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ADAPTATION AT SCALE IN SEMI-ARID REGIONS

2014–2018

PUTTING **PEOPLE** AT THE CENTRE TO ENABLE EFFECTIVE **CLIMATE ADAPTATION** IN SEMI-ARID REGIONS

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INDIAN INSTITUTE FOR
HUMAN SETTLEMENTS

VULNERABILITY AND ADAPTATION TO CLIMATE CHANGE IN SEMI-ARID MAHARASHTRA, INDIA

ASSAR'S FOCUS IN MAHARASHTRA, INDIA

India consists of a diverse set of ecosystems with a range of risks, climatic and non-climatic exposures, differential vulnerability profiles, and various institutional regimes. The country is complex, with multi-hazard environments and climate change hotspots. Negative impacts on key rural production systems like agriculture and forestry are already evident, and a range of losses and impacts across agricultural, water and forest-based systems are projected for the future. Major livelihood transitions are expected to take place along the rural-urban continuum, coupled with increasing urbanisation. A significant proportion of the population lives in extreme poverty and is highly vulnerable to both everyday risks and the impacts of extreme events.

The country also faces serious institutional and governance challenges, compounded by contested growth dynamics, rural-urban migration, and fluxes in the historically-established formal and informal sectors. These dynamics will combine to create pockets of risk where concentrations of historical and emergent challenges are amplified by climatic variability.

Maharashtra State is vulnerable to many of the risks detailed above, not least because of its challenges related to groundwater availability and management. The state is mostly semi-arid (73% of its geographic area is classified as such), and houses about a quarter of India's drought-prone districts. More than 30% of the state falls within a rain shadow, which suffers from scanty and erratic precipitation. In addition, continued overexploitation of groundwater has led to depleting aquifer stocks and falling water levels, which threaten the sustainability of agricultural economies built on the basis of groundwater irrigation. Groundwater is not uniformly available across the region and a disaggregated typology of groundwater, derived on the basis of aquifer settings, is an important consideration for groundwater management strategies.

The Maharashtra Groundwater Development and Management Bill of 2009 is the Maharashtra state government's initiative to regulate groundwater. It prohibits the drilling of deep wells, places restrictions on withdrawal of water from existing deep wells, and contains provisions for levying cess. It also requires that tubewell owners and drilling contractors are registered, and that contractors obtain permission before drilling a tubewell. However, implementation of the regulations has been a challenge.

The Watershed Organisation Trust (WOTR), a non-governmental organisation that has been actively working with communities in Maharashtra for the past 25 years, engages in developmental activities in the areas of natural resources management, watershed development, and climate change adaptation. From 2014 to 2018, as part of ASSAR, WOTR's team of researchers and practitioners worked with multiple stakeholders, including farmers, local village-level elected representatives, government functionaries (state and district level), and other research organisations, to develop strategies to bolster the resilience of farmers and rural households to climate risks, while strengthening local-level water management initiatives, including groundwater management.

Key insights

- Agricultural growth in semi-arid regions is largely dependent on groundwater. Depleting groundwater levels put the agrarian economy of the entire semi-arid region at serious risk. Raising farmer awareness about water management through effective communication, especially about groundwater use, is a crucial step towards implementing rules and regulations for groundwater management.
- Building people's adaptive capacities in Maharashtra requires understanding differential vulnerabilities to climate risks and capacities among the different social (castes) and farmer (based on land ownership) categories. This understanding can be used to inform and develop local-level livelihood adaptation strategies. At the same time, the needs and aspirations of people in these different social and demographic categories need to be taken into account when preparing local adaptation and development plans.
- Heat stress in the peak summer months is increasingly affecting people's health and livelihoods. Many factors influence vulnerability to heat stress, including age, pre-existing health conditions, occupation, and housing type. State- and local-level heat action plans that address the needs of rural and urban populations, are vital. Communities should also be made more aware of heat stress so that people can take adequate precautions.
- Despite there being a number of government and private Information Communication Technology initiatives in India aimed at supporting farmers, farmer access to usable information on weather and climate risks, and agro-advisories remains a challenge. There is also ambiguity around whether the available information meets famer requirements. A dynamic and responsive agro-met advisory system, that provides demand-driven, and location- and crop-specific information, can help to better manage climate risks and support adaptation.

ABOUT THE RESEARCH

Research priorities

To better understand how people in Maharashtra are exposed to climate risk, and what capacity they have to respond, we explored the biophysical and socially-differentiated vulnerabilities at play in the region, as well as the barriers and enablers to wellbeing of the communities we worked with. Our research examined the vulnerabilities and adaptation strategies of farmers in a dynamic context of increasing rainfall variability, land use/land cover (LULC) changes, reductions in groundwater levels and overexploitation of this resource, and long-term climate changes.

