ASSAR

ADAPTATION AT SCALE IN SEMI-ARID REGIONS

2014–2018

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

INSIGHTS FROM TAMIL NADU, INDIA

INDIAN INSTITUTE FOR
HUMAN SETTLEMENTS

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

ASSAR'S FOCUS IN TAMIL NADU, 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 is 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.

India's Moyar-Bhavani sub-region comprises a diverse landscape with abundant natural resources, complex systems of governance, and a multitude of actors with varying degrees of influence and levels of interaction within the system. Along with diverse wildlife and physiographic features, the landscape has very high human density, and a long history of human use. The area is inhabited by diverse indigenous tribal communities, as well as a large population of scheduled castes (socially-marginalised groups). Major livelihood activities include agriculture, fisheries, pastoralism, and collection of non-timber forest products (NTFP). The forest-agricultural socio-ecological system is a key aspect here.

There are existing stressors within the agricultural system including groundwater dependency, decreasing labour, low productivity, and low levels of mechanisation. Risks caused by the occurrence of droughts, increasing temperature profile, declining crop yields and livestock mortality are some of the sub-region's key challenges. With ongoing deforestation, the proliferation of invasive alien species, landscape fragmentation and local extinction impacts, natural ecosystems suffer from rapid land use changes. Considering the essential role that native ecosystems play in ensuring tribal livelihoods, climate change is projected to intensify existing vulnerabilities and amplify risks.

Key insights

- Climate change and climate variability have resulted in increased temperatures and unpredictable monsoons. Despite observed declines in rainfall and recurrent drought, some agricultural areas are greening due to a growing dependence on groundwater, and unauthorised lift irrigation from perennial rivers.

- An increase in agricultural water use, driven by government policy (e.g., free electricity), has enabled a shift from dryland agriculture to intensively-irrigated agriculture that may not be sustainable under future climates.

- The agrarian transition driven by changing aspirations has increased household incomes, especially of large and medium farmers. However, this increase has had little impact on women's capacity as they often cannot access these incomes for their own investments. The increased movement of men into non-agricultural livelihoods has opened up space for women in agriculture, but they remain constrained by a lack of asset ownership and consequent inabilities to increase land productivity.

- Although food security has improved in the region through the targeted Public Distribution System, undernourishment persists and may worsen with increasing urbanisation, shifts to high-value commercial farming (despite the risks), and water scarcity.

- Invasive alien species are adversely impacting native biodiversity and communities. Yet a lack of tenure, and the extensive network of protected areas in the region, complicate the use of these species by forest-dependent communities to supplement agricultural incomes.

- Poor access to services, and lack of knowledge and support constrain women, while men continue to maintain hegemony over technology-related, and indeed, more remunerative tasks. Education, however, remains one of the biggest assets to women, which allows them to diversify their livelihoods out of agriculture.

ABOUT THE RESEARCH

Research priorities

The Moyar Bhavani sub-region consists of two distinct landscapes of which one is an agricultural socio-ecological system (SES), and the other a forest-agricultural SES. In this landscape, ATREE's research focused on understanding socially-differentiated vulnerability, and the barriers to and enablers of adaptation. Our research priorities were informed through stakeholder engagement and scoping studies. Ecosystem services and the gendered impacts of resource use, were two important areas of questioning that were addended to our research agenda based on these engagements.

