Internet of things based agricultural drought detection system: case study Southern Somalia

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ABSTRACT

Drought is defined as a protracted lack of precipitation that lasts at least a season, resulting in a water deficit that affects plants, animals, and humans. It is a widespread and repeating feature of climate change in practically all temperate zones, ranging from excessively wet to burned. In Somalia, the government and farmers lack the technological skills to identify and monitor recurrent environmental issues. Our research created a technique for detecting droughts early on to reduce their impact. Using internet of things (IoT) devices, we created a system that measures temperature, humidity, and soil moisture. We then examined the data and used a line chart to show it in a web application (PHP and MySQL). The device reads these environmental parameters using an Arduino Uno, a DHT11 sensor, and a soil moisture sensor. The system deployed provides a real-time, cost-effective method for monitoring and controlling drought in modern agriculture.

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1. INTRODUCTION

It's a common, recurring element of climate change in almost all temperate zones, from extremely rainy to extremely dry [1]. Drought occurs after a prolonged absence of precipitation, generally lasting a season or more, resulting in a water deficit affecting plants, animals, and humans. It is a natural occurrence that occurs regularly and is associated with significant consequences [2]. It also elevates temperatures, which induces excessive evapotranspiration. Sustaining soil moisture deficits may significantly affect agricultural production, the environment, and cultural livelihood [3].

Lack of rain and natural hazards were the main reasons for increasing droughts worldwide [4]. According to Giovetti [5], years of drought have left approximately 50% of the country (Somalia) hungry. Droughts have been observed in the Deyr (October-December) season at intervals of 2-3 years and in consecutive Deyr and Gu’ (April-June) seasons for 8-10 years. There were ten severe droughts between 1918 and 1975, according to statistics. In the last quarter-century, Somalia has endured three cycles of prolonged drought and two times of famine [6]. In recent decades, extreme droughts have hit Somalia, devastatingly impacting agriculture, society, and the environment, severely affecting food production and water supplies [7]. The total cost of the drought in Somalia is expected to exceed USD 3.25 billion, including damages of USD 1.02 billion and losses of USD 2.23 billion [8].

Before the droughts in 2011, Somalia suffered several disasters, and we can find many parallels with past experiences. In 1974-1975, 2001, 2006, and 2008, various parts of Somalia faced droughts. The Somalia population could hardly face it, as 2011 was the decades-old driest year. In the summer of 2011, acute food insecurity emerged in some regions of Southern Somalia, and the drought turned into a major food crisis. Since 2011, Somalia has only experienced one good rainy season in 2013, with the remaining years falling far short of two rainy seasons per year. In 2017, it had become the "worst drought in decades." The long-awaited rains eventually arrived at the end of 2017, but they were insufficient to affect substantially [5]. Drought conditions increased dramatically across Somalia in 2021, following three consecutive failed rainy seasons and poor performance in the Deyr (October to December) rainy season [9]. On July 20, 2021, the United Nations declared lower shebelle and bakool a state of hunger. That year, between July and August, the state of famine expanded into another three regions [10].

As of 2022, the drought conditions are still going on, and the rescue plan is based on the 2017 drought experience [11]. More than 3.2 million people have been displaced in 66 of the country's 74 districts due to three consecutive below-average rainy seasons, with 169,000 fleeing their homes in search of water, food, and pasture [12]. However, global warming is the primary cause of droughts worldwide [13]. Studies also show that global warming is still happening despite all the decisive measures to reduce it [14].

Previous research has demonstrated the design and implementation of several internet of things (IoT) based models and systems for drought data acquisition and monitoring. The underlying concept of IoT is the integration of physical items, sensors, and other smart technologies into a single system. IoT offers exponentially expanding opportunities for new functionalities and capabilities that transcend traditional boundaries [15], [16]. Collecting data via IoT devices is then utilized for analysis, clustering, classification, or prediction [17]. A study used the IoT devices on drought conditions to record and process data to obtain optimal clusters and identify constraints and the amount of water required in agriculture [18]. Deep learning was utilized in this study to examine and optimize data for precision prediction and identification. After 30 days of the experiment, the result revealed that the system could save 13.89% more water than the conventional method. Another study designed and implemented hydroponic farming using IoT devices with ESP32 microcontroller via Google Firebase [19]. Such design and deployment of IoT-based monitoring systems went just as planned, with excellent results. The results of the tests also revealed that the linearity, accuracy, and precisions were relatively high.

