CGIAR Transforming Agrifood Systems in South Asia

Towards sustainable groundwater systems in South Asia

Data exploration in Nalanda district in Bihar, India

Research Note 2, Work Package 2
December 2022

SUMMARY

Groundwater resources and irrigation systems are a fundamental consideration for sustainable and inclusive food system transitions in South Asia. Over the course of the latter part of the 20th century and the early 21st century, groundwater has become the primary source of irrigation water across South Asia and globally. The aquifers in Western and Peninsula regions in South Asia have faced water scarcity and groundwater depletion. But in in the Eastern Gangetic Plains, aquifers are still considered underutilized by most planners and policymakers. This has resulted in increased investments in groundwater irrigation for water security and climate adaptation. However, the aquifer response to increasing irrigation water withdrawals remains poorly understood. To address this knowledge gap, TAFSSA is developing watershed assessment on sustainable groundwater use. Starting with Nalanda district in Bihar, India, a relatively water scarce district within the Eastern Gangetic Plains. This research note reports on the initial findings from existing groundwater data and outlines key steps towards building a groundwater model to support sustainable groundwater management and planning.

Photo: Irrigation in farmer's field. Photo credit: Abdul Momin

CIMMYT International Maize and Wheat Improvement Center | IFPRI International Food Policy Research Institute | IRRI International Rice Research Institute | IWMI International Water Management Institute | CIP International Potato Center | WorldFish | ILRI International Livestock Research Institute

KEY RESULTS

The Indo-Gangetic Plains (IGP) in South Asia hosts predominantly cereal-based farming systems (Aravindakshan et al., 2015, Jat et al. 2020). Considered the food basked of South Asia, the IGP's cereal production is crucial to food security as well as political and economic stability. However, parts of the IGP are threatened by unsustainable groundwater withdrawal – the region extracts one third of global groundwater withdrawals – spurred by existing irrigation incentives anchored in a number of key food and energy policies (Arshad et al., 2018, Dorosh et al. 2009). Farmers in this region are vulnerable and exposed to climate change and extreme weather (Lal et al. 2010, Kishore et al. 2021, McDonald et al. 2020), contributing to high risks for farmers that can lead to low incomes and rural out-migration away from agriculture (Aryal et al 2020). As a result, governments are investing in expanding groundwater irrigation to support intensified cropping and climate adaptation in agriculture. Interest across the region in these efforts collectively target nearly 22 million hectares that are currently fallowed during the dry season (Rasul et al. 2016, Krupnik et al. 2017, Urfels et al. 2020, Gumma et al. 2016).

In alignment with these efforts, TAFSSA supports coordinated efforts to transform the agrifood system in ways that ensure that people can equitably access and consume healthy diets produced within the environmental boundaries (cf. IFAD, 2021). Work package 2 (WP2) of TAFSSA emphasizes farm- and landscape-level interdisciplinary research, including the assessment of groundwater resources through numerical modelling approaches. The objective of groundwater modelling is to assess sustainable groundwater use at the landscape level, in order to provide information on what farm configurations and cropping patterns might be most suitable for producing nutritious foods while sustaining the natural resource base. Groundwater flow modelling can be used to assist in decision making to more effectively manage groundwater resources. It can provide quantitative indicators of aquifer characteristics and dynamic groundwater behavior. In this sense it can 'making the invisible visible'. Crucially, groundwater models can showcase and predict water deficit and water abundant locations within aquifers over time and varying scenarios of precipitation and groundwater use. As such, they can be useful in long-term agricultural resource planning.

Building groundwater models consists of two key steps, first building a conceptual model and second building a numerical model to examine scenarios based on Darcy's law and other fundamental hydrogeological equations. The remainder of this report describes initial findings aquifer systems research in Nalanda district – our initial focus district in Bihar, India.

The study area isf 2300 km^2 and includes one of TAFSSA's research learning analogue sites. Toposheets (72G/3, 4, 7, 8, 11, 12, 15, 16, H/5, 9) were used delineate the administrative and hydrological boundaries of the study area. The topographic elevation ranges from 35 to 450 m above sea level (masl). The average annual rainfall is 974.5 mm. The climate is sub-tropical to sub-humid, and is characterized by a hot summer and mild winter. About 89% of all rainfall takes place from June to September. Geologically, Nalanda district is mainly occupied by Quaternary sediments The exemption is a part of the South comprised of metasediments of Munger group belonging to middle Proterozoic age (CGWB 2022).