Heat stress emerged as an important issue, especially during the peak summer months when heatwave-related deaths were recorded across the country. Yet we found no comprehensive heat action plan for Maharashtra. In order to better explain the impacts of heat stress on rural populations, we focused on understanding differential vulnerabilities to heat stress among rural communities as well as the factors that influence these vulnerabilities.

To understand how global warming of 1.5°C and higher will affect India, we assessed the projected local impacts of increasing global warming scenarios on regional rainfall and temperature extremes across the country. This work can be used to inform local-level adaptation planning.

We also conducted micro-level studies to gain an understanding of: 1) farmer behaviour towards groundwater use; 2) the role of the agro-advisory system and farmer responses to climate risks; 3) the needs and aspirations of local communities; and 4) barriers and enablers to adaptation in local governance mechanisms.

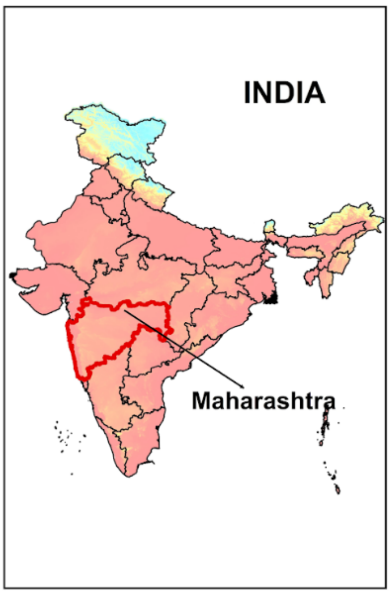
Case study sites

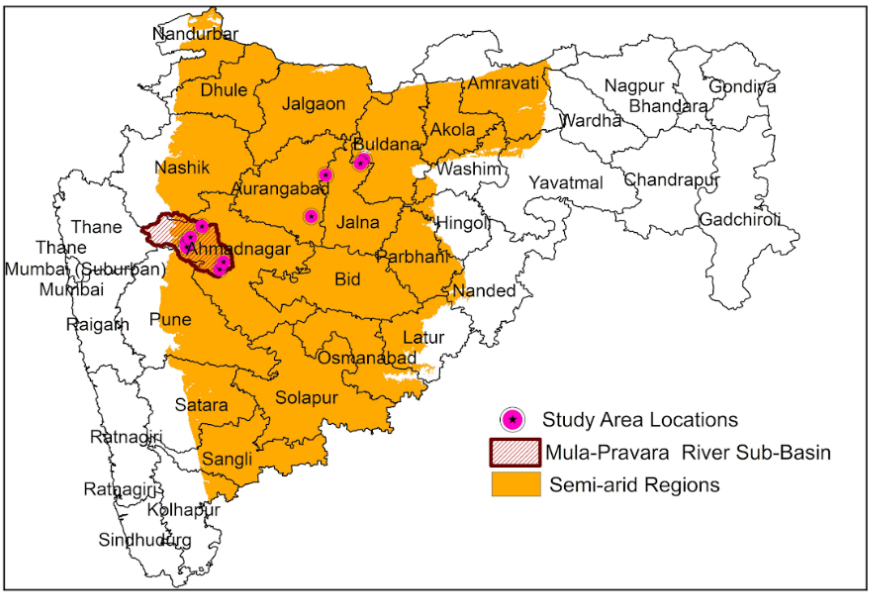
We worked across four districts in Maharashtra. Our main study site was the semi-arid Mula-Pravara region (part of Godavari basin) in Ahmednagar district. This district is centrally located in the state of Maharashtra and covers 17,114 km$^{2.}$ It has a population of 4,543,159 (2011 census) with a density of 226 people per km2; about 80% of the population is rural.

Ahmednagar district falls largely within the hot, semi-arid agro-ecological subzone of the Deccan Plateau, and has black soil. The district's position in the rain shadow area of the Western Ghats makes it susceptible to droughts, which occur every three years. The latest national groundwater assessment categorises the central part of the basin in the Sangamner administrative block as an "overexploited" groundwater zone.

Average annual rainfall in Ahmednagar district is 565 mm, with 94% of this falling from June to October. There has been a modest increase in annual average rainfall since the early 1990s, but there was also high variability in the contribution of sparse and moderate rain events. Projections indicate that there will be an increase in extreme rainfall and a decrease in the number of rainy days in the region in future. This is a matter of concern for agriculture. In recent years, Mula-Pravara's LULC has experienced dramatic changes. There has been a noticeable expansion in the agricultural area, along with shifts towards commercial crops, such as soybeans, sugarcane and pomegranates, with large dependence on groundwater for irrigation.

The increase in area irrigated through groundwater has led to a significant rise in groundwater draft, leading to overexploitation in many parts of the district. Between 2004 and 2011, groundwater draft in the Ahmednagar district increased from 74% to 82% of net annual availability, and groundwater depletion has become an important focus area.





