

IRRIGABLE: A HYDRO-SPATIAL APP FOR MANAGING IRRIGATION PERFORMANCE AT DIFFERENT SCALES FOR DIFFERENT PURPOSES

IRRIGABLE : UNE APPLICATION HYDROSPATIALE POUR GÉRER LES PERFORMANCES DE L'IRRIGATION À DIFFÉRENTES ÉCHELLES ET À DIVERSES FINS

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ABSTRACT

Higher irrigation performance paves the way for improved climate resilience, reduced water consumption, increased water productivity, improved equity, and better management of over-exploited surface and groundwater. However, irrigation systems, especially with open-channel networks, are complex, extensive, data-scarce and subject to many farmer's aims and perspectives. Solutions will have to; be adoptable at scale; leverage many eyes on irrigation (farmers); mesh satellite, canal and field-based measurements; help bring together disparate views, and incorporate comprehensive computations behind an easy-to-use dashboard.

Responding to these problems, the paper outlines a plan to build a mobile application ('app') called 'IrrigAble'. This will be a hydro-spatial dashboard app hosted on smartphones for discussing and managing irrigation performance across multiple scales for different purposes. Examples of these purposes include; planning irrigation scheduling for the season ahead, managing scheduling in real-time, and analysing performance. The paper is structured into three data types, inputs, intermediate calculations, and decision-support. The app will apply to at least six main scales; plot/field, farm, tertiary unit, secondary unit, main system and catchment.

Keywords: Irrigation performance; Water consumption; Water productivity; Irrigation scheduling; Decision-support.

RÉSUMÉ

L'amélioration des performances de l'irrigation ouvre la voie à une meilleure résilience climatique, à une réduction de la consommation d'eau, à une augmentation de la productivité de l'eau, à une plus grande équité et à une meilleure gestion des eaux de surface et souterraines surexploitées. Toutefois, les systèmes d'irrigation, en particulier ceux dotés de réseaux de canaux à surface libre, sont complexes, étendus, pauvres en données et soumis aux nombreux objectifs et points de vue des agriculteurs. Les solutions devront pouvoir être adoptées à grande échelle, tirer parti de la multiplicité des observations sur l'irrigation — notamment celles des agriculteurs —, intégrer les mesures satellitaires ainsi que celles réalisées dans les canaux et sur le terrain, contribuer à rapprocher des points de vue disparates et incorporer des calculs complets dans un tableau de bord facile à utiliser.

En réponse à ces difficultés, l'article présente un projet de création d'une application mobile appelée « IrrigAble ». Il s'agira d'une application de tableau de bord hydrospatial, hébergée sur des smartphones, destinée à examiner et à gérer les performances de l'irrigation à plusieurs échelles et à diverses fins. Ces fins comprennent notamment la planification du calendrier d'irrigation pour la saison à venir, la gestion de ce calendrier en temps réel et l'analyse des performances. L'article est structuré autour de trois types de données : les données d'entrée, les calculs intermédiaires et l'aide à la décision. L'application couvrira au moins six échelles principales : la parcelle ou le champ, l'exploitation, l'unité tertiaire, l'unité secondaire, le système principal et le bassin versant.

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Mots clés : Performances de l'irrigation; Consommation d'eau; Productivité de l'eau; Calendrier d'irrigation; Aide à la décision.

INTRODUCTION

Higher irrigation performance paves the way for improved climate resilience, reduced water consumption, increased water productivity, improved equity, and better management of over-exploited surface and groundwater (Ward, 2022). Thus, a more accountable irrigation sector sits at the heart of a more productive and sustainable nexus approach to land, water, energy and food (Shah, 2023). However, irrigation systems, especially with open-channel networks, are complex, extensive, data-scarce and subject to many farmer's aims and perspectives. Solutions will have to; be adoptable at scale; leverage many eyes on irrigation (farmers); mesh satellite, canal and field-based measurements; help bring together disparate views, and incorporate comprehensive computations behind an easy-to-use dashboard.

Responding to these problems, the paper outlines a plan to build an 'app' called 'IrrigAble'. This will be a hydro-spatial dashboard app hosted on smartphones for discussing and managing irrigation performance across multiple scales for different purposes. Examples of these purposes include; planning irrigation scheduling for the season ahead, managing scheduling in real-time, and analysing performance (Jaafar & Kharroubi, 2021). The paper is structured into three data types, inputs, intermediate calculations, and decision-support. The app will apply to at least six scales; plot/field, farm, tertiary unit, secondary unit, main system and catchment.

