moisture level for grass, it sends a subsequent wireless message to Valves V_1 and

V_2 and the water pump, causing the power supply to both valves and the water pump to be altered, closing the valves and the water pump, preventing water flow from the reservoir to Land Section 1.

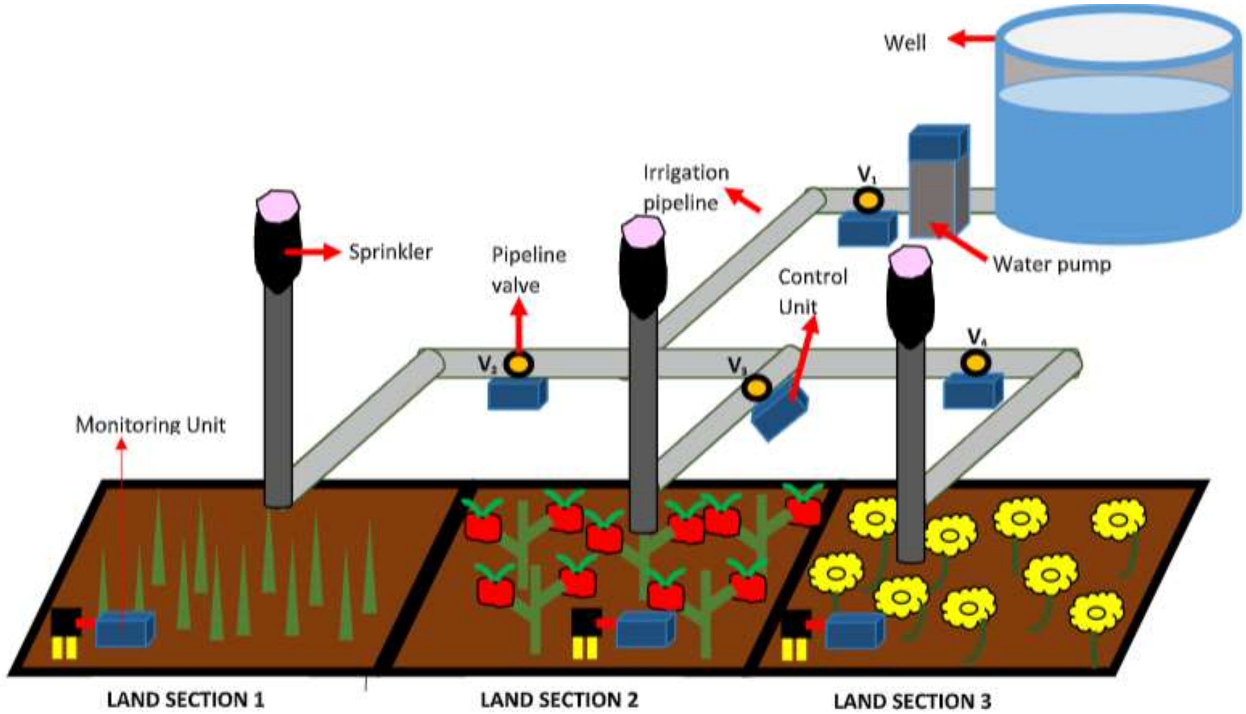
When the measurement of the moisture sensor in Land Section 2 drops below the minimum moisture level for tomatoes, it sends a wireless message to Valves V_1, and V_3, as well as the control unit for the water pump. This message causes the power supply to both valves and the water pump to be altered, opening the valves and switching on the water pump and allowing water from the well to flow into Land Section 2 only. When the measurement of the moisture sensor in Land Section 2 rises above the maximum moisture level for tomatoes, it sends a subsequent wireless message to Valves V_1 and V_3 and the water pump, causing the power supply to both valves and the water pump to be altered, shutting off the water pump and closing the valves, preventing water flow from the reservoir to Land Section 2.

When the measurement of the moisture sensor in Land Section 3 drops below the minimum moisture level for sunflowers, it sends a wireless message to Valves V_1, and V_4, as well as the control unit for the water pump. This message causes the power supply to both valves and the water pump to be altered, opening the valves and switching on the water pump and allowing water from the well to flow into Land Section 3 only. When the measurement of the moisture sensor in Land Section 3 rises above the maximum moisture level for sunflowers, it sends a subsequent wireless message to Valves V_1 and V_4 and the water pump, causing the power supply to both valves and the water pump to be altered, shutting off the water pump and closing the valves, preventing water flow from the reservoir to Land Section 3.