APPROACH

Our team comprised 15 researchers from varied research backgrounds, including geo-hydrology, natural resource economics, climate science, sociology, agriculture and agricultural engineering, coupled with teams of practitioners working at the grassroots level. Our main objective was to produce comprehensive transdisciplinary research with high application value that could make an impact on critical challenges in Maharashtra State.

Our Regional Diagnostic Study (RDS) helped us to identify key research gaps and critical barriers to effective, widespread and sustained adaptation in Sangamner sub-region. Detailed analyses of existing literature helped us delineate emerging themes and issues that exacerbate the impacts of climate change on natural, physical and social systems. Through multiple stakeholder engagements during the RDS phase we identified specific problems in the region that subsequently link to ASSAR's overarching research themes. At the local level, we identified key research themes that included the assessment of biophysical (LULC changes) and socio-economic vulnerabilities to climate change, water governance (focused on groundwater management), and agro-meteorology. We conducted a down-scaled assessment of groundwater vulnerability in selected villages in the Mula-Pravara sub-basin. As part of our Research-into-Use (RIU) efforts, especially with regard to water governance, we initiated steps to engage with various stakeholders so as to share information and identify topics for further research.

As a first step, we organised a stakeholder engagement event, where farmers, government functionaries, researchers and practitioners came together to discuss and identify key problems, which helped us to prioritise our research topics and questions. Groundwater use and its management emerged as key issues needing immediate attention. Next, we assessed the regional geo-hydrology and analysed the long-term LULC changes in order to identify areas of groundwater vulnerability and hotspots of land use change.

As part of our stakeholder engagement, we initiated a Transformative Scenario Planning (TSP) process in the drought-prone Jalna district. The TSP brought together 40 stakeholder representatives, including landless women, farmers from different landholding categories and farmer movements, members of the gram panchayat (village governing body), government officials, academic institutions, college students, non-governmental organisations (NGOs), media, and a scientist from the water sector. The TSP created new partnerships around a common burning issue: how can we identify equitable and transformative adaptation pathways to ensure water for domestic and livelihood needs in the medium-term future (2015-2030)? Participants agreed that the implementation of government policies and programmes, and collective action to manage water resources, were vital for helping Jalna district address its future water situation.

Our heat stress research provided an opportunity to link with Wageningen University, a partner in the Himalayan Adaptation, Water and Resilience (HI-AWARE) consortium (part of CARIAA). Through this partnership, we undertook a pilot study that monitored temperatures during peak summer in the houses of rural communities, giving us an improved understanding of their vulnerability to indoor and outdoor heat exposure.

FINDINGS AND RECOMMENDATIONS

CLIMATE CHANGE, LAND USE/LAND COVER CHANGES, AND OVEREXPLOITATION OF GROUNDWATER EXACERBATE VULNERABILITIES

In Maharashtra, increased access to groundwater has caused the area of land used for agriculture and horticulture to mushroom over the past 25 years. A major part of the Sangamner transect is now classified as groundwater 'overexploited.' Global warming of 1.5°C and higher is expected to add further challenges to existing groundwater vulnerability here, and exacerbate the impacts of recurrent droughts and heat stress.

Between 1991 and 2016, the Mula-Pravara river basin, located in the semi-arid region of Maharashtra state, has seen the area of land used for agriculture and horticulture increase by about 98% and 1601%, respectively. At the same time, unculturable and culturable wasteland (UCW) declined by 34.6%, and fallow lands declined by 60.5%. These changes can be majorly attributed to increased access to groundwater, irrigation projects, and watershed development programmes.

In the Sangamner sub-region, an assessment of precipitation trends indicated a modest increase in annual average rainfall since the early 1990s. It also recorded high variability in the contribution of sparse rain and moderate rain events. Due to increased groundwater dependence in the Sangamner transect, the major part of the block is now groundwater 'overexploited.'

We found that almost 87% of the area in the study villages is classified as having 'high' to 'extreme' groundwater vulnerability. These zones have very low hydraulic yields, with low capacities for groundwater storage in the hard rock basaltic aquifers. This makes it all the more important to use the groundwater resource judiciously. Vastly different vulnerabilities and current trends of groundwater use exist in the region that can shift areas of 'low' vulnerability to 'high' and 'extreme' vulnerability in the coming years. 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.

Amongst various schemes, farm ponds are being encouraged at a large scale by the government in order to drought-proof the region. In principle, farm ponds are traditional rainwater harvesting structures that are supposed to have an inlet to allow runoff to ingress in the pond, and an outlet to let out excess water. Their purpose is to help farmers adapt to the vagaries of the monsoon by harvesting rainwater. But these farm ponds have changed from their intended design and are now widely used as storage tanks to hold groundwater, which is extracted indiscriminately from the multi-layered aquifer system.