The app brings together four developments that should underwrite its success. 1) It builds on Lankford's experience and arguments that irrigation can be assessed and managed via the continuity equation given in Equation 1 (Lankford, 1992; Lankford, 1998). This in turn is based on applying and re-arranging the irrigation hydromodule. 2) It sources irrigation data from satellite-based measurements of land use, climate and weather (Amdar et al., 2024). 3) It uses data entry by farmers who are increasingly familiar with the functionality of smartphones linked to cloud computing (Jaafar & Kharroubi, 2021; Mehta et al., 2025). 4) It envisages farmers taking occasional channel flow measurements taken from a combination of hydraulic control at given points and a phone-based app (Carrel et al., 2019; Manfreda et al., 2024).

Equation 1. Continuity equation linking depth applied, time, flows, efficiency and area

$$mm\ applied = \frac{l/sec \times hours \times efficiency\% \times 0.36}{ha\ completed}$$

As far as the authors know, there is no such app in the world, although many current apps have elements to them that would apply to IrrigAble. Many apps help deliver improved irrigation scheduling (Migliaccio et al., 2015; Simonet & Alnaizy, 2020). One such example, [Hydrawise](#) is cloud-based and draws on multiple data types to inform commercial farmers of irrigation schedules. Although scheduling is a vital entry point, IrrigAble goes further than this by including groups of farmers, crop water productivity and strategic decisions.

IRRIGABLE – THE APP

App authorship

IrrigAble will be built by the authors of this paper. The authors bring together considerable experience in irrigation management, irrigation computing (Amdar et al., 2025; Lankford et al., 2025), software development (Mehta et al., 2025), a farmer-facing ethos, and phone-based discharge measurement.

Initially a proof-of-concept will be built using Excel. A screenshot of the current model in Excel is given below. Thereafter the app will be built in a modular fashion by the authors and <https://core-stack.org/>

according to their open-source, dialogue-enabling, farmer-first principles (Mehta et al., 2024), will connect to a flow measurement mobile application (<https://www.photrack.ch/dischargeapp.html>), and individual modules will also be accessible through open APIs and data standards for integration in other systems.

Data and scales overview

IrrigAble will be structured around three types of data entry and analysis. We term these 'data inputs' (or data entry), intermediate outputs and strategic decision-support. A schematic for this structure is given in Figure 1. The app will apply to six scales; plot/field, farm, tertiary unit, secondary unit, main system and catchment. These are covered in the following sub-sections.

Data input/entry data

The app uses many types of information as input data. These data, although given in what appears to be a linear sequence, also depend on earlier and later data. The benefit of first constructing the app in Excel is that a structured row-by-row approach can be first elucidated – see Figure 2.

Intermediate outputs

From these data, the app calculates intermediate outputs, such as; gross and estimated net volume applied per irrigation (m^3); refinements to classical irrigation efficiency estimate; demand and supply hydromodules (l/sec/ha); ideal irrigation progress (ha/day); adjusted irrigation progress (ha/day); water productivity (kg/m^3 net and gross), volumes of real water savings (m^3).

The data (and in brackets their sources) include:

1. Areal rainfall mm depths per stipulated period such as dekad, or monthly, recalculated to daily rainfall (satellite).
2. Entry for effective rainfall correction so that rainfall leads to effective rainfall (farmer adjusted or preset calculated).
3. ETo and ETa per period such as dekad or month derived to daily figures (satellite).
4. Crop patterns with area in hectares under fallow and different crops (farmer triangulated with GPS / remote sensed).
5. Starting and end cropping dates. Assuming auto-populated cropping factors, this gives crops at growth stages (farmer data triangulated with GPS and satellite).
6. Areas under different irrigation technologies, gravity, sprinkler and drip with an adjustment whether well or poorly managed (farmer data)
7. Soils data for irrigation scheduling zoned across the farm e.g. depth mm applied (farmer or from GIS digital information).
8. Soils data for seepage losses and shallow groundwater contribution to crops in mm/day (farmer estimate plus soils data).
9. Initial parameter estimates for classic irrigation efficiency (application, distribution and conveyance) which is refined as data comes in (farmers and support services).
10. Designed (ideal) tertiary and secondary piped or canal flows in l/sec (initial parameter estimate or auto-populated or from design specifications).
11. Actual tertiary and secondary piped or canal flows in l/sec (farmers using flow measurement - see below).
12. Ideal time durations for irrigation (hours) and irrigated area completed e.g. hours per hectare (calculated).