Figure 12a shows the automated irrigation system for drip irrigation of a single land section. The water source in this case is tap water. It is important to note that the manual valve in drip irrigation systems can now be replaced by an electronically controlled valve in the fully automated version. Figure 12 b shows the automated irrigation system for sprinkler irrigation of multiple land sections. Its operation is similar to that of the automated irrigation system for the localized irrigation shown in Figure 11b, except that the water is distributed using sprinklers instead of pipes.



(a)



(b)

Figure 12. Automated Irrigation System (a) Drip Irrigation for Single Land Section (b) Sprinkler Irrigation for Multiple Land Sections

The automated irrigation system can easily be adapted to suit any required type of irrigation and it is customizable because the size of the land to be irrigated may vary, the use of the land to be irrigated may vary, and the moisture requirement for the vegetation in the land may vary. The automated irrigation system can be used for home gardens, the agriculture industry and any other industry that requires irrigation.

DISCUSSION

A. AUTOMATION OF EXISTING IRRIGATION SYSTEMS

- *Water Source:* In order to fully automate an existing irrigation system, the water source must be considered. If the water is being mechanically pumped from the water source to the irrigation pipes as is usually the case for sources such as wells, rivers and lakes, the water pump must be modified so that it can be electronically activated and switched on and off by the control unit of the automated irrigation system. If the water source is tap water, then the valve in the tap head has to be altered so that it can be controlled electronically by the control unit of the automated irrigation system.

- *Irrigation Pipeline Valve Power Supply:* Most of the valves used in current irrigation systems are manually powered. In order to fully automate these systems, we would need to fit each valve with a small external power supply that will be connected to a control unit, as described in the methods section. The control unit for each valve will need to be individually programmed to be able to receive wireless messages from monitoring units embedded in land sections requiring irrigation through the irrigation pipeline housing that particular valve. As explained earlier, these messages are vital in establishing autonomous and automatic control of the irrigation pipeline valves. The external power supply is necessary for individual electronic control of each valve in the irrigation pipeline.

- *Optimization of Existing Irrigation Pipelines:* There are currently no framework or standards for laying out irrigation pipelines. A lot of irrigation systems are not easy to use and require some level of technical expertise for proper irrigation. Not everyone is able to accurately select the correct type of irrigation system for their specific application. And even when they do, few have the technical expertise to install the irrigation pipelines in a way that maximizes system efficiency. In order to fully automate existing irrigation systems, the irrigation pipelines may need to be optimized. The size of the land to be irrigated should be considered when selecting the diameter of the pipeline. Larger diameter pipes should be used for large land sizes to decreases irrigation time and increase irrigation coverage area of the irrigation system. The design layout of the irrigation pipeline network also needs to be optimized so that the minimum number of valves to achieve maximum system efficiency are used, and that these valves are well positioned. Accurate valve placement will have an effect on the number of valves needed in the irrigation system and the overall cost of the irrigation system. An optimized design layout of the pipeline network will also reduce irrigation time and maximize irrigation coverage area.

- *Watering Mechanism:* The watering mechanism is the means by which the irrigated water, having been successfully channeled through the irrigation pipelines, is dispersed to the land to be irrigated. Currently, it is done via the endpoints of the irrigation pipelines or sprinklers. The size, coverage area and type of the watering mechanism needs to be checked and altered if necessary

- *Monitoring Unit Placement and Characterization:* Placement of the monitoring unit in the land to be irrigated may be crucial for accurate water supply to the crops. While many irrigation systems report uniform distribution of water, the sensors in the monitoring unit can be used to ascertain that the land is being uniformly irrigated. For existing irrigation systems, monitoring units will need to be embedded at strategic locations from the watering mechanisms to evaluate water distribution. Larger land sizes will require a larger number of monitoring units. And since the moisture requirement for most crops have not yet been determined scientifically and experimentally, the monitoring units can be used extensively to measure, collect and provide this data from the agriculture industry.

- *Mechanism for Switching on Main Water Supply:* In most irrigation systems, the power to begin drawing/pumping water from the water source into the irrigation pipelines is usually turned on manually by means of a button or a switch that has to be physically pressed by the user. In order to automate these systems, some modifications will need to be made to the mechanism for switching on the main water supply to ensure thaw this can be done electronically and autonomously using a control unit of the automated irrigation systems.

