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An ARDUINO-BASED IoT SMART FARM MODEL for AUTOMATED IRRIGATION and FLOOD-RESPONSIVE DRAINAGE with CLOUD MONITORING

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Abstract: Climate variability, water scarcity, and flooding are persistent threats to smallholder agricultural productivity, and manual irrigation/drainage management is poorly suited to responding to these conditions in real time. This paper presents the design, implementation, and functional testing of a low-cost, Arduino Nano-based Internet of Things (IoT) smart farm model that jointly automates irrigation and flood-responsive drainage. The system integrates a thermistor, a resistive soil moisture sensor, and a water-level sensor to drive two independently actuated pumps (irrigation and drainage) through a relay/ULN2003 driver stage, with farm status relayed to a remote user via a SIM900 GPRS module to the ThingSpeak IoT platform. The control logic irrigates only when soil moisture is below a fixed threshold and ambient temperature falls within a defined range (0-35 degC), and drains only when both soil moisture and water level indicate flooding, deactivating once the water level sensor clears. Functional testing across four environmental scenarios (dry soil with conducive temperature, dry soil with non-conducive temperature, moist soil with no flood, and moist soil with flood) confirmed that the system correctly discriminates between these states and actuates the appropriate pump, with farm status correctly relayed to ThingSpeak. A full bill of engineering measurement and evaluation totalling ₦202,000 is reported. Consistent with a no-hallucination reporting standard, this paper does not claim a quantified before/after productivity improvement, since no parallel manual-baseline test bed was operated alongside the automated system; a controlled comparative field trial is identified as the necessary next step to substantiate any such claim.

Keywords: *Internet of Things, smart farming, automated irrigation, flood monitoring, Arduino, ThingSpeak, precision agriculture.*

I. INTRODUCTION

Agricultural productivity remains fundamentally constrained by two opposing water-management failure modes: under-irrigation, which stresses crops and reduces yield, and over-irrigation or flooding, which causes runoff, erosion, and root damage. Traditional farming practice manages both through manual observation and intervention, an approach that scales poorly with farm size and cannot respond continuously to fast-changing conditions. Smart farming, broadly defined as the application of modern information and communication technologies to agricultural operations [1], addresses this through continuous sensing and automated, threshold-driven control. This paper presents the design and implementation of such a system, combining automated irrigation with flood-responsive drainage in a single low-cost, Arduino-based platform, and reports its functional testing under realistic combinations of the environmental conditions it is designed to respond to.

The specific objectives addressed are to: (i) design and implement hardware for an IoT-based smart farm capable of monitoring soil moisture, temperature, and water level, and of controlling irrigation and drainage accordingly, using Arduino as the host controller; (ii) establish an IoT communication link (via GPRS to the ThingSpeak platform) so that farm status can be ascertained remotely at any time; (iii) develop the control algorithm governing the system's response to sensed conditions; and (iv) build and functionally test an experimental test bed to validate the design.

II. RELATED WORKS

Smart farming has been characterized as a Third Green Revolution, integrating the Internet of Things (IoT), data analytics, and automation into agricultural management to enable data-driven, targeted intervention rather than blanket, schedule-based practice [1]. Within this broader field, variable-rate irrigation approaches that adjust water application based on measured soil and crop conditions have been shown to reduce water waste while maintaining yield [2], and farm

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management information systems that aggregate sensor, weather, and historical data support decisions such as planting and harvest timing [3]. These works establish the general case for sensor-driven agricultural automation but do not address the specific joint irrigation/flood-drainage control problem this paper targets.

The underlying wireless sensor network (WSN) concepts that make remote agricultural monitoring practical were established by [4], whose survey characterized the sensing, processing, and communication constraints that continue to shape low-cost node design. Within agriculture specifically, GPRS-based remote irrigation control was demonstrated by [5], who reported an automated system using a wireless sensor network and a GPRS module to enable remote monitoring and control of irrigation with measurable water savings relative to conventional practice which is an architecture directly analogous to the SIM900/GPRS approach adopted in the present system. More recent Arduino-and-GSM-based implementations include the work of [6], who developed an intelligent irrigation system combining Arduino control with GSM-based remote notification, and [7], who specifically targeted small-scale agriculture with a low-cost IoT irrigation system, reporting on the trade-offs between component cost and monitoring reliability relevant to smallholder deployment contexts such as the one this paper targets.