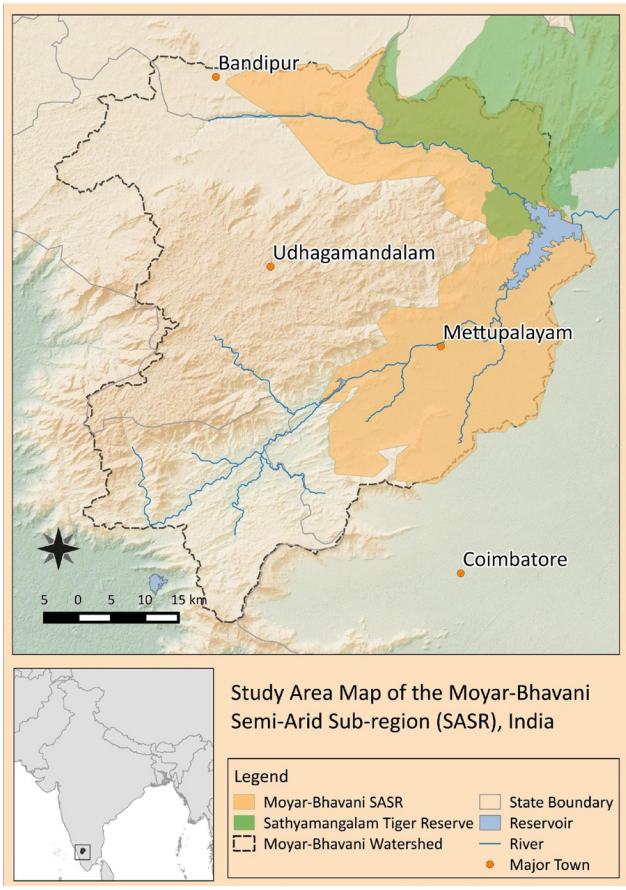
Our research priorities were formulated after an in-depth review of literature on the state of water, forest and agriculture sectors in Tamil Nadu. We then distilled research themes from the larger narrative emerging in the semi-arid regions of India that are characterised by depleting forest and water resources, increased vulnerability of natural resource-dependent communities, and our current inability to disentangle climatic and non-climatic causes of this vulnerability.

Insights from preliminary field visits, stakeholder workshops and interviews with key informants were integrated in the broad set of research questions. Our research was an iterative process where emerging insights were used to inform and calibrate existing research questions.

Specifically, we sought to understand: (1) non-climatic drivers of differential vulnerability; (2) current and future climate variability, non-climatic risks, and their interactive impacts; and (3) local and sub-regional institutional mechanisms of natural resource governance. We focused on key ecosystem services (agricultural productivity, biomass, water, non-timber forest products (NTFP)) and biodiversity, and how these are impacted by ongoing climate change, and the proliferation of invasive species.

CASE STUDY SITES

The combined catchment area of the Bhavani and Moyar rivers is located at the confluence of the Eastern and Western Ghats, and bounded to the north by the state of Karnataka, to the west by Kerala, to the east by the Bhavanisagar reservoir, and to the south by the Coimbatore plateau. The topography is undulating in the lower plateau and uplands, and rugged in the western parts. Vegetation is a mosaic of grassland, scrub, deciduous and evergreen forests, plantations of exotic tree species, and crops. Along with diverse wildlife and physiographic features, the sub-region has a very high human density and a long history of human use.



The sub-region is characterised by a diverse composition of ecological and human communities, and consists of two distinct landscapes. The Bhavani landscape is predominantly agrarian, and supports rural communities that are heterogeneous and made up of various castes. The forested Moyar landscape, on the other hand, supports a relatively homogeneous group of tribal communities that lives in close proximity to, or within, the protected area network. Livelihood profiles in both landscapes are dependent on agriculture, although agricultural practices differ. In the Bhavani landscape, agriculture is typically irrigated and more lucrative than the traditional rainfed farming system of the Moyar landscape.

APPROACH

Semi-arid regions are typically described as climatically stressed with high annual temperatures, and highly seasonal but low rainfall. Our first stakeholder engagement through key informant interviews suggested, however, that the Moyar-Bhavani sub-region had undergone substantial recent change. In order to disentangle climatic and non-climatic drivers of change here, we used a time-series of remotely-sensed vegetation data to detect sites where substantial change had occurred, and compared these with sites where relatively little change had occurred.