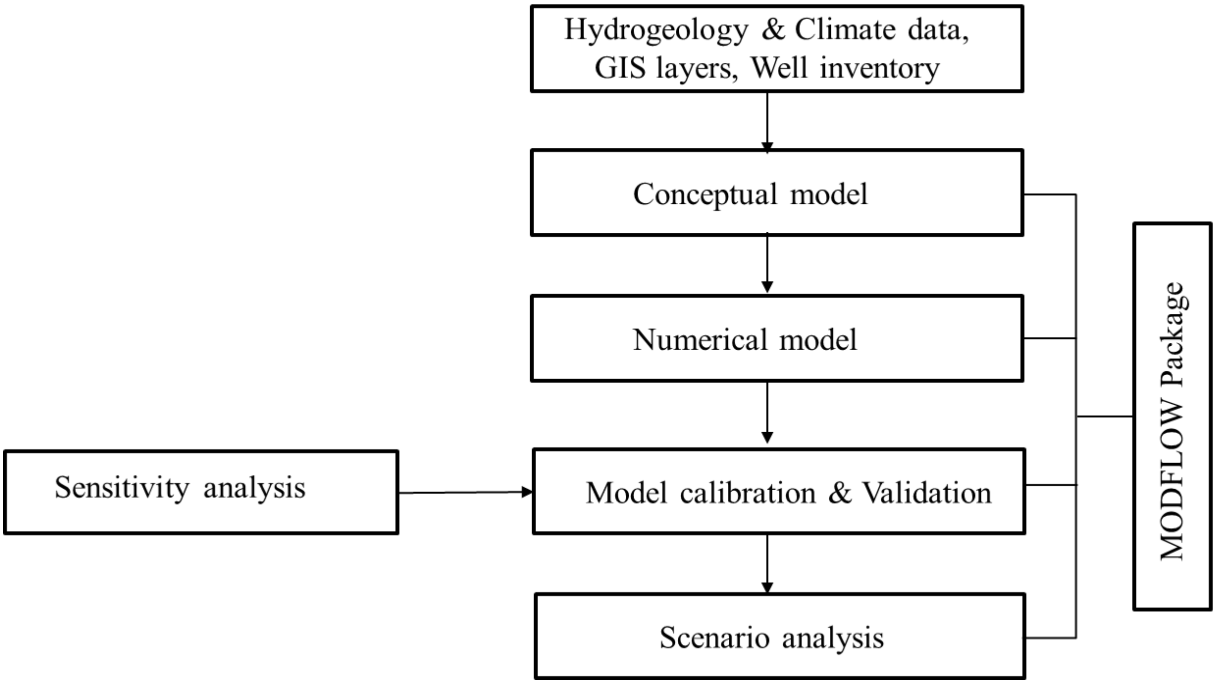

Figure 1. Analytical framework being employed in groundwater flow modelling.