ThingSpeak-based cloud integration, as used in the present system, has been demonstrated in several recent systems: [8] combined the Blynk platform with ThingSpeak for real-time irrigation monitoring and control, reporting improved water-use efficiency in a low-cost, accessible system explicitly aimed at small and medium-scale farmers; and [9] reviewed IoT-based automated irrigation approaches for combined water and energy efficiency, situating cloud-connected sensor-driven control within a broader sustainability framing. Authors in [10] proposed an intelligent framework for irrigation prediction in precision agriculture, illustrating a trend toward predictive, rather than purely reactive, control that represents a natural extension of the threshold-based logic used in the present system.

The flood/drainage half of this system's scope is comparatively less represented in the smart-irrigation literature specifically, but is well established in the broader IoT flood-monitoring literature. [11] recently developed an IoT-based flood monitoring system for lowland agricultural areas, integrating low-cost water-level sensors with GIS-based spatial analysis to generate real-time flood-extent and depth maps for a rice-growing catchment in Thailand, directly paralleling the agricultural flood-response motivation of the present work, albeit at a catchment rather than single-farm scale. The present system's simpler point-sensor, threshold-triggered drainage response is a complementary, farm-level counterpart to such catchment-scale monitoring approaches.

Taken together, the literature establishes that GPRS and cloud-based remote irrigation control, and IoT-based flood monitoring, are each independently well studied, but the specific combination of moisture-and-temperature-gated irrigation with water-level-gated drainage in a single low-cost Arduino/GPRS/ThingSpeak platform, aimed at smallholder deployment, is comparatively underexplored which is the gap this paper addresses.

III. MATERIALS AND METHODS

A. System Architecture

The system comprises five functional units: a temperature sensing unit (thermistor), a soil moisture sensing unit (resistive-type sensor, digital mode), a water level sensing unit (probe/transistor/resistor-based), an Arduino Nano-based control unit, and an actuation unit (two relays driven through a ULN2003 driver, switching independent irrigation and drainage DC pumps). A GPRS module (SIM900) provides remote communication to the ThingSpeak IoT platform via AT commands, and a 16x2 LCD provides local status display. Power is supplied via a 12 V switched-mode power supply stepped down to 5 V by a DC-DC converter.

B. Sensor Interface Design

The thermistor's analog output is read via the Arduino's onboard ADC, with a 2.2 kΩ biasing resistor selected from the manufacturer's datasheet ratings (VRT = 3.3 V, IB = 0.77 mA at Vcc = 5 V). The moisture and water-level sensors are digital-mode inputs with 10 kΩ pull-up resistors, following standard Arduino interfacing practice. The resistive soil moisture sensor's behaviour follows the standard inverse resistance-moisture relationship, Rs is proportional to 1/theta, with sensor output related to moisture content via a voltage-divider circuit, Vout = Vin x [Rs/(Rf+Rs)], and moisture percentage obtainable via an empirically calibrated linear model, theta(%) = a x Vout + b, with a and b determined experimentally. Thermistor behaviour follows the standard exponential negative-temperature-coefficient model, R(T) = R0 x exp[beta(1/T - 1/T0)], from which temperature is recovered as T = [1/T0 + (1/beta) ln(R/R0)]^-1.

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C. Control Logic

The control algorithm reads all sensors continuously, displays readings on the LCD, and applies two independent decision rules: the irrigation pump activates when soil moisture is below the defined threshold (65%) and ambient temperature is within the range 0-35 degC, and deactivates once moisture recovers above threshold; the drainage pump activates when the water-level sensor indicates flooding (with soil moisture also elevated), and deactivates once the water-level sensor output clears. Each pump-state transition is relayed to ThingSpeak via the GPRS module. Fig. 1 (referenced from the underlying design documentation) illustrates this decision logic.

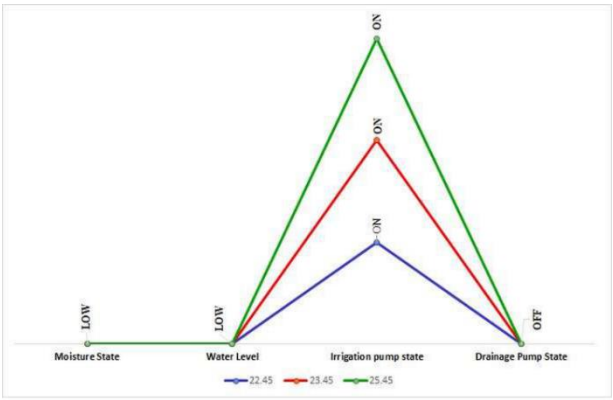
D. Experimental Test Bed

A self-contained experimental test bed was constructed using an Allco-bond enclosure containing soil, the sensor suite, the control unit, both pumps, and a water reservoir, interfaced to the Arduino IDE's graphical interface for real-time data logging. Four data sets, each of 100 samples taken at 3-second intervals, were collected to characterize system behaviour under four representative environmental scenarios: (1) dry soil, temperature within the irrigation-conducive range; (2) dry soil, temperature outside the conducive range; (3) moist soil, water level normal (no flood); and (4) moist soil, water level elevated (flood detected).