In the Bhavani landscape, we selected four villages and conducted a detailed vulnerability and wellbeing assessment by sampling 415 households across these villages. We used a stratified proportional sampling approach to ensure weighted representation across landholding size (large, medium and small landholders) and caste. We supplemented the survey with information from a gender-disaggregated survey in 200 of the 400 households, a nutritional survey conducted in 100 households, 20 focus group discussions (FGD) and 25 in-depth interviews conducted with women in the study area in the years 2016-2017.

The Moyar landscape is characterised by extensive areas under the protected area network and communities dependent on these native ecosystems. Here we conducted two stakeholder engagement events, to gain insights on the changes in governance regimes, communities, climate and ecosystems, and the impacts of these on livelihoods. We then sampled 400 households across 11 hamlets in the landscape to conduct a detailed assessment of the vulnerability and wellbeing of these communities, with an emphasis on the use and role of ecosystem services in community livelihoods.

Our key informant interviews suggested that invasive alien species (IAS) were a major challenge in the Moyar landscape, and we established and measured a series of vegetation plots and transects to understand the impacts of IAS (particularly *Prosopis juliflora*) on native species and the non-timber forest produce that the communities depend on.

Across the two landscapes, we sought to understand how communities manage risk in response to environmental and development stressors and the key vulnerabilities that impact their adaptive capacities. Using both primary (household interviews, FGDs and vegetation plots) and secondary (satellite imagery and weather stations) data, we identified and investigated changes in the quality, quantity and distribution of key ecosystem services (biomass, agricultural productivity, water and NTFP) over the last few decades. Finally, we examined national and sub-national priorities that shape legal, jurisdictional, economic and environmental implications of multi-layered governance in our sub-region.

FINDINGS AND RECOMMENDATIONS

EFFECTIVE ADAPTATION TO, AND MANAGEMENT OF, INVASIVE ALIEN SPECIES REQUIRES BOTH TOP-DOWN AND LOCAL PARTICIPATORY APPROACHES

Forests in the semi-arid tropics play a key role through provisioning services to tribal communities, which are strategically used to buffer risks. In the Moyar Bhavani, IAS are negatively impacting native biodiversity and ecosystem services. The ability of local forest-dependent communities to develop management practices and adaptation strategies to the emerging novel ecosystems is constrained by lack of land tenure due to the delayed implementation of the Forest Rights Act (2006) in Tamil Nadu, and confounded by the protected area status of a large part of the landscape. Meanwhile, the capacity of the Forest Department, NGOs and local communities in understanding the temporal and spatial dynamics, and magnitude of the problem, is constrained. Potential short- and long-term management strategies remain reactive, and are uninformed by scientific studies.

Prosopis (*Prosopis juliflora*) was introduced to the landscape in the 1960s and was expected to contribute to provisioning services through fuel and animal feed, thus increasing the productivity of grasslands. The expansion of *Prosopis* is driving a significant greening of vegetation along the Moyar valley. *Prosopis* in the region is now impacting biodiversity (blackbuck in the region prefer native species, and avoid *Prosopis*-dominated landscapes) and community livelihoods (crop raiding on farm lands from herbivores is linked to increases in *Prosopis* growth). The impacts of *Prosopis* may also worsen in the near future as the consumption of pods by wild herbivores is augmenting the dispersal of this species by blackbuck and elephants.

At higher elevations, the expansion of Lantana (*Lantana camara*), another IAS, has impacted local livelihoods significantly. Livestock pasturing areas have reduced, and NTFP productivity in the region has been impacted by the spread of IAS.

Resistance from state agencies (especially the Forest Department) to implement the Forest Rights Act, and the pertinacious focus on physical solutions for IAS spread in the region has neglected the potential of community-led solutions. Furthermore, the spatial and temporal dimensions of the spread of IAS, and their impacts on NTFP, livestock grazing, and wild herbivores, is not adequately acknowledged and more research is needed on the factors that drive their occupancy and persistence.