The absence of an efficient Somali government, which could play a role in warning against droughts and helping natural disasters, left citizens alone to handle disasters independently. Drought deficiencies resulted in damages estimated at billions of dollars, which affected different aspects of life [10]. Therefore, a solution is required to indicate and detect drought conditions. So, this study proposes and develops a drought detection system to help humanitarians and disaster management identify droughts early and suggest when to take corrective measures. This system will present the sensors' collected data from the environment and visualize it in a line chart.

2. METHOD

To indicate and detect drought conditions and their intensity in the early stage from different locations across the country, we propose and build a drought monitoring system using IoT devices. The developed system consists of multiple sensor devices that monitor a specific area by collecting critical environmental parameters such as temperature, humidity, and soil moisture. The data collected by each sensor device will be sent to a MySQL database and then displayed on the web using line charts. Figure 1 shows the system architecture of the proposed method. Humidity and temperature sensors, soil moisture sensors, GSM/GPRS modem, and an Arduino Uno microcontroller are selected for the proposed system. The data from sensors communicate wirelessly using the arduino uno microcontroller chip. Below are described the pieces mentioned above of equipment as follows.

2.1. Humidity and temparature sensor

The DHT11 is an inexpensive temperature and humidity sensor. It reads the ambient air and sends a digital signal to the data pin. It's easy to use, but data collecting necessitates precision timing. When utilizing the Adafruit library, sensor readings can be up to 2 seconds outdated [20]. This sensor will read the environmental temperature and humidity to monitor the current weather conditions. Then the captured data will be sent to the microcontroller.

2.2. Soil moisture sensor

The soil moisture sensor works straightforwardly. The fork-shaped probe works as a variable resistor, which varies with soil moisture content. This resistance is inversely related to soil moisture. According to the opposition, the sensor provides an output voltage, which we may measure to estimate the moisture level [21]. The sensor will detect moisture in the soil and send the information to the microcontroller.

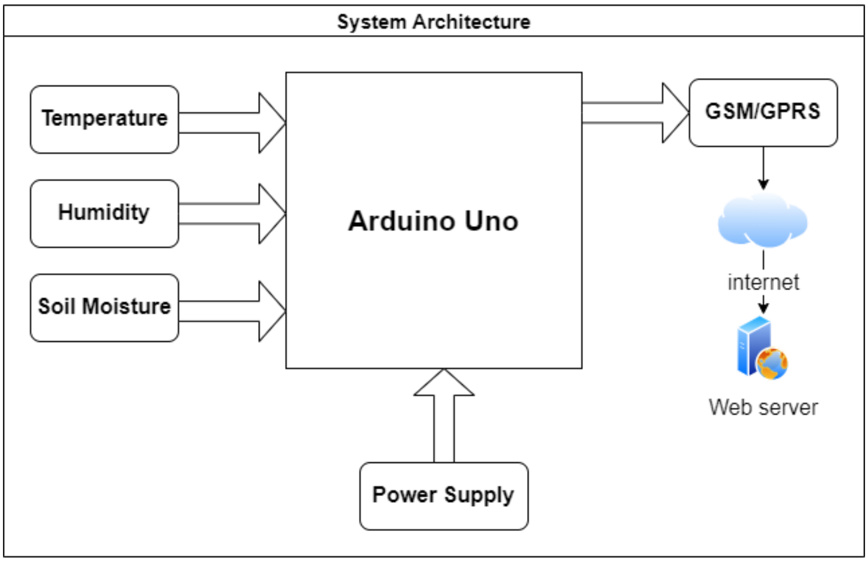

Figure 1. Proposed system architecture

2.3. GSM/GPRS modem

We used a small GSM modem to integrate our project, the SIM800L GSM/GPRS module. This module can do nearly all standard cell phone functions, including sending and receiving SMS text messages, making and receiving phone calls, connecting to the internet via GPRS, and transmission control protocol/internet protocol (TCP/IP). Because the module works with a quad-band GSM/GPRS network, it can be utilized practically anywhere [22]. Using the internet functionality provided by this module, we sent the data that we collected from the environment to a web server.

