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A Cost-Effective IoT Smart Irrigation Node with Soil-Moisture-Triggered Watering and Cloud Reporting

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Abstract

This paper reports the design of a low-cost Internet-of-Things irrigation node intended for smallholder use, in which a soil moisture probe and a temperature and humidity sensor feed an ESP8266 microcontroller that switches water only when the soil requires it and publishes every channel to an Adafruit IO cloud channel that the farmer can open in a browser. The stated aim of the project is to irrigate only on demand and to compare the resulting water use across three soil types, being sand, clay and sandy clay, against traditional practice. This paper formalises the soil-water, triggering and water-accounting relations that such a comparison rests on, and then examines what the comparison requires. Two findings follow, and both are quantitative. First, the published water-retention bands for these three textures do not overlap in the way a single firmware threshold assumes: sand reaches field capacity between about 0.10 and 0.18 cubic metres per cubic metre while clay does not reach its permanent wilting point until about 0.25 to 0.30, so a soil reading of 0.20 is above field capacity for sand and below wilting point for clay. A single threshold applied to all three soils therefore triggers at a different plant-water state in each, and the resulting water use differs for that reason before any property of the controller is considered. Second, a soil moisture probe of this class outputs an uncalibrated analogue count rather than a volumetric water content, and the calibration relating the two is itself soil-specific, so the three-soil comparison depends on exactly the calibration that such builds ordinarily omit. A percentage water saving additionally requires both a metered delivered volume and a defined baseline practice, and the component set described contains no flow measurement. The paper computes the per-event refill depth each soil requires, specifies the three additions that would make the comparison valid, and states clearly that it was prepared from the project abstract alone, so every status entry is marked for confirmation against the full record rather than asserted.

Nomenclature

Symbol	Meaning
θ	Volumetric water content (m^3/m^3)
θ~FC, θ~PWP	Water content at field capacity and at permanent wilting point
AWC	Available water capacity, the difference between the two (m^3/m^3)

θ~trig	Water content at which irrigation is triggered
p	Allowable depletion fraction before irrigation
Z_r	Root-zone depth (mm)
d, A, V	Refill depth (mm), irrigated area (m^2) and water volume (m^3)
V_{base}, V_{IoT}	Water volume used by the baseline practice and by the system
S	Water saving (%)
ADC	Raw analogue reading returned by the moisture probe
T_a, RH	Air temperature (degrees Celsius) and relative humidity (%)
ET_0, ET_c, K_c	Reference and crop evapotranspiration (mm/day) and crop coefficient

Introduction

Irrigation accounts for the largest share of freshwater withdrawal in most agricultural economies, and a substantial part of it is applied on a fixed schedule rather than on demand. Watering by calendar rather than by need means water is applied when the soil does not require it, which wastes the water, leaches nutrients below the root zone and, in some soils, harms the crop. A sensor that reports the soil's actual state, and a controller that acts on it, addresses this directly and at low cost [1], [2].

The economics are now favourable at smallholder scale. A Wi-Fi microcontroller, a soil moisture probe and a temperature and humidity sensor cost a few dollars in total, and free cloud channels such as Adafruit IO provide dashboards and remote access without any server of one's own [5], [6]. This paper reports a node of that kind: soil moisture and air conditions sensed in the field, watering switched on a threshold, and every channel published to a cloud channel the farmer opens in a browser.

The project's stated aim goes beyond demonstrating that the node works. It sets out to compare water use across three soil types, sand, clay and sandy clay, against traditional practice. That is the right question to ask, and it is a considerably harder one than switching a pump. This paper formalises what it requires.

1. Problem Statement

Reported smart-irrigation prototypes are numerous and nearly all demonstrate the same thing: a threshold is crossed, a pump runs, a dashboard updates. Comparatively few report a water volume, and fewer still define the baseline practice against which a saving is claimed. Where a comparison across soil types is attempted, an additional difficulty is usually left implicit: the sensor reading that triggers irrigation does not mean the same thing in different soils, so a single threshold does not represent a single agronomic decision. This paper makes both requirements explicit and quantifies the second.