Recommendations

- The Forest Department invests significant effort in the control of IAS in protected areas, albeit sporadically. An ecological monitoring effort is needed to assess the effectiveness of current strategies.
- Information on IAS is patchy and restricted to protected areas, and the potential of technological advances (e.g., smartphones and tablets) to map and monitor the spread of IAS frugally and efficiently remains underused.
- The management of IAS needs to move from the rhetoric of state-funded extraction alone to community-led solutions that take into consideration the potential for livelihood generation through the removal of IAS by communities. A novel ecosystem framework is needed to assess the potential of IAS for livelihoods, biodiversity and ecosystem services.

CLIMATE CHANGE AND VARIABILITY ARE DISCORDANT WITH OBSERVED CHANGES IN LAND USE AND LAND COVER

Large parts of Tamil Nadu receive the bulk of their annual rainfall during the northeast monsoon (Oct-Dec), but our analysis reveals a shift in the monsoon, with less rain falling during the winter months. The winter rains are crucial for agriculture, and this reduction in moisture, combined with warming, is likely to pose a challenge to the resilience of these socio-ecological systems. These shifts in rainfall regimes are, however, being currently buffered by increasing dependence on groundwater, which is driving greening in cultivated areas. Farmers are reducing risks by opting for non-agrarian livelihoods, and increasing – and likely unsustainable – dependence on groundwater. Future climate is likely to reduce moisture availability and elevate temperature, but SWAT (Soil and Water Assessment Tool) hydrological models are not adequate to capture changes in evapotranspiration under different land-cover change scenarios.

We noted a significant decline in the southwest (Jun-Sep) monsoon in the semi-arid regions of north-west and central India from 1951-2007. Although these declines are not observed in Tamil Nadu, large parts of the state are witnessing declining contributions from the northeast (NE) monsoon in areas historically adapted to receiving the bulk of their annual rainfall in these (Oct-Dec) months. This shift in monsoonal regime is also accompanied by delays in the onset and amount of rainfall received through the NE monsoon, driving changes in cropping patterns. Our analysis also revealed significant increases in mean annual temperature, and summers are now reported to be hotter and starting earlier.

Despite the declines in precipitation we observed, we noted significant greening in the Moyar-Bhavani semi-arid region (from 2001-2015), with rapid change occurring from 2006-2015. In the agrarian socio-ecological systems along the Bhavani River, this reflects an increasing dependence on lift irrigation from the river, and groundwater extraction for crop irrigation. The current risk-management strategies of farmers, which include non-agrarian livelihood diversification, groundwater dependence and shifting of cropping patterns, have adverse implications for household wellbeing and gender relations within the household, which may not be sustainable.

We also conducted an assessment of the impacts of future climate and potential land-use change on hydrology in the Moyar-Bhavani by combining statistically-downscaled climate variables with a SWAT hydrological model. Our assessments reveal a projected decline in precipitation, and an increase in minimum temperatures by 2100 under the conservative RCP2.6 (Representative Concentration Pathway 2.6) with respect to the baseline (1970-2000). Currently, evapotranspiration is observed to be more than half of the incident precipitation, followed by soil moisture, runoff and deep recharge. This is expected to change dramatically under future climate scenarios with nearly 90% being consumed by evapotranspiration at the cost of contributions to soil moisture and runoff. Changes in landuse and landcover were explored using a scenario-based approach that incorporated (10%, 25%, and 50%) changes in the extent of forest cover, agriculture, plantations and barren land, but these results were inconclusive. Evapotranspiration under future climate is likely to be a key driver of water stress.