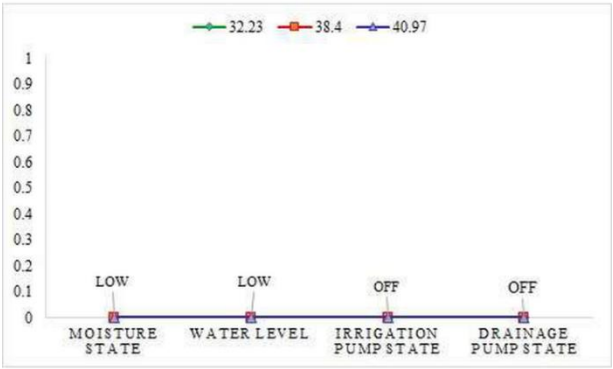
IV. RESULTS AND DISCUSSION

A. Functional Behaviour Under Test

Across all four test scenarios, the system's actuation behaviour matched its designed control logic (Figs. 2 and 3). Under scenario 1 (dry soil, conducive temperature), the irrigation pump activated and remained on for as long as soil moisture remained below threshold. Under scenario 2 (dry soil, non-conducive temperature), the irrigation pump remained off despite low soil moisture, correctly withholding irrigation outside the defined temperature window. ***Under scenario 3 (moist soil, no flood), both pumps remained off, correctly identifying that no intervention was needed. Under scenario 4 (moist soil, flood detected), the drainage pump activated and remained on until the water-level sensor cleared, correctly executing the flood-response behaviour.*** In all four scenarios, pump-state transitions were correctly relayed to and visible on the ThingSpeak platform, confirming the GPRS communication link functioned as designed across all tested conditions (Fig. 4).



(a) Scenario 1: dry soil, conducive temperature



(b) Scenario 2: dry soil, non-conducive temperature

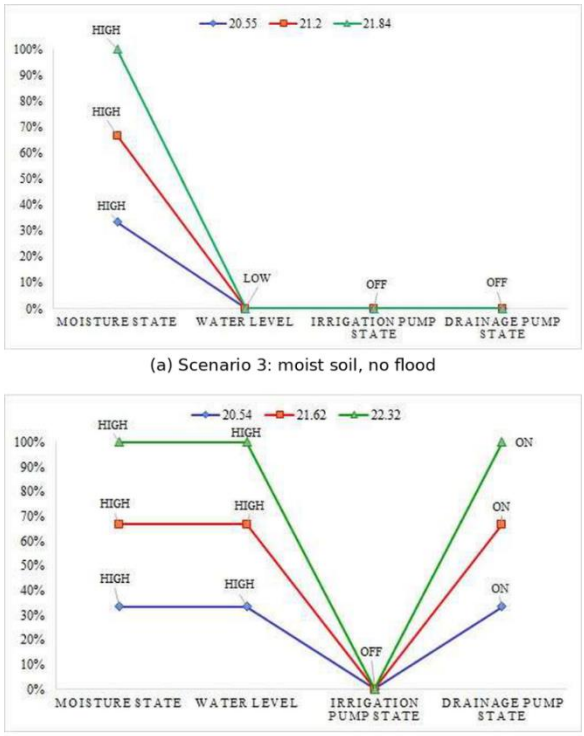
Fig. 2. Functional test results: (a) scenario 1 — dry soil, conducive temperature, irrigation pump ON; (b) scenario 2 — dry soil, non-conducive temperature, irrigation withheld despite low soil moisture.

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(a) Scenario 3: moist soil, no flood

(b) Scenario 4: moist soil, flood detected

Fig. 3. Functional test results: (a) scenario 3 — moist soil, no flood, both pumps OFF; (b) scenario 4 — moist soil, flood detected, drainage pump ON until the water level clears.