We found that the benefit-cost ratios were higher in the case of smaller farm ponds as compared to large farm ponds. When considering externalities of pumping out groundwater and storing it in surface water structures (e.g., value of evaporation losses, and opportunity costs of land lost to farm pond structure) as costs, then the Net Present Values (NPV) decreased for all sizes of farm ponds. Only the smaller farm ponds were found to be viable with a positive NPV and benefit-cost ratio.

Global warming of 1.5°C and higher is expected to result in local temperatures in much of India rising more than the global average. This will likely usher in further climate challenges that exacerbate current community vulnerabilities to land use/land cover change, and groundwater overexploitation.

Recommendations

- It is essential for India's current national and state action plans on climate change and adaptation to consider the local implications of global warming of 1.5°C and 2°C in India and make informed policy decisions around these.

- Overdependence on groundwater could have serious implications for regional agricultural sustainability. State government needs to prioritise groundwater management by formulating strategies to operationalise the recently-enacted Maharashtra Groundwater (Development and Management) Act, 2009 to regulate groundwater. This is a first step towards addressing groundwater governance issues, and will require the reductions of the conflicting development programmes and subsidies that sometimes inadvertently lead to groundwater overexploitation.

- 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. Farming of water-intensive crops, such as sugarcane and sweet lime, should be avoided.

- A better, more fine-scale/local-level understanding of underground common-pool, multi-layered 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 in lieu of changing rainfall regimes.

- Farm ponds converted to groundwater storage structures should be closely managed to minimise and prevent misuse. For this to happen, the gram panchayat needs to proactively engage in monitoring and regulating the extraction of groundwater for storage in farm ponds, as well as farm pond size.

- It is important to generate knowledge and evidence about groundwater status at the local level, create awareness among different stakeholders (farmers, concerned government authorities, researchers), and create a platform for dialogue for local solutions at the community level. Such a platform could help to bridge knowledge gaps pertaining to hydrogeological information at the community level, and contribute to making more robust groundwater management plans at the village and aquifer levels.

ADAPTATION PLANS NEED TO FACTOR IN THE DIFFERENTIATED VULNERABILITIES, NEEDS AND ASPIRATIONS OF DIFFERENT SOCIAL GROUPS IN RURAL COMMUNITIES

Building people's adaptive capacities in Maharashtra requires understanding differential vulnerabilities to climate risks and capacities among the different social (castes) and farmer (based on land ownership) categories. This understanding can be used to inform and develop local-level livelihood adaptation strategies. At the same time, the needs and aspirations of people in these different social and demographic categories need to be taken into account when preparing local adaptation and development plans.

In rural Maharashtra communities identified both climate risks (associated with changes in temperature and rainfall) and non-climatic risks, that combine to significantly influence their crop management decisions. For our research, we categorised farmers according to gender, land ownership (large, medium, and small and marginal), and whether or not they were landless. All farmers demonstrated a high sensitivity to both climate and non-climatic risks; however we found differential vulnerabilities across farmer categories, as we detail below.

Sometimes access to, and investments in, irrigation do not necessarily reduce vulnerability, and conducting rainfed farming does not necessarily increase vulnerability. For example, despite the small and marginal Mali community farmers having access to irrigation – as they practice groundwater-dependent, high-profit commercial crops such as pomegranate – their lands and crops are at a higher risk from future climate impacts and declining groundwater resources. Conversely, the *Banjara* community farmers, who have no access to irrigation sources, successfully manage their agriculture and semi-intensive livestock rearing in rainfed conditions.

Caste and social standing also majorly impact whether farmers can access resources and subsidies, leading to further differentiated vulnerabilities. For example, lower caste groups are unable to access subsidies and government programs. Furthermore, the knowledge and skills of different castes or social groups can be culture-specific, and can inherently affect resilience to climate change.

Vulnerabilities are also reflected through people's needs, and the satisfaction they get from different areas of their lives. Identifying the differential needs and aspirations of the diverse demographic (adults, young adults – both men and women) and socio-economic groups (based on social categories, land ownership, and economic criteria) in rural communities is an important step not only towards understanding specific vulnerabilities, but also towards achieving the Sustainable Development Goals. For example, all socio-economic groups were dissatisfied with food, health care and sanitation, but there were relatively higher levels of satisfaction among some socio-economic groups regarding credit and agricultural inputs.

Climate change impacts existing vulnerabilities by creating stressors and shocks. Such shocks magnify the impacts of existing social fissures, either harming or benefiting people's adaptive capabilities. For example, the forward communities have more land holding, and are primarily engaged in agriculture. They face higher risks from rainfall variability. Scheduled tribes and scheduled caste communities have lower land holdings, and depend on wage labour as their major livelihood source. They are also prioritising education in attempts to secure regular employment in the government sector (due to reservations and other enabling environments). Given expected climate change impacts, these backward communities could thus potentially become more resilient due to their diversification into alternate livelihoods.