Recommendations

- More effort needs to be invested in studying the NE monsoon, as monsoon research tends to be focused on studying the southwest monsoon. This will help in the development of appropriate adaptation options for communities that depend on these rains.
- Shifts in monsoonal regimes need to be investigated under ongoing and future climate change as these are expected to impact regional ecology, agriculture and adaptation options.
- Further work is needed to assess the hydrological response of changing land cover (e.g., by using different hydrological models) under future climates, by choosing physical hydrologic models or combinations of models that are able to mimic the key hydrologic fluxes in a particular basin (e.g., evapotranspiration in semi-arid regions).
- Adaptive management of groundwater under a changing climate is a key ingredient of adaptation.

PROTECTED AREAS IN INDIA RESPOND DIFFERENTLY TO GLOBAL CLIMATE DRIVERS COMPARED TO SIMILAR AREAS IN AFRICA AND INDIA

Natural and human-dominated semi-arid ecosystems show clear signals of CO_2 fertilisation effects across protected areas and their buffers in India and Africa. Although the amplitude of the annual seasonal cycle is increasing over time in all regions, there are clear differences in the response of protected areas and their agro-pastoral buffers in India and the three African regions. In India, the protected areas have a smaller amplitude of annual seasonal change compared to the buffer which we attribute to their relatively greater moisture-storage regimes; these trends are reversed in the African semi-arid regions where protected areas and buffer zones respond similarly.

The amplitude of annual seasonal phenology is increasing over time; some of this is due to decreases in dry-season vegetation, and some to greater greening at the peak of the growing season. A comparison of protected areas with agro-pastoral buffers (20 km) around them, indicated that semi-arid protected areas in India have a relatively lower amplitude of annual seasonal change, which we attribute to the higher elevations, and the protected watersheds in which these protected areas tend to be located.

Greening and browning had very different impacts on key ecosystem services in the region. In some cases greening was associated with increased productivity and improved ecosystem services, while in other cases it was driven by a proliferation of detrimental invasive species. These vegetation changes impact communities, households and individuals through changes in the availability of ecosystem services such as biomass, water and food, which are mediated by social differentiation and governance regimes. We found clear evidence for CO_2 fertilisation causing higher greening trends, particularly across sites in the 350-800 mm rainfall gradient, supporting the hypothesis that this effect would find its highest expression in moisture-stressed sites.

Recommendations:

- Better communication of global and local drivers of ecosystem change and emerging trends amongst policy makers and communities may result in more robust adaptation practices. For example, a better understanding of the effects of CO_2 fertilisation and sequestration can help understand a few of the positive impacts that IAS have on global change.

- The connectivity in ecological and hydrological processes between protected areas and their buffer areas should be reflected in land-use policies in the buffer zones. Specifically, recharge areas for groundwater inside protected areas should be recognised for their role in sustaining agriculture outside.

- The capacity of multi-disciplinary teams of practitioners, land managers, and scientists needs to be built to: improve their understanding of the ongoing changes in socio-ecological systems, including the dominant local, regional and global drivers of ecosystem change (and their feedback mechanisms); and enhance their abilities to generate future scenarios of change.

- The overall implications of greening linked to bushy encroachment of invasive tree species should be considered when designing adaptation options under near-future and multi-decadal time-scales.

RURAL RISK-MANAGEMENT STRATEGIES ARE SHAPED BY CONTEMPORARY NON-AGRARIAN ASPIRATIONS

The Bhavani basin exemplifies the dynamic nature of rural livelihoods in India. The region has shifted from a feudal land system, to a textile hotbed, and back to an agrarian landscape. The type of agriculture here has also undergone profound change, shifting from dryland agriculture to intensively-irrigated agriculture. Enabling government policy has played an essential role in these shifts; free electricity coupled with a lack of regulation on groundwater has allowed farmers to shift to resource-intensive irrigated crops. Although lucrative in the short run it has resulted in the overexploitation of groundwater in the region, bringing into question the sustainability of these modes of agriculture.

Government policy in the Bhavani basin is determined largely by a populist agenda. Although profitable to communities in the short run, the lack of long-term considerations, particularly considering additional stressors from climate change, has resulted in unsustainable resource use regimes. Communities dependent on these resources are now impacted by their decline, and these impacts are differentiated by age, caste and gender.