B. IMPLEMENTATION OF NEW AUTOMATED IRRIGATION SYSTEMS

- *Land Assessment:* The size of the land to be irrigated and the topography of the land have to be considered and assessed prior to designing and installing the automated irrigation system. An increase in land size will result in an increase in the cost of the automated irrigation system. System installation may be a bit more difficult for lands with uneven or sloping surfaces. The water source and its proximity to the land should also be considered. The closer the water source is to the land requiring irrigation, the less expensive the customized automated irrigation system will be. The type of water source will also play a crucial role in the selection of the water pump and the complexity in the installation of the automated irrigation system. The use of the land requiring irrigation is also very important. The user will need to provide a comprehensive list of the different types of crops he/she wishes to cultivate on that particular land. This is necessary so that the user interface for the monitoring unit can be customized to provide the options requested by the user. If for instance, the user wishes to cultivate wheat and tomatoes on the land, then the monitoring unit will display those options. If the user selects wheat, then the monitoring unit will automatically begin measuring and monitoring the soil moisture to make sure it is acceptable for wheat. If tomatoes is selected, it will do likewise for tomatoes. The acceptable moisture level, the minimum moisture level triggering automatic land irrigation, and the maximum moisture level cutting off automatic land irrigation for each user-requested crop will be programmed into the monitoring units of the automated irrigation system.

- *Design of Irrigation Pipeline Network:* After land assessment, the network irrigation pipeline for the land can be designed and optimized using customized software prior to installation. The topography of the land may impact physical installation. It is far easier to install the irrigation pipeline network on lands with even and level surfaces, as opposed to mountainous, sloping and uneven surfaces. The customized design for the irrigation pipeline network should use the minimum length of pipeline to achieve maximum irrigation coverage area, as well as the minimum number of pipeline valves for automatic distribution of water. Fewer valves and smaller pipeline networks reduce the overall cost of the system. Moreover, each valve also requires its own separate power supply and control unit. A power supply of o12 V is preferable to 24 V for the irrigation valves in order to reduce power consumption. The power supply for the main water pump connected to the water source must be automated by a connection to a control unit. The selection of the main water pump will depend on the proximity of the water source to the land, the required flow rate during irrigation and the diameter of the irrigation pipelines, among other factors. The appropriate watering mechanisms will need to be selected based on the land size, land topography and the crops to be cultivated on that land. The irrigation pipeline material will be selected based on several factors including durability, resistance to corrosion, as well as cost.

- *Monitoring Unit Placement and Characterization:* The monitoring unit for the automatic irrigation system has been described extensively in the materials and methods section. It is customizable, based on the user's irrigation requirements. The accurate placement of the monitoring units in the land is crucial to ensure that he land is irrigated with the correct volume of water for the crops being grown on that land. In addition to ensuring the approximate volume of water is disbursed during irrigation, the monitoring units can also be used to ensure that the water is also uniformly distributed during irrigation. If the user requires additional features, such as plant and livestock cooling, frost protection and dust suppression, these can also be easily integrated into the automated irrigation system by upgrading the customized program for the monitoring units.

The impact of automated systems on the agriculture industry is enormous. These systems, once installed can run continuously and autonomously without requiring any user intervention. This means the system can be turned on once at the start of the growing season (April 1) and left on until the end of the growing season (October 1), and it will continuously and autonomously irrigate the land with the required amount of water during this time period without any human intervention. This will save the users a lot of time and physical exertion. It will also ensure maximum crop production and the total cost of the automated irrigation system when compared with other systems is far less when you factor in the savings of time, strength and energy during the growing season, as well as the maximum productivity associated with automatic and accurate irrigation of the cultivated crops.

Future work includes construction, implementing, testing and characterization of a prototype of the automated irrigation system, as well as the rigorous characterization of the soil moisture requirements for various agricultural crops.

CONCLUSION

Irrigation Systems are not yet automated because of a lack of collaboration between the agriculture industry and other technologically savvy industries, as well as an inaccurate perception of the industry in general. Automated Irrigation Systems work by continuously monitoring the soil moisture content and wirelessly activating the pipeline valves to open when the moisture level drops below the minimum threshold for the cultivated crop, causing the land to be irrigated. When the moisture level rises above the maximum threshold, the system deactivates the irrigation pipeline valves, causing them to close and ceasing land irrigation. The automated irrigation system can be customized for different types of irrigation and existing systems can be upgraded to automated irrigation systems. Future work includes construction, implementing, testing and characterization of a prototype of the automated irrigation systems, as well as the rigorous characterization of the soil moisture requirements for various agricultural crops.

CONFLICTS OF INTEREST

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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