2. Objectives

The specific objectives of the work are as follows:

- To build a low-cost node that senses soil moisture, air temperature and humidity, switches irrigation on demand, and publishes all channels to a cloud channel accessible to the farmer.
- To consolidate the soil-water, triggering and water-accounting relations on which an on-demand irrigation claim rests.
- To establish, from published retention data, what a single moisture threshold means in each of the three soils the project compares.
- To compute the refill depth and event volume each soil requires, so that the comparison has predicted values against which measurements can be checked.
- To state what a percentage water saving requires, being a metered volume and a defined baseline.
- To specify the minimum additions that would make the cross-soil comparison valid.

3. Scope and Delimitation

The study covers the node design, the soil-water and scheduling relations, the published retention data for the three textures, and the specification of what the water-saving comparison requires. It does not report a water volume, a percentage saving, a soil moisture value in volumetric terms, or a crop outcome, because this paper was prepared from the project abstract and no such data were available to it. It makes no claim about what the campaign did or did not record; that determination belongs to the full report.

4. Contributions

1. A consolidated set of soil-water, triggering and water-accounting relations for an on-demand irrigation node.
2. A statement, from published retention data, of the field capacity and wilting point of the three textures the project compares, showing that clay's wilting point lies above sand's field capacity.

3. A demonstration that a single firmware threshold therefore triggers at a different plant-water state in each soil, so part of any measured difference between soils is an artefact of the threshold rather than a property of the system.
4. Computed refill depths and event volumes for each soil, giving the comparison predicted values to be checked against.
5. An explicit statement of what a percentage saving requires, being a metered delivered volume and a defined baseline practice.
6. A three-item measurement plan sufficient to make the cross-soil comparison valid.

The remainder of the paper is organised as follows. Section II reviews related work and fixes the soil data. Section III develops the relations. Section IV describes the node. Section V examines the comparison. Section VI discusses the findings, Section VII states the limitations, and Section VIII gives the measurement framework. Sections IX and X give the conclusion and the future scope.

Related Work and Reference Data

Sensor-driven irrigation scheduling is established practice at commercial scale, and the agronomic basis is standard: irrigation is triggered when the water content in the root zone falls to a defined fraction of the available water capacity, and enough water is applied to return the root zone to field capacity without exceeding it [1], [2]. Allen and colleagues [3] give the reference method for crop water requirement, which relates the atmospheric demand to the crop stage through a coefficient. Saxton and Rawls [4] provide the widely used relations predicting water-retention properties from soil texture, which are the basis of Table II. On the instrumentation side, low-cost resistive and capacitive soil probes are widely used in prototype systems and are well documented to require soil-specific calibration, because their response depends on bulk electrical conductivity and packing as well as on water content. The ESP8266 platform [5] and the Adafruit IO service [6] supply the compute and reporting layers used here.

Table 1. Representative Related Work and its Relation to This Study

Ref.	Year	Focus and scope	Method and validation	Relation to this work
[1]	—	Sensor-based irrigation scheduling	Field trials; extension practice	The triggering method adopted
[2]	—	Soil water and irrigation thresholds	Extension guidance	Definitions used in Eqs. (2), (3)
[3]	1998	Crop evapotranspiration, FAO-56	Reference method	Basis of Eq. (8)
[4]	2006	Retention from soil texture	Regression on a large database	Source of the bands in Table II
[5]	—	ESP8266 platform	Vendor documentation	Controller and Wi-Fi stage
[6]	—	Adafruit IO service	Vendor documentation	Cloud channel and dashboard

Entries [1] and [2] point to bodies of extension and field literature rather than to individual works. Specific works should be named before submission; they are marked here rather than replaced with citations that could not be verified.

1. Water Retention of the Three Soils Compared

The comparison the project sets out to make is across sand, clay and sandy clay, and everything in Section V follows from how differently these three hold water. Table 2 gives the published bands.

Table 2. Published Water-Retention Bands for the Three Textures

Texture	Field capacity θ~FC	Wilting point θ~PWP	Available water capacity
Sand	0.10 to 0.18	0.05 to 0.08	About 0.05 to 0.11 where sand exceeds half the mass
Sandy clay	intermediate; not separately tabulated	0.25 to 0.30	Narrow; between the other two
Clay	0.38 to 0.42	0.25 to 0.30	About 0.12 to 0.16 where clay exceeds 35 % of the mass

Values are volumetric water contents in cubic metres per cubic metre, from published texture-based retention relations [4]. Field capacity is conventionally taken at a matric potential of about −10 kPa in coarse soils and −33 kPa in fine soils, and the permanent wilting point at −1500 kPa. The field capacity of sandy clay is not separately tabulated in the cited source and is described here as intermediate rather than given a number. These are published ranges for texture classes, not measurements of any field, and a real installation should have its own soil characterised.

