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The five-year (2014-2018) ASSAR project (Adaptation at Scale in Semi-Arid Regions) uses insights from multi-scale, interdisciplinary work to inform and transform climate adaptation policy and practice in ways that promote the long-term wellbeing of the most vulnerable and those with the least agency.

KEY FINDINGS

- In the semi-arid regions of Maharashtra, there are low rates of groundwater flow, and low capacities for groundwater storage in the hard rock basaltic aquifers. These factors make people reliant on rainfall for water, and so climate variability – and its impact on precipitation – places communities at extreme risk of water shortages.
- Current practices of groundwater exploration and use (pumping excessively; storing groundwater in farm ponds; drilling new and deeper wells) can impact base water flows and dramatically reduce water availability.
- A better, more fine-scale understanding of underground common-pool, multi-layered¹ aquifers and groundwater flow patterns can guide the regulation of borehole drilling, determine the best placement of water-saving measures, and assist communities with their water management efforts.

Groundwater meets more than 50% of India's general irrigation needs, and more than 80% of irrigation needs in the semi-arid regions of the country.

In the semi-arid Ahmednagar District of Maharashtra hydrological drought conditions are a common phenomenon. In the past few decades, groundwater withdrawal for public supplies, agriculture and industrial use, has increased significantly. This increase, together with a high degree of spatial variation in local aquifer storage characteristics and insufficient rainfall for recharge, has depleted the availability of groundwater for farmers, and led to recurrent crop failures.

Amid these conditions, desperation among farmers to secure agriculture and its allied livelihood has resulted in rampant drilling of boreholes. But these boreholes commonly fail due to overexploitation of groundwater and incorrect site selection, pushing many farmers into spiralling debt and severe distress.

Variable aquifer characteristics (below ground), unsustainable resource use patterns (on ground) and deficiencies in rainfall (climatic externalities) are barriers that have the potential to seriously cripple agrarian livelihoods.

If groundwater distribution and availability patterns were better known and better communicated to agrarian communities, then farmers could more effectively and sustainably manage this crucial common-pool water resource.

MAPPING GROUNDWATER VULNERABILITY ZONES

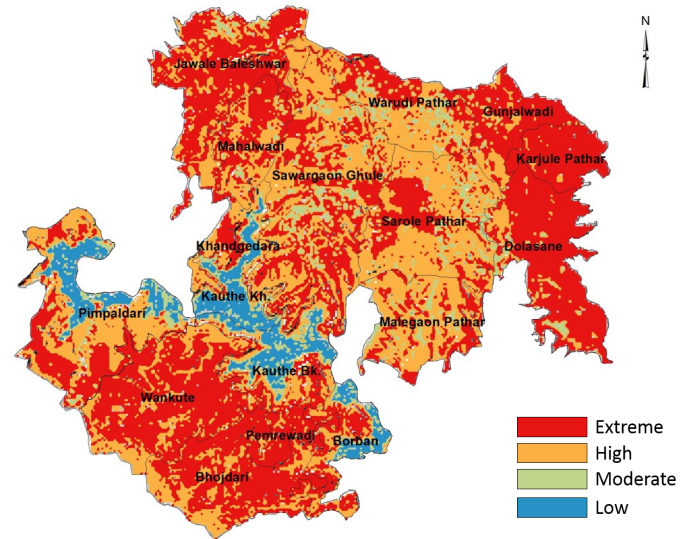
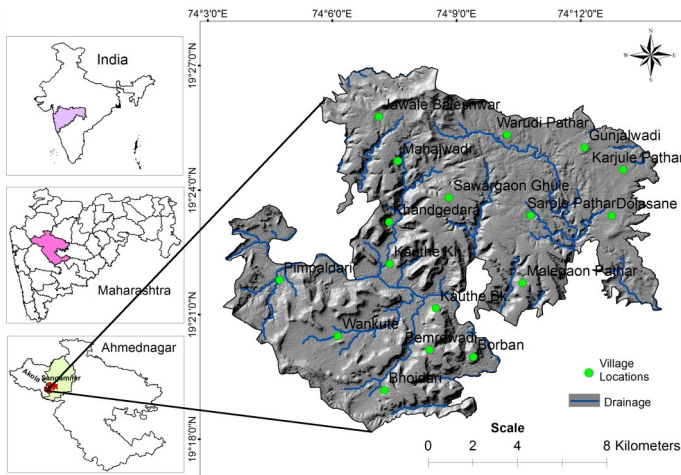
The indiscriminate abstraction of groundwater can have adverse impacts on water availability.

By developing an understanding of local distributions and availabilities of groundwater, hydrogeological studies can guide the sustainable use and timely management of groundwater resources.

This is particularly necessary in places where rainfall is limited or highly variable.

Working in 17 villages from the blocks of Sangamner and Akole, in the Ahmednagar District, we researched the region's groundwater patterns to understand site-specific differences in people's vulnerability to water scarcity.

We used a combination of physical groundwater mapping, hydraulic well-testing, and digital mapping techniques to classify this area into four vulnerability classes: Extreme, High, Moderate and Low.



We categorised the majority of villages as Highly or Extremely vulnerable to groundwater drought. Also, as differences in underlying geology cause the distribution of accessible groundwater to be highly variable and patchy, we found that even people living nearby within the same area, or the same village, could have vastly different vulnerabilities. More worryingly, current trends of groundwater use (addition of new wells; tapping multiple aquifers; pumping out groundwater to store in farm ponds) can bring on category shifts from Low vulnerability to High and Extreme vulnerabilities in the coming years.

The persistent pressure on the limited groundwater resources needs to be properly managed to ensure that water remains available into the future.

Impacts on Groundwater Availability

As part of a drought-proofing initiative of the Maharashtra Government, farmers desperate to secure agricultural productivity under changing rainfall patterns often establish farm ponds. These ponds are intended to harvest rainfall through surface run-off.