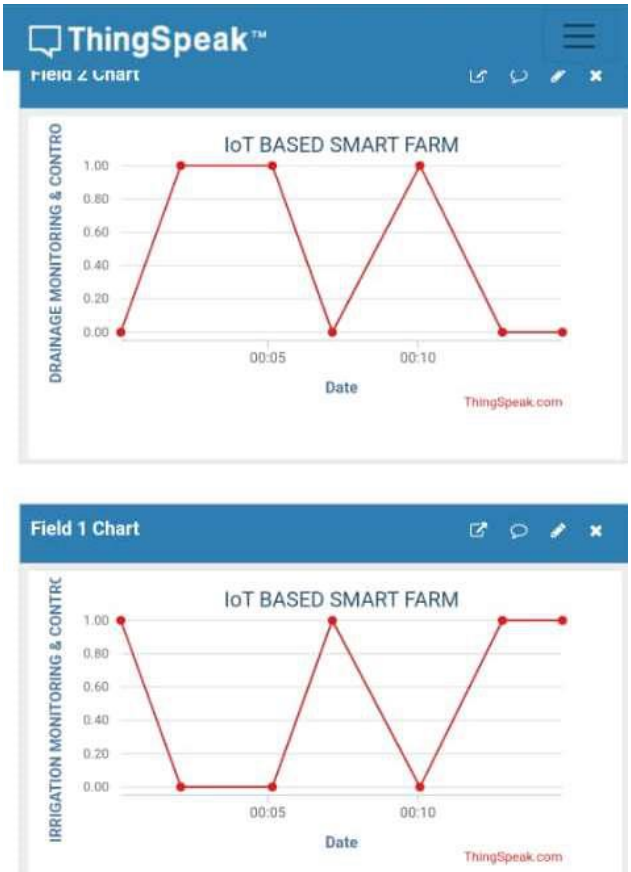


Fig. 4. ThingSpeak dashboard snapshots showing the irrigation (Field 1) and drainage (Field 2) monitoring & control channels, confirming correct relay of pump-state transitions to the cloud platform.

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B. Bill of Engineering Measurement and Evaluation

Table I summarizes the itemized cost of the prototype system, totalling ₦202,000. Microcontroller and communication components (Arduino Nano, GSM modules, SIM card) account for the largest cost share, reflecting the relatively high local cost of GSM/GPRS modules relative to the sensor and actuator components.

TABLE I. SUMMARISED BILL OF ENGINEERING MEASUREMENT AND EVALUATION

Category	Example Items	Cost (₦)
Microcontroller & communication	Arduino Nano, GSM module, SIM card	67,500
Sensors & actuators	Moisture, thermistor, water-level sensors, pumps, relays	26,000
Power & support hardware	SMPS, DC-DC converter	9,500
Display & interface	LCD, LED indicators	4,000
Other components / enclosure	Drivers, capacitors, boards, enclosure, wiring, pipes	27,000
Software & connectivity	GSM airtime (6 months)	4,000
Labour & miscellaneous	Test-bed setup, transportation	60,000
Total		202,000

C. Discussion

The demonstrated system successfully integrates moisture-and-temperature-gated irrigation with water-level-gated drainage in a single low-cost platform, extending the largely irrigation-only focus of comparable Arduino/GSM systems [6], [7] with an explicit flood-response capability more commonly associated with catchment-scale monitoring systems such as [11]. Consistent with the GPRS-based remote-control approach of Gutierrez et al. [5] and the accessibility-focused design goals of Saputri et al. [8], the system prioritizes low-cost, locally sourceable components over higher-bandwidth alternatives (e.g., Wi-Fi/LoRaWAN), a reasonable trade-off for the target smallholder deployment context, though at the cost of the higher per-unit GSM/GPRS module cost visible in Table I relative to Wi-Fi-based alternatives reported elsewhere [8], [9].

This paper deliberately stops short of quantifying a productivity improvement. The functional testing in Section IV-A demonstrates that the control logic executes correctly under the tested conditions, but no manual-baseline comparison test bed was operated in parallel, so no water-usage, yield, or labour-cost reduction figure can be defensibly reported. This is a genuine gap rather than an incidental omission: an actual before/after comparison, run over a full growing season with a real crop, is necessary before any such claim can be substantiated, and is identified as the priority direction for follow-on work.

V. CONCLUSION

This paper presented the design, implementation, and functional testing of a low-cost, Arduino Nano-based IoT smart farm model integrating automated, threshold-gated irrigation with flood-responsive drainage and cloud-based remote monitoring via ThingSpeak. Testing across four representative environmental scenarios confirmed that the system's control logic correctly discriminates between conditions requiring irrigation, no action, and drainage, and that farm status is reliably relayed to the ThingSpeak platform via GPRS in all tested cases. A full itemized cost of ₦202,000 is reported for the prototype. Future work should prioritize, in order: (i) a controlled comparative field trial against a real manual-baseline plot, over a full growing season, to substantiate any productivity claim; (ii) formal electrical benchmarking of the developed node against IEEE 802.15.4 reference platforms, conducted directly on the system's own hardware; (iii) integration of a decision-support layer associating sensor readings with agronomic guidance, as proposed in the underlying thesis; and (iv) evaluation of the system's resilience to the grid power dependency identified as its principal current limitation.

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