One feature of Table II governs the whole of Section V and is worth stating on its own. Clay does not reach its permanent wilting point until about 0.25, whereas sand has already reached field capacity by 0.18. The two ranges do not merely differ; they do not overlap. There is no water content that is agronomically comparable across the two soils, and consequently no single sensor threshold that represents the same decision in both. Fig. 1 shows this directly.

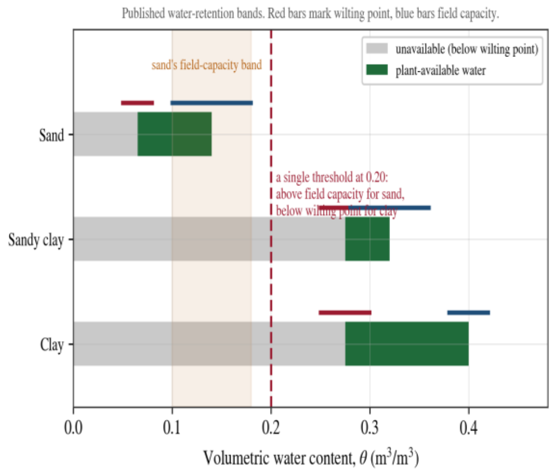

Figure 1: Published retention bands for the three textures. Clay's wilting point lies above sand's field capacity, so the two ranges do not overlap.

Soil-Water and Scheduling Relations

1. Water Content and Available Water

The state variable is the volumetric water content,

$$\theta = \frac{V_{water}}{V_{soil}} \quad [\mathrm{m^3/m^3}] \tag{1}$$

of which only the part between the wilting point and field capacity is available to the crop,

$$AWC = \theta_{FC} - \theta_{PWP} \tag{2}$$

Water above field capacity drains away under gravity within hours in a coarse soil and over a day or two in a fine one, so applying more than field capacity is waste by definition. Water below the wilting point is held too tightly for roots to extract. Equation (2) is therefore the entire budget within which irrigation operates.

2. The Trigger Point

Irrigation is triggered when a defined fraction of the available water has been depleted,

$$\theta_{trig} = \theta_{FC} - p(\theta_{FC} - \theta_{PWP}) \tag{3}$$

where the allowable depletion fraction depends on the crop and its stage, commonly around one half for a crop not under stress management. Equation (3) is the agronomic meaning of the threshold that the firmware implements, and Section V-A shows what happens when the firmware threshold is set without reference to it.

3. How Much Water to Apply

The depth of water required to return the root zone to field capacity is

$$d = (\theta_{FC} - \theta) Z_r \quad [\mathrm{mm}] \tag{4}$$

and the volume follows from the irrigated area,

$$V = dA \quad [\mathrm{m^3}] \tag{5}$$

Equations (4) and (5) are what convert a moisture reading into a quantity of water, and they are also what a controller needs if it is to stop at field capacity rather than run for a fixed time.

4. What a Saving Means

A water saving is a ratio of two volumes,

$$S = \frac{V_{base} - V_{IoT}}{V_{base}} \times 100\,\% \tag{6}$$

so it requires both a metered system volume and a defined, metered baseline. Neither term can be inferred from a moisture trace or from pump switching alone. Fig. 5 in Section V-D sets out what each term requires.

5. The Sensor Does Not Report Water Content

A low-cost soil probe returns an analogue count, related to water content by

$$\theta = f_{soil}(\mathrm{ADC}) \tag{7}$$

where the function is specific to the soil, because the probe responds to bulk permittivity or conductivity, which depend on texture, packing, temperature and salinity as well as on water. The subscript in Eq. (7) is the crux of this paper: a comparison across three soils requires three calibrations, not one.