Instead, farmers frequently fill their ponds by pumping groundwater from their wells and bore-wells immediately after the monsoon.

This, together with other problematic groundwater-extraction activities – such as the deepening of existing wells, and the competition among farmers to drill new and deep bore-wells in close proximity to each other – can dramatically reduce the availability of groundwater in the underlying aquifers.



Meteorological droughts

occur when there is insufficient rainfall in an area. These droughts can prolong hydrological droughts and affect agrarian livelihoods.

Hydrological droughts

occur when water supplies (in streams, reservoirs, and groundwater stores) become low. These droughts are common in the semi-arid areas that have underlying hard rock aquifers.



CATEGORISING VULNERABILITY

Vulnerability to Groundwater Drought	Typology and Dominant Aquifer Type	Implications
<p>Extreme 52% of the study area</p>	<p><i>Typology:</i> Basalts (compact)</p> <p><i>Dominant aquifer type:</i> Simple, confined² aquifers</p>	<ul style="list-style-type: none"> Water is tapped from deep confined aquifers, due to the depletion of unconfined³ aquifers. However, there is a serious risk of multiple confined aquifers being depleted due to: <ul style="list-style-type: none"> Reduced rainfall. The presence of massive basaltic units limiting groundwater recharge availability. Significant land use/land cover changes. Excessive pumping of wells for irrigation.
<p>High 35% of the study area</p>	<p><i>Typology:</i> Basalts (weathered and vesicular)</p> <p><i>Dominant aquifer type:</i> Compound lobate – sheet lobate aquifers</p>	<ul style="list-style-type: none"> Limited groundwater storage in shallow unconfined aquifers. Excessive pumping of wells. Gradual shift to groundwater exploration of deeper confined aquifers. No sources of surface water.
<p>Moderate 7% of the study area</p>	<p><i>Typology:</i> Basalts (fractured/jointed)</p> <p><i>Dominant aquifer type:</i> Sill, dykes and joints (columnar and sheet)</p>	<ul style="list-style-type: none"> Presence of dykes, fractures, weathered rocks and drainage lines provides moderate amounts of water. However, the availability of water requires fracture connectivity and depends on how frequently groundwater is pumped from these lineament zones.
<p>Low 6% of the study area</p>	<p><i>Typology:</i> Alluvium</p> <p><i>Dominant aquifer type:</i> Unconfined to semi-confined with clay lenses</p>	<ul style="list-style-type: none"> Presence of thick alluvial aquifers that have a higher capacity to store and transmit groundwater. Groundwater and surface water availability is almost year round, but is dependent on annual replenishment of aquifers from rainfall.

When groundwater storage capacities and water-flow potential is low, inconsistent and highly variable, and when these aquifer characteristics intersect with low levels of rainfall and unsustainable water-use patterns, they have the potential to severely cripple agrarian livelihoods and compromise people's wellbeing.

These hardships can be further aggravated by existing social vulnerabilities and inequities, such as those tied to gender, age, socio-economic status and caste. Making matters even worse are market price fluctuations, decreasing land holding sizes due to fragmentation of households, and the high dependence of farmers on loans to meet the increasing input costs of agriculture.



¹ **Multi-layered aquifer:** stacked or overlapping layers of permeable basalt rock strata that vary in thickness and size.

² **Confined aquifer:** upper surface of the aquifer is closed to the atmosphere due to impermeable overlying rock layer.

³ **Unconfined aquifer:** upper surface of the aquifer is open to the atmosphere through permeable overlying material.

RECOMMENDATIONS

- To ensure that measures taken to access and use groundwater do not inadvertently hamper the overall and long-term availability of this key resource, state groundwater regulations and water schemes should be both socially and ecologically sustainable.
- Farm ponds and wells should be closely managed to minimise and prevent misuse.
- In zones identified as being Highly or Extremely vulnerable to groundwater scarcity, the use of inefficient and unsustainable irrigation practices like flood irrigation should be reduced, and farming of water-intensive crops, such as sugarcane and sweet lime, should be avoided.
- Farmers should instead be encouraged to adopt micro-irrigation and climate-resilient agricultural practices – such as the system of crop intensification (SCI) – that use minimal amounts of water, but yield high levels of production.
- Farmers should also be incentivised to pool groundwater and upscale water-efficient systems. These activities can increase farm productivity and improve farmers incomes while reducing competitive drilling and contributing towards the sustainable management of aquifers.
- Our research methods could be applied to other drought-prone areas to precisely delineate areas vulnerable to groundwater scarcity. These delineations can help to develop adaptation strategies and can guide the regulation of borehole drilling, determine the best placement of water-saving measures, and assist communities with their water management efforts.

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Groundwater occurrence is dependent on the architecture and morphology of multi-layered basalts



Misplaced wells can significantly alter the discharge of springs that tribal communities depend on for their drinking water



Unregulated bore-well drilling and bore-well use can lower the water table



Farmers resort to deepening their wells in the hope of tapping more groundwater



Common pool groundwater resources are comparable to people drawing water from the same bucket



It is important for stakeholders to understand spatial variation in groundwater availability

ABOUT ASSAR

ASSAR uses insights from multiple-scale, interdisciplinary work to improve the understanding of the barriers, enablers and limits to effective, sustained and widespread climate change adaptation out to the 2030s. Working in seven countries in Africa and South Asia, ASSAR's regional teams research socio-ecological dynamics relating to livelihood transitions, and the access, use and management of land and water. One of four consortia under the Collaborative Adaptation Research Initiative in Africa and Asia (CARIAA), ASSAR generates new knowledge of climate change hotspots to influence policy and practice, and to change the way researchers and practitioners interact.

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