Community priorities (needs and satisfaction) are influenced by village resource endowments, awareness of government programmes and schemes, and literacy. Our assessments of these priorities brought into focus the extent to which local governance mechanisms sufficiently support local communities, especially in the context of village-level development plans (Gram Panchayat Development Plans), and helped us to identify the functional constraints of village-level institutions. For example,we found that health care, sanitation, education, and employment opportunities were the most commonly identified priorities of the communities. In most cases, the Gram Panchayat Development Plans reflected these community priorities, even though community members from different villages varied in terms of how satisfied they were about the way the plans were executed on the ground.

Recommendations

- Caste and social standing play a major role in determining access to resources, land ownership, and livelihood choices, thus differentially impacting people's vulnerability to climate change. Accordingly, any local-level adaptation plans by local governance institutions (panchayats) have to correspond to the specific vulnerabilities (to climatic and non-climatic risks) of community groups. These vulnerabilities should be assessed using cluster-based, holistic and participatory approaches, with assessments conducted at fine scales (rather than treating districts as a single category) to account for the way that climate risks vary across and within village clusters.

- Efforts need to be directed toward addressing the structural and institutional barriers of local-level governance. Improved engagement with communities can foster more inclusive village-planning processes. For example, sometimes the large size of gram panchayats becomes an impediment when reaching out to all the villages or hamlets within the panchayat. It is therefore important to increase the number of community social workers (gram sevaks), thereby reducing the risks of overburdening them, or having to reorganise large panchayats into smaller panchayats.

- Illiteracy, and a lack of knowledge about leadership roles and responsibilities of elected representatives, are barriers to active participation in local governance, especially for women. Focused training and capacity building of elected representatives (whether women or men) to build their managerial skills, and inform them about the legal or constitutional powers vested in their respective positions, could be done using various multimedia tools.

HEAT STRESS POSES SERIOUS AND DIFFERENTIAL RISKS TO PEOPLE'S HEALTH AND LIVELIHOODS

Heat stress in the peak summer months is increasingly affecting people's health and livelihoods. Many factors influence vulnerability to heat stress, including age, pre-existing health conditions, occupation, and housing type. State- and local-level heat action plans that address the needs of rural and urban populations, are vital. Communities should also be made more aware of heat stress so that people can take adequate precautions.

People in the region are also at risk of heat stress, with some groups being more vulnerable than others. The major heat-related symptoms reported include headaches, heavy sweating and fatigue, which were mild or moderate in nature. We found that differentiated vulnerabilities to heat stress are based on type of livelihood, type of housing, wealth, age, gender, and pre-existing health conditions.

For example, working men and women (31-59 years old) were found to be most vulnerable when compared to all other age groups, given that they frequently work outdoors during the middle of the day. In addition, homes in Yavatmal district with tin roofs and poor indoor ventilation had higher indoor afternoon temperatures than houses with other roofing types, increasing the heat stress risks of those inside at that time of day (the elderly, children and women).

Recommendations

- There is an urgent need for pre-emptive strategies to reduce the vulnerability of people in heat-stress prone areas. Early detection is crucial, and communities should be made more aware of heat stress so that people can take adequate precautionary measures.
- Rural health infrastructure should be upgraded to handle heat stress-related incidences, such as having cooling rooms in primary health centers (PHC) in the villages.
- Effective planning by Maharashtra State's Public Health Department and Rural Development Department could help to mitigate and avoid heat-related illnesses and deaths, through development of surveillance mechanisms to monitor heat-related mortalities and morbidity.
- At present there are heat action plans for only some states and few cities in India. Developing a state-level heat action plan for Maharashtra, which addresses urban and rural communities, should be a priority.

COLLABORATIVE KNOWLEDGE SYSTEMS SUPPORT FARMERS TO BETTER MANAGE CLIMATE RISKS

Despite there being a number of government and private Information Communication Technology initiatives in India aimed at supporting farmers, farmer access to usable information on weather and climate risks, and agro-advisories remains a challenge. There is also ambiguity around whether the available information meets famer requirements. A dynamic and responsive agro-met advisory system, that provides demand-driven, and location- and crop-specific information, can help to better manage climate risks and support adaptation.

Farmers and other rural actors can benefit from numerous types of advisory services. There have been many initiatives (from both government and private sector) to provide weather-based crop advisories for India's farming community, based on location-specific, medium-range weather forecast for the districts under different agro-climatic zones. The success of an advisory system depends upon the quality of its inputs, and the interactions between the different organisations and subject-matter specialists involved.

For example, WOTR provides knowledge-embedded services to farmers in our study region. Farmers receive crop and locale-specific agro-advisories, based on weather forecasts and the particular crop growth stage, in order to reduce their risks and improve their agricultural productivity. Our advisory system is based on a collaborative partnership with key developmental, scientific, and academic institutions (government, private and farmers), which makes it possible to pool and share valuable resources and expertise across domains and institutional boundaries. This collaboration facilitates mutual learning, co-generation of practical knowledge, and technology transfer.