6. The Air Channels

Air temperature and relative humidity contribute to atmospheric demand, which sets crop water requirement through

$$ET_c = K_c ET_0 \tag{8}$$

The reference evapotranspiration in Eq. (8) requires radiation and wind in addition to temperature and humidity under the standard method [3], so the two channels this node measures are not sufficient to compute it. They remain useful as context and as a record of growing conditions, and reduced-set estimation methods exist that use temperature extremes, but the node as described senses conditions rather than driving the irrigation decision from them. This is a scope observation, not a criticism: the soil-moisture trigger is the more direct control variable in any case.

The Node

1. Architecture

Fig. 2 shows the node. A soil moisture probe and a temperature and humidity sensor feed the ESP8266 microcontroller, which switches the pump or valve through a relay and publishes all channels over its built-in Wi-Fi to an Adafruit IO channel that the farmer opens in a browser. The two items shown at the foot of the figure are what Section V shows the water-saving comparison to require.

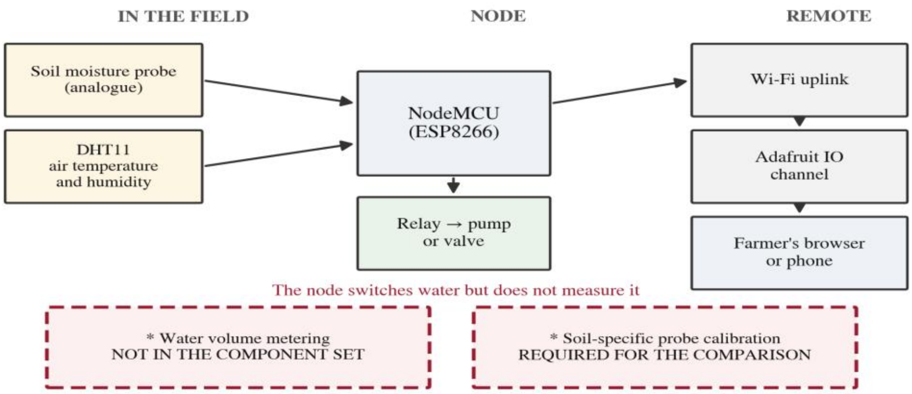

Figure 2: Node architecture. The node switches water on a soil-moisture threshold and reports to a cloud channel, but does not meter the water it delivers.

2. Apparatus

Table 3. Node as Described

Item	Type / rating	Quantity
Controller	NodeMCU (ESP8266) with integrated Wi-Fi	1
Soil moisture probe	Analogue output; type and range to be stated	1
Temperature and humidity sensor	DHT11, digital	1
Switching stage	Relay to pump or solenoid valve	1
Cloud service	Adafruit IO channel	1
Power supply	To be stated	1

The probe type and range, the irrigated area, the root-zone depth, the crop, the trial duration and the pump or valve rating are not given in the abstract. Several are needed to evaluate Eqs. (4) to (6), and they should be recorded in the full report.

What the Cross-Soil Comparison Requires

1. A Single Threshold Is Three Different Decisions

The project compares water use across sand, clay and sandy clay. Table 2 showed that these soils hold water over ranges that do not overlap. The consequence for a threshold-triggered controller is direct, and Fig. 3 shows it: a firmware threshold set at a fixed reading corresponds to a different fraction of available water in each soil.

Taking a threshold at 0.20 as an illustration, that reading is above field capacity for sand, so a controller using it would water a sandy soil that is already full and the water would drain past the root zone; and it is below the wilting point for clay, so the same controller would not water a clay soil until the crop had already passed the point of recovery. Neither behaviour is a fault of the electronics. Both follow from applying one number to three soils.

This matters for the project's own conclusion. If the three soils are watered by a single threshold, they will consume different volumes, and a report could correctly observe that the volumes differ. But part of that difference is an artefact of the threshold rather than a property of the irrigation system, and separating the two requires the threshold to be set per soil from Eq. (3). Doing so is not difficult; it requires only that each soil's field capacity and wilting point be known, which Table II supplies approximately and a gravimetric calibration would supply exactly.