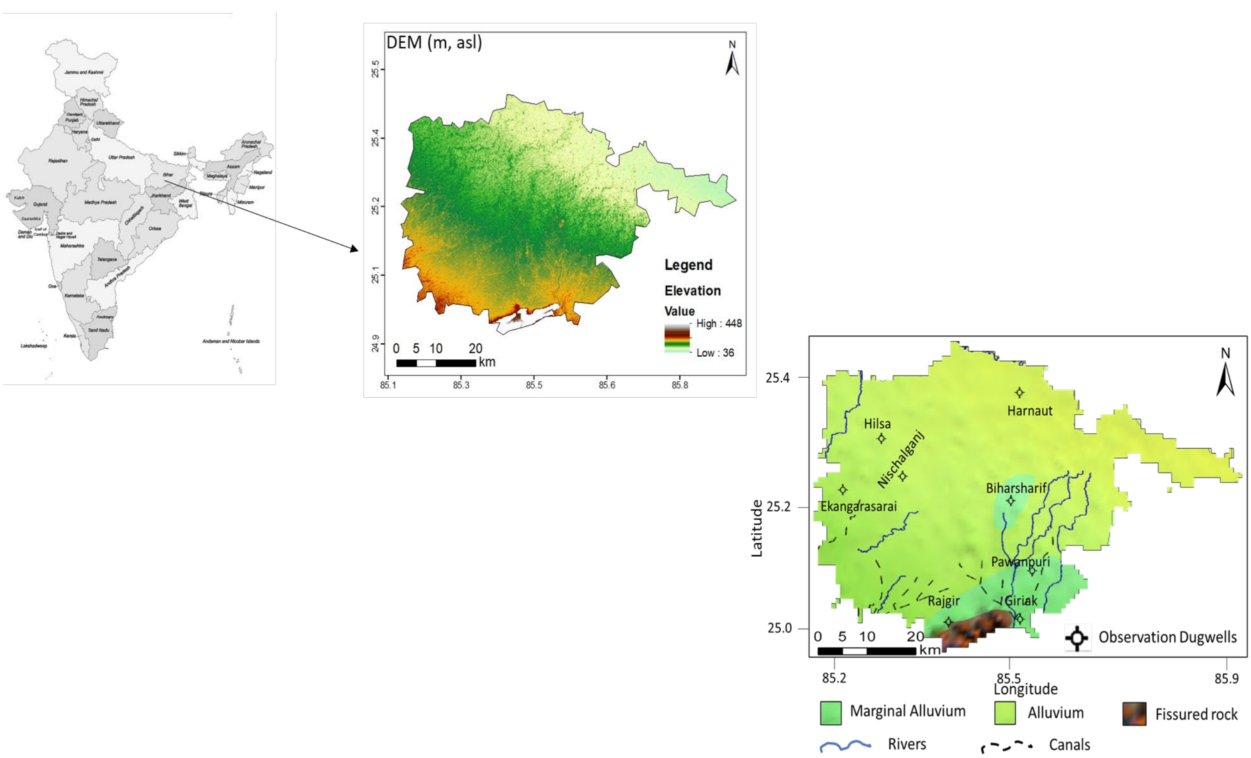

Figure 2. The Digital Elevation Model (DEM) and hydrogeological conceptual map of Nalanda district in Bihar, India.

3

Metasediments include highly folded and fractured quartzite, phyllite and schist. These are combined with intrusive granite and pegmatites. The study district is located within the Mid-Ganga basin, in the southern margin of the Gangetic plains. Flat alluvium terrain is common, with the exception of Rajgir Hill (~ 443 masl) in the south (CGWB 2022).

About 90% of the area is used for agricultural purposes with cereal-based farmland far exceeding any other land uses. Built-up area is the second largest land use category. Nalanda district is part of the Harohar Basin, and generally slopes towards the northeast. Major rivers include the Mohana, Panchane and Sakri rivers. These all flow towards the north east and empty into into the Ganges. The whole district is covered by alluvium, except the crystalline rock areas in Rajgir. In the alluvial areas, several aquifer layers exist and have been explored to the depth of 250 m below ground in the northern part of the district. In the crystalline hard rock areas, water well discharges are highly variable. The conceptual hydrogeological map of Nalanda district is presented in Fig 2.

Lithologically, Nalanda known for clay beds, inter-bedded with sands (Saha, 2007). In the northern part of the study area, aquifers are more fully developed, and, four alluvial fills, starting with coarse sand and gravel at base and clay at the top, have been reported within 100- 120 m bgl.

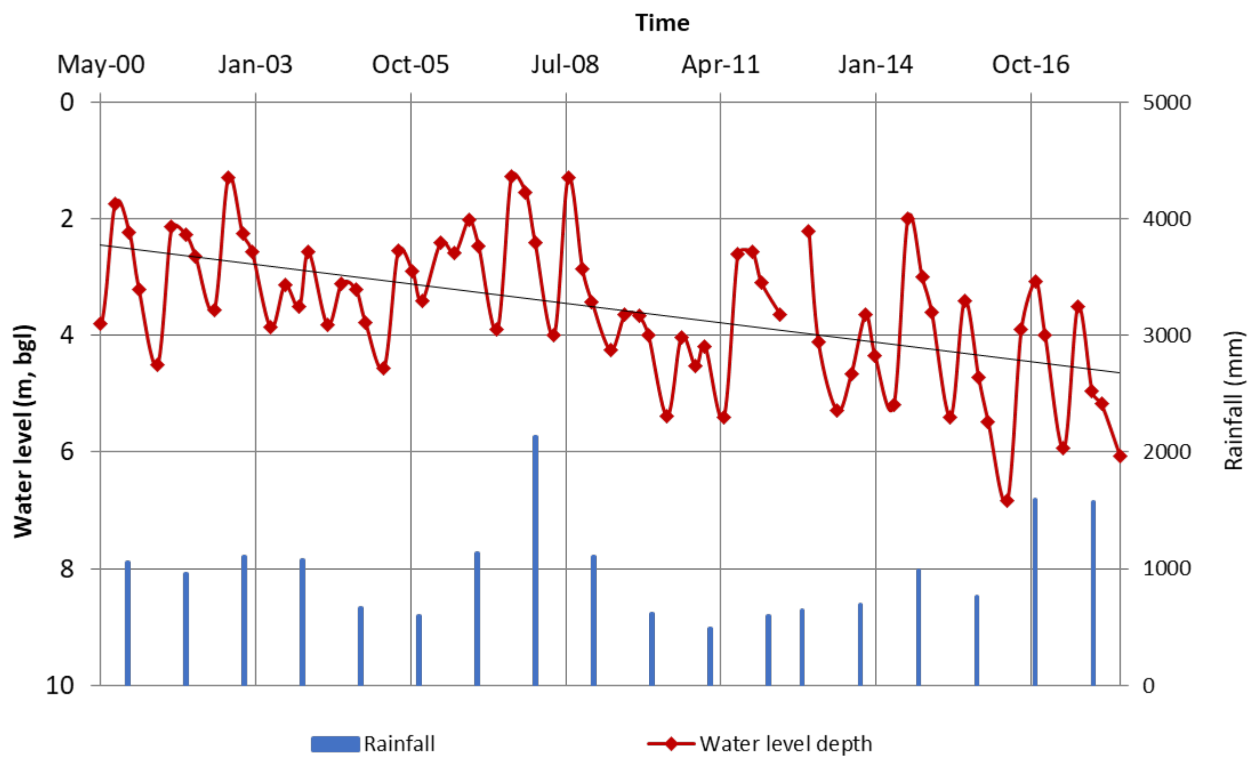

Figure 3. Observed groundwater level trend of Nalanda district.