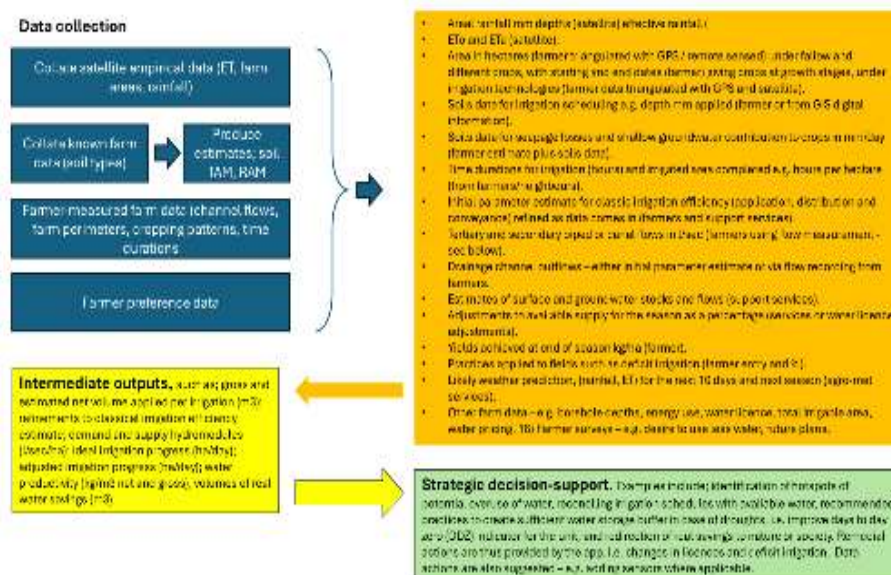


Figure 1. Schematic of data management and analysis within IrrigAble

1	To determine actual tertiary unit classical irrigation efficiency for rotational irrigation during different irrigation periods				Farmer sourced or measured
2	Days in period	30	Days		Satellite sourced
3					Mixed data use
4	DESIGN OR TARGET SYSTEM				
5	Variable	Abb	Source & notes	Per period	Per day
6	Irrigation scheduling calculations				Units
7	1. Farm name, location data, gross area		Satellite, farmers, secondary data		
8	2. Soil estimated total soil moisture from soil type	TSM	From secondary data, services, or farmers	140	mm
9	3. Readily available water	P	From services, or farmers	15%	
10	4. Soil RAM	RAM	Calculated	77	mm
11	5. Actual crop ET	ET _c	From satellite, net data & farmers	7.5	mm/day
12	6. Average rainfall	P	From satellite, net data & farmers	70	mm/day
13	7. Effective rainfall correction	P _c	From satellite, net data & farmers	0.8	
14	8. Effective rainfall	P _c	Calculated	6.10	mm/day
15	9. Surface water contribution to crop ET	S	From secondary data, services, or farmers	0.50	mm/day
16	10. Irrigation need or soil moisture deficit (ET _c - P _c - S)	IN	Calculated	4.90	mm/day
17	11. Irrigation scheduling interval in 24 hour days		Calculated	16	days
18	12. Irrigation design calculations				
19	13. Command area of TI	A	From satellite, services & farmers	150	ha
20	14. Volume irrigating the field per day	V	From secondary data, services, or farmers	13	mm
21	15. Net water hydropower for 24 hour days	HM	Calculated	0.507	Use/ha
22	16. Net water hydropower for irrigating days		Calculated	1.104	Use/ha
23	17. TI design net flow for 24 hour irrigation		Calculated	85	Use/ha
24	18. TI required net flow corrected for hours in the day		Calculated	170	Use/ha
25	19. Tertiary unit design irrigation distribution efficiency	Ed%	From design estimate or 100% to begin with	90%	
26	20. Tertiary unit design irrigation application efficiency	Ea%	From design estimate or 100% to begin with	90%	
27	21. Tertiary unit design crop	C%	Calculated	17%	
28	22. Gross water hydropower for 24 hour days	HM	Calculated	0.742	Use/ha
29	23. Gross water hydropower for irrigating days	HM	Calculated	1.483	Use/ha
30	24. TI design gross flow for 24 hour irrigation		Calculated	111	Use/ha
31	25. TI required gross flow corrected for hours in the day		Calculated	323	Use/ha
32	26. Irrigation or target irrigation management calculations				
33	27. Intended irrigation depth applied net		Calculated	77	mm
34	28. Intended irrigation depth applied gross, correcting for GRS		Calculated	101	mm
35	29. Ideal time duration completion		Calculated	189	hours
36	30. Ideal time duration completion for 24 hour days (hours / 24)		Calculated	7.9	24 hr days
37	31. Ideal time duration completion corrected for hours/day irrigation		Calculated	18	irrigating days
38	32. Target progress rate of irrigation in hours		Calculated	0.80	hr/day
39	33. Target progress rate of irrigation corrected for hrs/day irrig		Calculated	0.59	hr/day
40	34. Check cells: Net area irrigated		Calculated	77	mm corrected