2.4. Arduino Uno

Arduino is a microcontroller that allows people to interact with interactive things and their surroundings. The Arduino Uno board uses the Atmega328 microprocessor. A 16 MHz ceramic resonator is included, a USB connection, in circuit serial programming (ICSP) header, a power connector, a reset button, six analog inputs, and 14 digital input/output pins [23]. All the sensors will be connected to the Arduino Uno, and the Arduino Uno will send the captured data to the webserver using GSM/GPRS modem.

3. RESULTS AND DISCUSSION

The agricultural drought detection system has been implemented in agricultural regions near Mogadishu, the capital city. Afgoye (lower shabelle) and Balad (mid shabelle) were chosen from two areas. The devices successfully read the two districts' temperature, humidity, and, most importantly, soil moisture. The US Department of Regional Environment Office for South Asia supported the development of a drought monitoring system [24]. Compared to our agricultural drought detection system, their system uses an online database of remote sensing to track the growth of drought by continuously evaluating the condition of ground vegetation; it works fine at a remotely sensed (0.5×0.5 km) and in near real-time, it allows to add of new data for every 9 or 16 days. Likewise, our system was successfully deployed as a web application hosted on a web server storing the data (the two districts' temperature, humidity, and soil moisture). After deployment to the environment, the system successfully sent and delivered the data to the web server in seconds.

On the other hand, the Germans developed a German drought monitor (GDM) system that measures soil drought conditions with high spatial precision and compares current drought events to the past [25]. GDM system score previous drought cases in Germany and anticipates seasonal droughts across Europe. The GDM framework is data fed to the hydrologic model after importing and interpolating meteorological data from the national weather service. The hydrologic model calculates the soil moisture index by estimating the entire root zone. Regularly the soil moisture index is defined and visualized [25]. The GDM offers a readily available agricultural drought information system on a state and national basis. It adds value by making previously inaccessible data available regularly in high resolution. The GDM is driven by an observational dataset that allows for higher spatial precision drought projections (4×4 km^2) than other items. Every day, with a four-day latency, a soil drought map for Germany is issued to the public [25]. Unlike the GDM, our system captures the data from the devices and transfers it to the database on the web server in real-time. The data is then analyzed and displayed in a graph (line chart). In addition, a global integrated drought monitoring and prediction system (GIDMPS) was developed [26], providing drought information (conditions) upon various indicators, including monitoring and forecasting: the standardized precipitation index (SPI), standardized soil moisture index (SSI), and multivariate standardized drought index (MSDI). The GIDMPS system includes a near-real-time monitoring component and a seasonal probabilistic forecast module. The GIDMPS system's data sets include historical drought intensity data from the monitoring component and probabilistic seasonal projections from the prediction module. Therefore, all the devices successfully transmitted the data during the system's deployment, as Tables 1 and 2 show, which present the raw data of district and national drought conditions, respectively. Table 2 presents the raw data of national based drought condition sent by the system. After the data is sent from the devices, it is analyzed and presented as a graph in Figure 2. This figure shows the drought conditions based on the district. While Figure 3 shows the drought conditions at a national level.

Table 1. District based raw data

#	Temperature (celcius)	Humidity (%)	Soil moisture (%)	Districts	Date
2	28	72	80	Afgooye	2021-08-18 22:18:47
3	28	72	80	Afgooye	2021-08-18 22:19:07
4	28	72	80	Afgooye	2021-08-18 22:19:27
5	28	72	80	Afgooye	2021-08-18 22:19:47
6	28	72	80	Afgooye	2021-08-18 22:20:07
7	28	72	79	Afgooye	2021-08-18 22:20:27
8	28	72	81	Afgooye	2021-08-18 22:20:47
9	28	72	79	Afgooye	2021-08-18 22:21:07
10	28	72	79	Afgooye	2021-08-18 22:21:27
11	28	72	79	Afgooye	2021-08-18 22:21:47
12	28	72	79	Afgooye	2021-08-18 22:22:07
13	28	72	79	Afgooye	2021-08-18 22:22:27

Table 2. National based raw data

#	Temperature (celcius)	Humidity (%)	Soil moisture (%)	Districts	Date
78	30	71	80	Afgooye	2021-08-19 09:21:47
79	30	71	80	Afgooye	2021-08-19 09:22:07
80	30	71	80	Afgooye	2021-08-19 09:22:27
81	29	73	75	Balcad	2021-08-19 09:22:47
82	29	73	75	Balcad	2021-08-19 09:23:07
83	29	73	75	Balcad	2021-08-19 09:23:27
84	29	73	75	Afgooye	2021-08-19 09:23:47
85	30	71	80	Afgooye	2021-08-19 09:24:07
86	30	70	77	Afgooye	2021-08-19 09:24:27
87	29	72	79	Balcad	2021-08-19 09:24:47
88	29	74	79	Balcad	2021-08-19 09:25:07
89	29	74	79	Balcad	2021-08-19 09:25:27