Advisory systems need to be responsive to farmer needs. Thus, it is equally important to understand farmers' responses (adoption or non-adoption) to different types of agro-met advisories. In this context, we found that there were differences in uptake depending on the type of crop grown. In general, farmers tended more often to follow advisories for commercial crops (e.g., onions) than food crops (e.g., pearl millet). Not all farmers followed up on all the advisories, with some crop advisories being more readily adopted than others. Weather advisories had good uptake irrespective of crop type (food or commercial).

Recommendations

- To develop a dynamic farmer-responsive agro-advisory system, it is important for diverse stakeholders (farmers, NGOs, research institutions, government institutions, private organisations) to collaborate, and pool their respective strengths. For example, the Indian Meteorological Department (IMD) – with its expertise in providing short-term weather forecasts – could coordinate more closely with the state agriculture department, state and central government, academic and research institutions (such as State Agricultural Universities and the Central Research Institute for Dryland Agriculture), and with NGOs such as WOTR that can facilitate interactions with farmers on the ground.
- To enable IMD to better calibrate their weather models (given the diversity of topographies and agro-climatic ecologies in the region), the government needs to generate high-quality data points by increasing the number and density of Automated Weather Stations.
- Advisory systems need to be demand-driven and should provide information that is locally relevant and crop-specific. The systems can also be continually improved by ensuring that there are communication flows and feedback mechanisms between the users and generators of information.

WORKING WITH STAKEHOLDERS TO IMPROVE ADAPTATION AT MULTIPLE SCALES

In 2013, the Government of Maharashtra activated the previously dormant Groundwater Act of 2009. However, the application of this act remains a challenge. According to the Act, villages in clusters (along aquifers) need to work together to manage their water resources judiciously. Based on an awareness of how much water is available, villagers are required to draw up prospective crop plans (agriculture and water-use plans) and follow those diligently. The proper application of the Act requires that people be motivated and mobilised to work together as a community, and are incentivised for positive action.

To support action on groundwater management, we initiated a stakeholder engagement process to bring together concerned agencies, farmers, and other practitioners to work on operationalising the Groundwater Act. We disseminated the findings from our study on groundwater vulnerability, and the vulnerability assessment study, through stakeholder engagement workshops in Sangamner's Ahmednagar district. This contributed to a better understanding by the community members of the regional groundwater characteristics and the differential vulnerabilities of farmer categories in the village.

Through experiential learning games (such as the Common Bucket Game), participants realised and appreciated the finite nature of groundwater resources, and the need for each generation to use water sustainably. Another method we used to help farmers understand the common pool nature of groundwater resource (shared aquifer) was the application of a tool called "Community Driven Vulnerability Evaluation – Visual Integrator (CDVI)." This involves producing a 3D model of the hydro-morphology of the village(s) together with participating villagers.

Transformative Scenario Planning (TSP) is an approach that brings together stakeholders who often have conflicting perspectives and who then work together towards a shared outcome. In our TSP process in Jalna district we explored the "Water situation in rural Jalna in 2030: for domestic and livelihoods needs." As a result of the TSP workshops, participants identified two concrete needs: (i) to capacitate and train people on how to prepare 'water budgets'; (ii) to use TSP in other parts of the district to motivate people in those areas to prepare similar water-management plans. To help address these needs, we conducted three further workshop events, with support from Oxfam, taking the TSP experiences to a wider audience in Jalna. Through these events we engaged with farmers from 38 villages.

For many years, WOTR has been working on the issue of groundwater management, and has trained local youth to use tools, such as water budgeting, to more effectively manage water resources. We used an ASSAR Grant for Local Adaptation Support to train and motivate leaders from the gram panchayat to prepare village water budgets. We also linked up with WOTR's Water Stewardship Initiative where villagers are motivated to manage groundwater and develop crop plans based on the annual availability of water. All these efforts helped in generating momentum on the ground to operationalise the Groundwater Act.

In order to further understand heat stress vulnerability, we convened meetings with subject-matter specialists (national and international). We generated awareness about heat stress among communities and local health authorities through a research survey, and disseminated pamphlets and posters on heat stress management (in English, Hindi, Telugu, and Marathi). We also produced a heat stress film: 'Under the blazing sun.'

NEXT STEPS FOR RESEARCH, POLICY AND PRACTICE

Our findings point toward the need for systemic and immediate changes to adaptation planning that take into account state- and local-level realities. For example, groundwater levels have declined due to the government policies and development activities that promoted groundwater abstraction, while at the local level, farmers need support in coping with various climatic and non-climatic risks, and managing natural resources effectively.

An important aspect of this systemic change is the need to include research in the design of adaptation projects, which can help to minimise maladaptation. Furthermore, a transdisciplinary approach that involves different stakeholder groups in 'action research' will play an important role in reducing the research-action-research feedback loop.