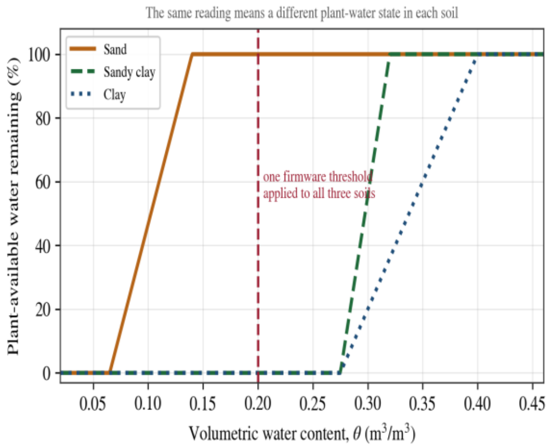

Figure 3: Plant-available water remaining against water content for the three textures. One threshold intersects the three curves at three different agronomic states.

2. The Probe Must Be Calibrated Once per Soil

The difficulty compounds, because Eq. (7) is soil-specific. Even a controller that correctly intends to trigger at, say, half depletion cannot do so unless it can convert its analogue reading into a water content in the soil it is sitting in. A probe calibrated in sand and then moved to clay will report a systematically different value at the same true water content, and the direction and size of that error are not predictable without measurement.

The calibration itself is straightforward and needs no special equipment: take samples across the wet-to-dry range, record the probe reading, weigh each sample, oven-dry it, weigh again, and fit the resulting gravimetric water contents against the readings. Repeating this for each of the three soils yields the three functions Eq. (7) requires. It is the single addition that would convert a three-soil comparison from a comparison of readings into a comparison of water states.

3. How Much Water Each Soil Actually Needs

With the retention bands of Table 2. Eqs. (3) and (4) predict what a correctly triggered system should apply in each soil. Table IV gives these at a 300 mm root zone and 50 per cent allowable depletion, and Fig. 4 plots the refill depths. These are predictions from published texture data, not measurements, and their purpose is to give the campaign values to check its own results against.

Table 4. Predicted Trigger Point and Refill Depth per Soil (Computed Here)

Soil	Trigger θ~trig	Refill depth	Volume on 100 m^2	Relative event size
Sand	0.103	11.3 mm	1.13 m^3	1.0
Sandy clay	0.297	6.7 mm	0.67 m^3	0.6
Clay	0.338	18.8 mm	1.88 m^3	1.7

Computed from Eqs. (3) and (4) using the mid-points of the bands in Table II, a root-zone depth of 300 mm and an allowable depletion fraction of 0.5. The sandy clay row rests on an interpolated field capacity and is the least reliable of the three. These are predictions from texture classes, not measurements, and a field with its own characterised soil would give different values.

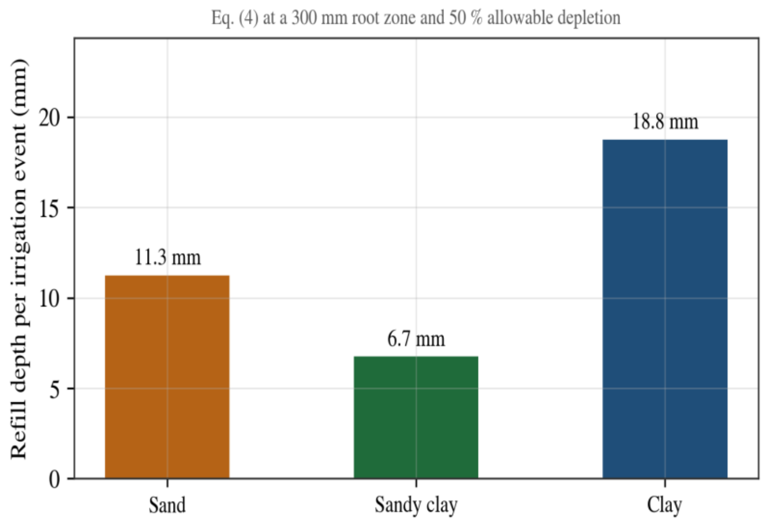

Figure 4: Predicted refill depth per irrigation event from Eq. (4), at a 300 mm root zone and 50 per cent allowable depletion.

The pattern is worth noting because it is counter-intuitive and bears on how the comparison should be read. Clay requires the largest application per event, roughly two-thirds more than sand, because it holds the most available water and therefore has the most to replace. But sand will reach its trigger point far sooner, because it holds the least in total and dries fastest. Over a season the two effects work in opposite directions, so the total volume difference between soils is smaller than the per-event difference and may run either way depending on weather and crop. A comparison that reports only a seasonal total, without the event count and the trigger point, will not show which mechanism produced the result.