Figure 2. Screenshot of Excel model of IrrigAble

13. Actual time durations for irrigation (hours) and irrigated area completed e.g. hours per hectare (from farmers/neighbours).
14. Drainage channel outflows – either initial parameter estimate or via flow recording from farmers.
15. Estimates of surface and groundwater stocks and flows (support services).
16. Adjustments to available supply for the season as a percentage (services or water licence adjustments).
17. Yields achieved at end of season kg/ha (farmer).

18. Practices applied to fields such as deficit irrigation (farmer entry and %).
19. Likely weather prediction, (rainfall, ET) for the next 10 days and next season (agro-met services).
20. Other farm data – e.g. borehole depths, energy use, water licence, total irrigable area, water pricing.
21. Farmer surveys – e.g. desire to use less water, future plans.

Strategic decision-support

The above data inputs and intermediate outputs provide for strategic decision-support (Tegegne et al.). Examples include; identification of hotspots of potential overuse of water, reconciling irrigation schedules with available water, recommended practices to create sufficient water storage buffer in case of droughts, i.e. improve days to day zero (DDZ) indicator for the unit (Lankford et al., 2023); and redirection of real savings to nature or society. Remedial actions are thus provided by the app, i.e. changes in licences and deficit irrigation. Data actions are also suggested – e.g. adding sensors where applicable.

Scale and levels

The app will apply to six main scales; plot/field, farm, tertiary unit, secondary unit, main system and catchment. However as Figure 3 presents, there are many more scales and scale-functions within an irrigated system, including up to the transboundary river basin scale. To cope with the size of the catchment and its levels, scales within the app are likely adjustable and collapsable.

IrrigAble is also designed to bridge gaps that arise on large-scale irrigation systems. Figure 3 also highlights how the IrrigAble will bridge between 1) farmers, 2) Ministry of Agriculture and 3) Ministry of Water. Farmers aim to protect crops in the face of uncertain and curtailed supplies yet also sustain their income. The Min of Ag desires to maximise water use for agricultural production and food security and exports, while the Min of Water aims to cap or even reduce this water use in order to meet other sectoral obligations.

Level / scale	Who	Details	Purpose
Transboundary	TBA	Transboundary basin authority for water distribution, international obligations, cooperation	
National	Min of water	NAP, water and food security, energy production, use & efficiency	
River (Basin)		Seasonal / annual supply dynamics, hydrological forecasts, environmental flow	
Main Canal		Infrastructure, conveyance losses, operation, maintenance, pumping/energy factors	
Secondary Canal		Infrastructure, conveyance losses, operation, maintenance, pumping/energy factors	
Tertiary Canal	Ministry of agriculture & farmers	Infrastructure, conveyance losses, operation, maintenance, pumping/energy factors	
Farm Scale		Size of farm, on-farm water storage, metering	
Irrigation Mgt		Deficit irrigation, mulching, effects on energy requirements	
Irrigation Tech		Furrow, sprinkler, drip, plus their energy requirements	
Field		Land levelling, canal density, furrow length, infield water control	
Crops		Type, variety, planting density / rows spacing (mandated, new crops, rotation)	
Soils		Corrections for GW depth, salinity management, gravimetric water	
Agrometeorology		Dekad (10-day) ETo modelling	

Figure 3. Scales and functions within the IrrigAble app

Given that most farmers use smartphones rather than computers, developing a mobile application could serve as a vital tool to bridge the gap between farmers, service providers, water managers and policy makers. Such an app would enable real-time, two-way communication to better manage water resources based on actual demand and supply conditions. Additionally, it would promote transparent

data sharing, improve operational water management and inter-farmer equity of water supply, and ultimately help boost agricultural productivity. Accordingly, this app would allow farmers to 1) accommodate cuts to water supplies due to upstream drought or other water shortages; 2) understand and improve inter-farm and inter-tertiary unit equity, and 3) enhance their on-farm irrigation scheduling and management to cumulatively assist the productivity and performance of the whole system.