As part of future strategies, and in order to strengthen farmers' capacities to adapt, it is important to: (1) generate increased awareness among farmers about short-term and long-term climate change risks and adaptation measures; and (2) improve information flow and feedback mechanisms between research agencies, practitioners, and farming communities.

As the depletion of groundwater resources is a critical concern for semi-arid regions, it is imperative to develop village-level water management plans. To this end, local people should be trained to become water stewards, and should be equipped with the skills and knowledge that enables them to better manage groundwater and surface water.

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ADDITIONAL RESOURCES

ASSAR. 2015. *ASSAR's animated climate messages for India.* [Video]. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link.

ASSAR. 2015. *Planning for climate change in the semi-arid regions of India*. [Information brief]. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link.

ASSAR. 2015. *South Asia regional diagnostic study: Report summary.* [Information brief]. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link.

ASSAR. 2016. *Climate change in the semi-arid regions of India - Warli animation*. [Video]. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link.

ASSAR. 2016. *Key findings from ASSAR's regional diagnostic study & initial research: Sangamner sub-region, Maharashtra*. [Information brief]. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link.

ASSAR. 2017. *The impact of drought in Latur Region, Maharashtra, India*. [Video]. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link.

ASSAR. 2018. *Heat stress: How does one recognise heat stress? What should you do when a person suffers from heat stress?* [Pamphlet]. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link to pamphlet.

ASSAR. 2018. *Heat stress symptoms and ways of managing them.* [Poster]. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link.

ASSAR. 2018. *Transformative Scenario Planning (TSP) in practice: Jalna, India.* [Video]. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link.

ASSAR. 2018. *Under the blazing sun.* [Video]. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link

Bendapudi, R., Kumbhar, N., Gaikwad, P. and Lobo, C. 2019. Agro-met services and farmer responsiveness to advisories: Implications for climate-smart agriculture. In: W. L. Filho (ed.) *Handbook of climate change resilience.* Cham: Springer. Link to book. Link to chapter. Link to poster.

Bendapudi, R., Yadav, A., Chemburkar, S., D'Souza, M. and Thomas, R. 2019. *Adaptation or maladaptation: Case of farm ponds converted into storage tanks in Maharashtra: Implications for groundwater governance*. CARIAA-ASSAR Working Paper. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link. Link to poster.

CARIAA. 2018. *Climate adaptation policy.* [Information brief]. Collaborative Adaptation Research in Africa and Asia (CARIAA). Link.

CARIAA. 2018. *Understanding vulnerabilities using a hotspot approach.* [Information brief]. Collaborative Adaptation Research in Africa and Asia (CARIAA). Link.

Chaturvedi, R., Bazaz, A., Shashikala, V., Krishnaswamy, J., Badiger, S., Bunyan, M., Sanjay, J. and Mujumdar, M. 2018. *Regional climate messages for South Asia.* CARIAA-ASSAR Working Paper. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link.

D'Souza, M., Rao, B. and Awashi, S. 2016. Community-driven vulnerability assessment and resilience building: Cases from development contexts. In: J. Aleta, S. Huq, C. Ochleng, V. Orindi and T. Owiyo (eds.) *Enhancing Adaptation to Climate Change in Developing Countries Through Community-Based Adaptation: Think Globally and Act Locally. African Centre for Technology Studies (ACTS): Nairobi, Kenya, pp. 123-139.* Link to book. Link to chapter.

D'Souza, M., Rao, K. B., Awasthi, S., Nazareth, D. and Bendapudi, R. 2017. *Identifying climate risks and assessing differential vulnerability of communities in Ahmednagar and Aurangabad Districts of Maharashtra.* CARIAA-ASSAR Working Paper. Adaptation at Scale in Semi-arid Regions (ASSAR). Link.

D'Souza, M. and Misquitta, K. 2018. *From me to we... from mine to ours! A story of how motivation changes people's perceptions and drives community action.* [Story of Change]. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link.

D'Souza, M., Daware, H., Misquitta, K. and Mhaskar, B. 2018. *Stakeholder engagement report: Watershed Organisation Trust.* Adaptation at Scale in Semi-Arid Regions (ASSAR). Link.

Duraisamy, V., Bendapudi, R., and Jadhav, A. 2018. Identifying hotspots in land use land cover change and the drivers in a semi-arid region of India. *Environmental Monitoring and Assessment*, 190: 535. DOI: 10.1007/s10661-018-6919-5. Link to summary.

Few, R., Bendapudi, R., Mensah, A. and Spear, D. 2016. *Transformation in adaptation: Learning from ASSAR's regional diagnostic studies.* CARIAA-ASSAR Working Paper. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link.

Few, R., Morchain, D., Spear, D., Mensah, A. and Bendapudi, R. 2017. Transformation, adaptation and development: Relating concepts to practice. *Palgrave Communications,* 3: 17092. DOI: 10.1057/palcomms.2017.92. Link to summary.