Observed ground water behavior data across the district's total 39 National Hydrograph Monitoring Stations were chosen for calibration and validation of the model. Out of 39 stations only eight Dug water wells contain water level data since 1998. Al remaining wells provide data from 2013 to the present. The two decades of water level observations in dug wells is shows a significant decline in water levels (Fig. 3). Considering the the current expansion of electrically powered groundwater for irrigation, this declining trends signals some concern for the district's efforts to both develop *and* sustainably manage groundwater.

The overall mean water level is 3.5 m bgl with a standard deviation of 1.2. As described above, most surface water flows towards the north-east following the predominant topography, but several local flows are also present in different directions based on the hydraulic gradient (Fig. 4). The Biharsharif block (a sub-urban area of the district) has a deeper water level following the Rajgir area. These represent the crystalline hard rock aquifers.

CONCLUSIONS AND NEXT STEPS

Despite being considered part of the groundwater abundant Eastern Gangetic Plains, Nalanda district is already showing signs of groundwater depletion. TAFSSA is testing the hypothesis that ongoing investments in irrigation infrastructure could amplify this trend. Careful management of groundwater resources is likely to be required to ensure that food systems transitions do not endanger groundwater related ecosystem service provisioning or create inequitable groundwater access across for users.

To assist these efforts, conceptual model shown in Figure 1 will need to be calibrated and validated with observed values to produce a numerical groundwater model. The validated model will subsequently be used for participatory and co-creative scenario runs that – through TAFSSA's multi-stakeholder platforms – are expected to assist planners to ensure that food security and water security objectives are met without breaching local ecological resource limits.

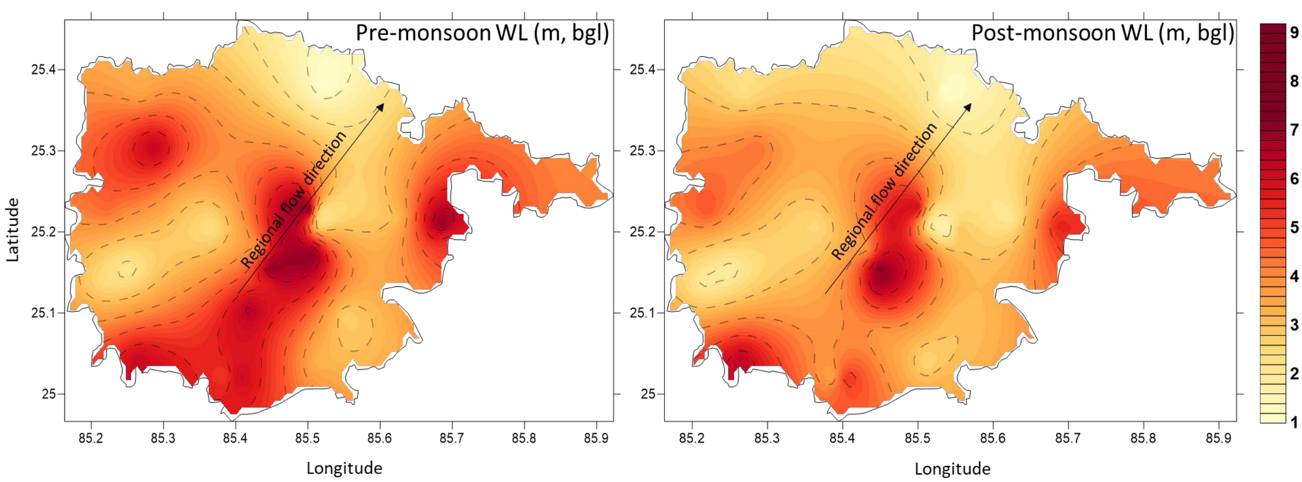

Figure 4. Mean water level map including estimated groundwater flow direction of Nalanda district during the pre- and post monsoon season.

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ABOUT TAFSSA

TAFSSA is a CGIAR regional integrated initiative to support actions that improve equitable access to sustainable healthy diets, improve farmers' livelihoods and resilience, and conserve land, air, and water resources in South Asia.

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