DISCUSSION

Benefits of common platform for irrigation management

Although IrrigAble is not being thought of or constructed as a tool to boost irrigation efficiency it will have the ability to improve irrigation management – and therefore indirectly alter irrigation efficiency. For example it can reconcile irrigation efficiency at the field level with aggregate water savings at the catchment scale. Regarding water management in irrigated systems, the proposed IrrigAble app offers the following key benefits.

- Flexible application across all scales and canal systems, from individual farmers and tertiary canals to main and transboundary systems
- Operational, real-time updates of water demand and supply, with daily information refresh
- User-friendly design accessible to stakeholders of all knowledge level
- Versatile use for training young irrigators and farmers
- Educational value as a tool to teach future generations about water management
- Analytical capabilities to support policy and decision makers
- Integration with hydro-meteorological data and water availability forecasts
- Improvements in field application, distribution and conveyance irrigation efficiency
- Enhanced transparency and equity in water allocation
- Increased responses and resilience to droughts and water shortages
- Calculations of system and catchment water savings and budgets
- Improved crop and water productivity, measured in kg/m³ or \$/m³
- Scalability for expansion to other countries in a transboundary context
- Facilitation of farmer involvement in water management and allocation discussions at all scales

On irrigation system gadgets and gizmos

While there is no doubt that a critical view might see IrrigAble unfavourably as a 'gizmo' or 'gadget' (Banham & Sparke, 1981) that does not match the complexity found on irrigated systems. Therefore what makes IrrigAble an appropriate gizmo for managing irrigation systems? To answer this question, our paper distinguishes between 'gizmos as problem gadgets' (that keep us inside-the-box, or retains the black box) and 'gizmos as systems discovery' (that opens up the box).

Regarding the former, our gizmo-gadget definition is "a systems-blind single-scale force-fitting of technology to solve ill-discovered problems" (email from Aditeshwar Seth, IIT Delhi. Email to Bruce Lankford December 20th 2025). Gizmos are unique and discrete gadgets usually named after their (single) function. The gizmo-as-gadget is a problem – it does not provide systems solutions. Examples of gizmos as gadgets include; soil water sensors by IWMI, treadle-pumps by the Commission for Africa (Commission for Africa, 2005), and drip systems by Water Resources Group 2030. These are:

- Single scale, single problem – not fitted to or within its surrounding system
- Supply-side thinking, we know better than farmers

- Hardware to be bought, subsidised, gifted, & evidenced via impact for donors
- Can be used to promote discussion but post-hoc their introduction

On the contrary we think IrrigAble is an example of a 'gizmo as systems discovery'. Reflecting on Banham and Sparke's paper, Hyde (2010) went on to ask could we approach architecture using gizmo-type thinking? This is where the gizmo is defined by its ability to synthesise across different disciplines, knowledges, practices both within and outside of architecture – and importantly to make known the black box of complex systems. Thus we believe IrrigAble follows Hyde's approach to gizmos.

CONCLUSIONS

Large scale irrigation has proved difficult to revitalise unless one wholesale switches to pressurised irrigation delivery from the source to the crop. Even with the latter technological change there are problems with water and energy use, especially under smallholder rather than commercial systems. This paper takes a farmer-oriented approach to revitalising this sector, in contrast to any 'new' top-down institutional reform (Lankford et al., 2016).

In conclusion, the key aims of IrrigAble are the following:-

- To show how the existing built infrastructure can be investigated for its design appropriateness to deliver equitable and accurate water supplies.
- To show how actual seasonal supplies, which may change due to drought, can communicate and 'force' a reduction in water supplied to farms.
- To show how hydromodules produce seasonal total norms and irrigation norms.
- To exhibit how a farm-scale user phone-based app might utilize this approach so that farmers can be part of the system-wide raising of irrigation performance. We think farmers will want to be part of this given their interests in managing drought, crop production and inter-farmer equity,
- To link irrigation water demands and management to water productivity and crop production.
- To demonstrate how water accounting can be incorporated so that real water savings and regional water budgets can be achieved and then allocated.

While there is no proof as yet that our smartphone app will deliver beneficial change to gravity irrigation, the ingredients for success are built into the app. These ingredients include; built for and tested in South Asia; oriented to and data entry by farmers (Mehta et al., 2025); rapid assimilation of data from existing or satellite information; cloud and or phone-based computing of intermediate and strategic data; a philosophy of iterative development and learning.

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