Few, R., Singh, C., Spear, D., Davies, J., Tebboth, M. G. L., Sidibe, A, Mensah, A. and Thompson-Hall, M. 2018. *When adaptation barriers and enablers intersect: Key considerations for adaptation planning drawn from ASSAR's findings.* [Information brief]. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link.

Kale, E., Khabiya, P. and Joshi, V. 2018. *Using Transformative Scenario Planning to think critically about the future of water in rural Jalna, India.* Adaptation at Scale in Semi-Arid Regions (ASSAR). Link.

Misquitta, K. and Thatte, K. 2018. *Whose appropriate technology? Understanding the adoption of micro-irrigation in the face of climate and policy uncertainty*. CARIAA-ASSAR Working Paper. Adaptation at Scale in Semi-arid Regions (ASSAR). Link.

Phadtare, A., Banerjee, S. and Bendapudi, R. 2019. *Are changes in land use land cover influencing gender dynamics in semi-arid areas*. CARIAA-ASSAR Working Paper. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link.

Pillai, S. and Bendapudi, R. 2019. *Inclusion of local aspirations in village development plans in Maharashtra*. CARIAA-ASSAR Working Paper. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link.

Pradyumna, A., Bendapudi, R., Zade, D. and D'Souza, M. 2018. *Health vulnerability to heat stress in rural communities of the semi-arid regions of Maharashtra, India.* [Information brief]. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link.

Pradyumna, A., Bendapudi, R., Zade, D. and D'Souza, M. 2018. *Heat stress – vulnerability, health impacts, and coping strategies in rural communities in the semi-arid region of Maharashtra, India.* CARIAA-ASSAR Working Paper. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link.

Pradyumna, A., Bendapudi, R., Zade, D., D'Souza, M. and Tasgaonkar, P. 2018. Managing the increasing heat stress in rural areas. In: W. L. Filho (ed.) *Handbook of climate change resilience.* Cham: Springer. DOI: 10.1007/978-3-319-71025-9_46-1. Link to chapter.

Rao, B., Nazareth, D., Awasthi, S., Bendapudi, R. and D'Souza, M. 2019. Assessing differential vulnerability of communities in the agrarian context in two districts of Maharashtra, India. *Climate and Development*. DOI: 10.1080/17565529.2019.1593815.

Revi, A., Bazaz, A., Krishnaswamy, J., Bendapudi, R., D'Souza, M. and Pahwa Gajjar, S. 2015. *Vulnerability and adaptation to climate change in semi-arid areas in India*. CARIAA-ASSAR Working Paper. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link.

Scodanibbio, L. 2017. *Visiting WOTR's Sangamner sites.* [Photo essay]. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link.

Sinha, B. 2017. *High and dry.* [Photo essay]. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link.

Sinha, B. and Bendapudi, R. In prep. Identifying differential vulnerabilities of rural communities in semi-arid region of Maharashtra through a wellbeing approach. Link to poster.

Singh, C., Daron, J., Bazaz, A., Ziervogel, G., Spear, D., Krishnaswamy, J., Zaroug, M. and Kituyi, E. 2018. The utility of weather and climate information for adaptation decision-making: Current uses and future prospects in Africa and India. *Climate and Development,* 10(5): 389-405. DOI: 10.1080/17565529.2017.1318744. Link to summary. Link to video.

Singh, C., Solomon, D., Bendapudi, R., Kuchimanchi, B., Iyer, S. and Bazaz, A. 2019. What shapes vulnerability and risk management in semi-arid India? Moving towards an agenda of sustainable adaptation. *Environmental Development*. DOI: 10.1016/j.envdev.2019.04.007. Link to summary.

Singh, C., Solomon, D., Bendapudi, R., Kuchimanchi, B., Iyer, S. and Bazaz, A. In prep. Examining barriers and enablers to adaptation in semi-arid India.

Tasgaonkar, P., D'Souza, M., Bendapudi, R. and Jacobs, C. 2018. *Vulnerability to heat stress: A case study of Yavatmal, Maharashtra, India.* [Information brief]. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link.

Thomas, R. and Duraisamy, V. 2017. *Vulnerability to groundwater drought in semi-arid areas of western Ahmednagar District, India.* [Information brief]. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link to English version. Link to Marathi version

Thomas, R. and Duraisamy, V. 2018. Hydrogeological delineation of groundwater vulnerability to droughts in semi-arid areas of western Ahmednagar district. *The Egyptian Journal of Remote Sensing and Space Science,* 21(2): 121-137. DOI: 10.1016/j.ejrs.2016.11.008. Link to summary. Link to English information brief. Link to Marathi information brief.

Yaduvanshi, A., Nkemelang, T., New, M. and Bendapudi, R. In prep. Impacts of 1.5 and 2 degree global temperature rise on temperature and rainfall extremes across India.

Yaduvanshi, A., Zaroug, M., Bendapudi, R. and New, M. In prep. Regional impacts of 1.5 and 2 degree global temperature rise on different states of India. Link to poster.

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