4. A Percentage Saving Requires Two Metered Volumes

The abstract's central claim is a reduction in water use relative to traditional practice. By Eq. (6) that is a ratio of two volumes, and Fig. 5 sets out what each requires.

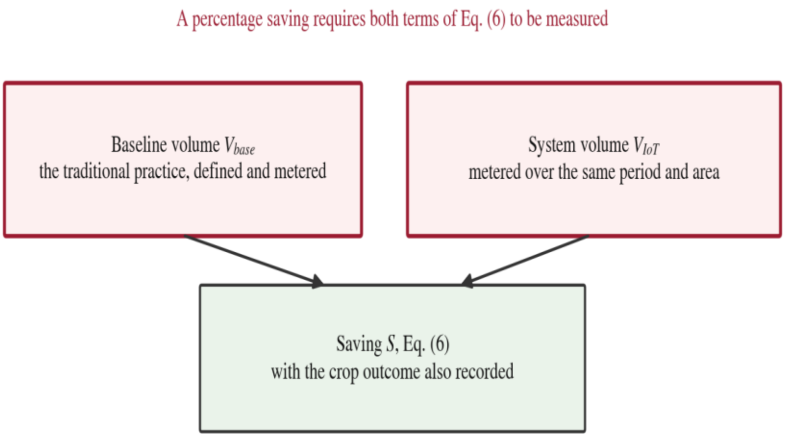

Figure 5: What a percentage saving requires. Both terms of Eq. (6) must be metered over the same period and area.

The system volume can be obtained in either of two ways: an inline flow meter, which is the direct method, or the pump run-time multiplied by a separately measured flow rate, which is cheaper and adequate provided the flow rate is measured rather than taken from a nameplate. The component set described in the abstract contains neither, so if a volume is to be reported one of the two must be added.

The baseline is the harder term and the one most often left undefined. Traditional practice is not a single thing: it may mean a fixed schedule, a fixed duration per event, or the farmer's own judgement, and these give quite different volumes. Whichever is chosen, it must be stated and metered over the same period, the same area and the same crop, because a saving computed against an unmeasured baseline is not a measurement of anything. It is also worth recording the crop outcome alongside, since a system that saves water by under-watering is not saving water; it is reducing yield, and the two are distinguishable only if yield is observed.

5. What the Study Supports

Table 5 lists the quantities involved and what each requires. The status column is deliberately left as a determination for the authors, for the reason given at the head of this paper.

Table 5. Quantities, What Each Requires, and Status to Be Confirmed

Quantity	What it requires	Status
Node switches on threshold	Firmware and relay	to be confirmed from the full record
Cloud channel reports	Wi-Fi and Adafruit IO channel	to be confirmed
Soil moisture in θ terms	Gravimetric calibration per soil, Eq. (7)	to be confirmed
Trigger point per soil	θ~FC and θ~PWP per soil, Eq. (3)	to be confirmed
Delivered water volume	Flow meter, or run-time with measured flow rate	no metering in the described component set
Baseline volume	A defined traditional practice, metered	to be confirmed
Water saving S	Both volumes, Eq. (6)	to be confirmed

Crop outcome	Yield or condition observation	to be confirmed
Irrigated area and root depth	Recorded at the site	not given in the abstract
Trial duration and crop	Recorded at the site	not given in the abstract
Retention bands, three textures	Published texture relations	reference data, Table II
Predicted refill depths	Eqs. (3) and (4)	computed here, Table IV

Discussion

The design is a sound response to a real problem, and the choice to compare across soil types is more ambitious than most prototypes of this class attempt. That ambition is also what raises the evidential bar, because a cross-soil comparison has requirements that a single-soil demonstration does not.

1. The Comparison Is Worth Doing Properly

It is worth being clear that the difficulty identified in Section V-A is not a reason to abandon the comparison. It is a reason to set the threshold per soil. Once each soil's trigger point is derived from Eq. (3), the comparison becomes exactly the interesting one: whether on-demand irrigation saves more water in a fast-draining sand, where fixed schedules waste most, or in a clay, where the reservoir is larger and the schedule matters less. That question has a real answer and this node could produce it.

2. Qualitative Position

Table 6 sets out the structural properties that can be asserted, each with the relation or source that supports it.