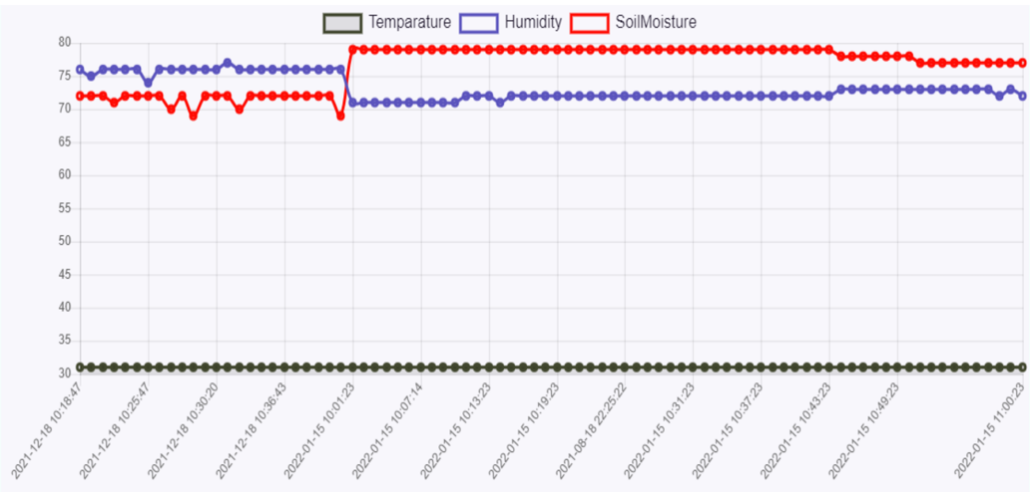

Figure 2. District condition

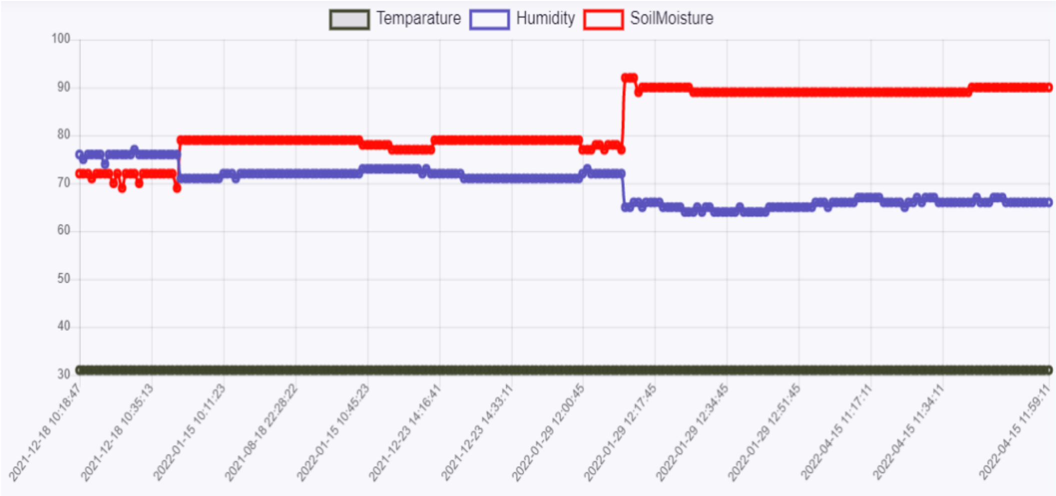

Figure 3. National level condition

4. CONCLUSION

Our research conceived and created a drought warning system based on IoT devices. A model that provides a low-cost, real-time approach for identifying droughts. IoT devices (sensors) were employed to read environmental data such as soil moisture, humidity, and temperature. By installing the system in two districts (lower and middle shabelle), the data was successfully supplied into the database and then exhibited on the web application using a line chart. Using the suggested and established architecture, humanitarian and disaster management organizations in the public and commercial sectors may cope with, and even benefit from, receiving updated information. It also aids in detecting drought in its early stages, signaling when corrective steps should be taken.

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