Table 6. Qualitative Properties and Their Basis

Feature	Property	Basis
On-demand triggering	Applies water only when the soil is depleted	Eq. (3)
Soil moisture probe	Reports a count, not a water content	Eq. (7)
Single threshold	Means a different state in each soil	Table II, Fig. 3
Refill depth	Largest in clay, smallest in sandy clay	Eq. (4), Table IV
Event frequency	Highest in sand, which holds least	Eq. (2)
Cloud reporting	Remote visibility without a server	[6]
Air temperature and humidity	Context; insufficient alone for Eq. (8)	[3]
Water saving	Requires two metered volumes	Eq. (6), Fig. 5

Limitations

The following limitations bound every claim made in this paper.

- This paper was prepared from the project abstract alone. It makes no statement about what the campaign measured, and the status column of Table V is a set of questions for the authors rather than findings.
- The retention bands of Table II are published ranges for texture classes, not measurements of any particular field. A real installation should have its own soil characterised, and the values will differ with bulk density, organic matter and clay mineralogy.
- The field capacity of sandy clay is not separately tabulated in the cited source. The sandy clay row of Table IV rests on an interpolated value and is the least reliable of the three.
- The predicted refill depths of Table IV assume a 300 mm root zone and a 50 per cent allowable depletion. Both depend on the crop and its stage, neither of which is given.
- The threshold of 0.20 used in Section V-A is an illustration chosen to fall between the three soils' ranges. It is not a value taken from the project.
- No water volume, percentage saving, calibration curve or crop outcome is reported here, because none was available to this paper.
- Equation (8) is included to place the air channels in context. Reference evapotranspiration requires radiation and wind in addition to the two channels sensed, so no evapotranspiration figure is computed.

Proposed Measurement Framework

Fig. 6 shows the three additions that would make the cross-soil comparison valid. All three are inexpensive relative to the rest of the installation.

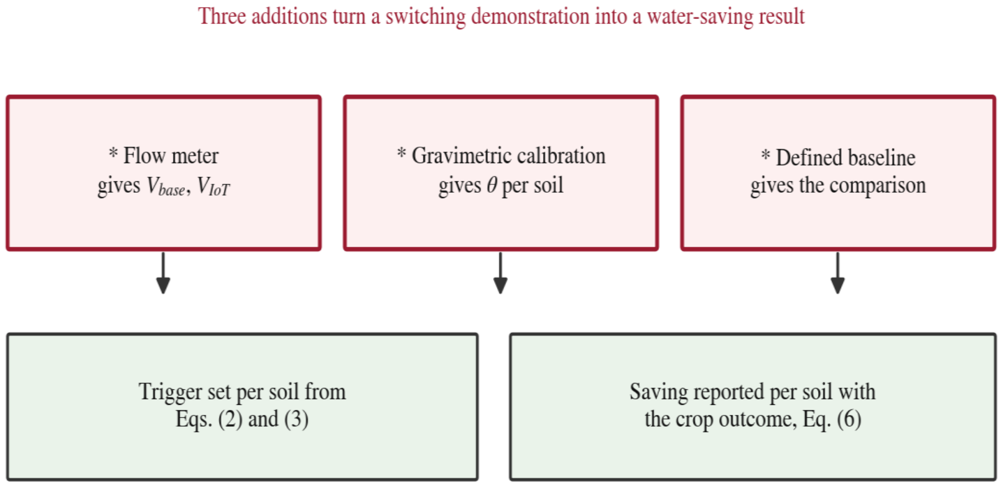

Figure 6: Measurement framework. Three additions turn a switching demonstration into a water-saving result.

1. Measurement Plan

Table 7 sets out the steps, and Table 8 records the values used in this paper with their provenance.

Table 7. Measurement Plan Required for the Water-Saving Comparison

Step	Method	What it yields
Calibrate the probe per soil	Paired probe readings and oven-dry gravimetric samples across the wet-to-dry range	The three functions of Eq. (7)
Characterise each soil	Field capacity after free drainage; wilting point from texture or laboratory	θ~FC and θ~PWP for Eqs. (2) and (3)
Set the trigger per soil	Apply Eq. (3) with the crop's allowable depletion	Three thresholds representing one agronomic decision
Meter the delivered water	Inline flow meter, or run-time with a measured flow rate	V_{IoT} for Eq. (6)
Define and meter the baseline	State the traditional practice and meter it over the same period, area and crop	V_{base} for Eq. (6)
Record area, depth, crop and duration	Site record	Makes Eqs. (4) and (5) evaluable and the trial reproducible
Record the crop outcome	Yield or condition at harvest	Distinguishes saving water from under-watering
Report per soil	Volume, event count and trigger point for each texture	Shows which mechanism produced the difference

Table 8. Figures Used in This Paper and Their Provenance

Item	Value	Status
Sand field capacity	0.10 to 0.18	published band [4]
Clay field capacity	0.38 to 0.42	published band [4]
Clay and sandy clay wilting point	0.25 to 0.30	published band [4]
Sandy clay field capacity	intermediate	interpolated; not tabulated in [4]
Root zone and depletion fraction	300 mm, 0.5	assumptions for Table IV
Refill depth, sand and clay	11.3 mm and 18.8 mm	computed, Eq. (4)
Illustrative threshold	0.20	chosen for Section V-A; not from the project

Measured water volume	—	not available to this paper
Measured water saving	—	not available to this paper

Published bands are texture-class values, not measurements of any field. Computed entries follow from the stated relations and assumptions. No measurement of the project's own system appears anywhere in this paper.

Conclusion

A low-cost Internet-of-Things irrigation node was described, in which a soil moisture probe and a temperature and humidity sensor feed an ESP8266 controller that switches water on demand and publishes every channel to an Adafruit IO channel the farmer can open in a browser. The soil-water, triggering, water-accounting and calibration relations on which such a system rests were consolidated.

The project's stated aim of comparing water use across sand, clay and sandy clay was then examined, and two requirements were established quantitatively. First, the published retention bands for these textures do not overlap: sand reaches field capacity between about 0.10 and 0.18 cubic metres per cubic metre while clay does not reach its wilting point until about 0.25. A single firmware threshold therefore triggers at a different fraction of available water in each soil, so part of any measured difference between soils would be an artefact of the threshold rather than a property of the irrigation system. Setting the threshold per soil from the depletion relation removes this, and doing so turns the comparison into the interesting question of where on-demand irrigation saves most. Second, the probe reports an analogue count whose relation to water content is itself soil-specific, so a three-soil comparison requires three calibrations, obtainable by a straightforward gravimetric procedure needing no special equipment.

Predicted refill depths were computed for each soil, giving the campaign values to check against: about 11 mm per event in sand, 19 mm in clay and less in sandy clay at a 300 mm root zone and half depletion. Clay needs the largest application per event but sand triggers most often, so the seasonal totals may run either way and a comparison reporting only totals will not reveal which mechanism produced the result. Finally, a percentage saving was shown to require two metered volumes and a defined baseline practice, together with a crop outcome to distinguish saving water from under-watering; the component set described contains no water metering, so one of two straightforward methods must be added.

This paper was prepared from the project abstract alone and therefore makes no statement about what the campaign recorded. The relations, the published soil data and the computed predictions are complete; the status column of Table V is a set of questions for the authors to answer from their full record.

Future Work

Several extensions follow directly from the limitations above.

- Calibrate the probe in each soil-Take paired probe readings and oven-dry gravimetric samples across the wet-to-dry range for sand, clay and sandy clay, so that Eq. (7) is available for each and readings become water contents.
- Set the trigger per soil-Characterise each soil's field capacity and wilting point and apply Eq. (3), so that one agronomic decision is implemented in all three rather than one number.
- Meter the water-Add an inline flow meter, or measure the pump's flow rate and log run-time, so that the delivered volume becomes a measured quantity.
- Define and meter the baseline-State what traditional practice means for this trial and meter it over the same period, area and crop, so that Eq. (6) has both its terms.
- Record the site and the crop-Log the irrigated area, root-zone depth, crop, stage and trial duration, without which Eqs. (4) and (5) cannot be evaluated and the trial cannot be reproduced.
- Record the crop outcome-Observe yield or crop condition alongside the water volumes, so that a saving can be distinguished from under-watering.
- Report per soil, not only in total-Give the volume, the event count and the trigger point for each texture, so that the mechanism behind any difference is visible.

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