Aspirations are an important variable – as can be witnessed in the rise of loans taken for educational purposes – that policy makers fail to consider. Farmers in the region, frustrated by increasing risks to their livelihoods, prefer that their children move out of agriculture, using resources and investments accordingly, and often prioritise short-term gains over longer-term sustainable practices.

To enhance overall wellbeing, the priorities and aspirations of both older and younger generations should be addressed by development and land-use policies.

Recommendations

- Growing precarity of groundwater resources in the region must be regulated through policy. Additional emphasis on the development, maintenance, and management of alternative and traditional irrigation sources, such as traditional tanks, is required to diversify irrigation sources.
- Policy makers must consider the non-agricultural aspirations of contemporary farming communities to understand how farmers view their own wellbeing, and manage risks.
- Recognising how aspirations change is key, and can be used to inform investments by the state and private actors into sectors such as commerce, health, education (including vocational training), and industry. It can also help with effective implementation of agricultural policies, and other programmes targeted at improving rural wellbeing, particularly in supporting youth with skillbuilding programmes, and beyond-farm livelihood opportunities.

CLIMATE- AND MARKET-DRIVEN CROPPING PATTERNS IMPACT HOUSEHOLD FOOD AND NUTRITIONAL SECURITY

Food and nutritional security is the foremost development challenge in India, with ~15% of the total population described as undernourished despite food security having recently improved. Over the last few decades, increasing urbanisation, amplified variations in rainfall and temperature, and intense use of land and water resources, have altered cropping patterns. Food security, and more specifically nutritional security, has been severely affecting the overall wellbeing of the vulnerable due to stagnating and declining agricultural productivity. The threats of climate change, water scarcity, potentially increasing population size and higher food demand, further complicate the challenge of achieving food, water and nutritional security.

Agriculture plays a pivotal role in Tamil Nadu with more than 40% of the population of Tamil Nadu dependent on this sector for their livelihood. Although the state reports one of the highest agricultural productivity rates, this performance is not consistent, and the frequency of drought has increased over time. Two consecutive years, 2014-15 and 2015-16, have seen rainfall deficits, which have enhanced the drought conditions. Agriculture in many semi-arid parts of the state is dependent on groundwater or rain, and increasingly common droughts threaten farmers' livelihoods. In the lower Bhavani, multiple endogenous and exogenous factors have resulted in shifting cropping patterns, and implications on rural household nutrition. Dietary patterns in the region have shifted due to various developmental policies, such as the White Revolution, and targeted Public Distribution System.

There has been a significant change in dietary composition: primary cereals have shifted from millets to rice, and dairy products have been added to the diet. Cropping pattern has a weighted influence on household nutritional status. Farmers have shifted from subsistence farming to high-value commercial farming in the hope for a 'bumper crop', which would offer a solution to all their problems. Given India's focus on nutrition security, it has become imperative to understand the impacts of the agricultural transition on household diets. These insights provide empirical evidence to suggest nutrition is being compromised as a result of commercial farming, though food security itself may have improved at the household level.

Recommendations

- To improve food and nutritional security, the Public Distribution System needs to supplement staples with an assortment of pulses and traditional millets, which should be customised to seasonal produce.
- Agricultural policies in the region should provide incentives to produce non-staples which are less resource-intensive and rich in nutrition. Adequate market support ensuring commercial viability of these products should be provided to farmers for enhancing income, including mainstreaming distribution of these supplements in the existing Public Distribution System.
- Households in the region are highly dependent on livestock for consumption of dairy products as well as income generation. Policies should be targeted towards enhancing milk productivity and linking farmers to the dairy value chain.
- Only a handful of villages are currently benefiting from existing nutritional schemes; institutional arrangements should be made to reach out to the areas with limited accessibility.

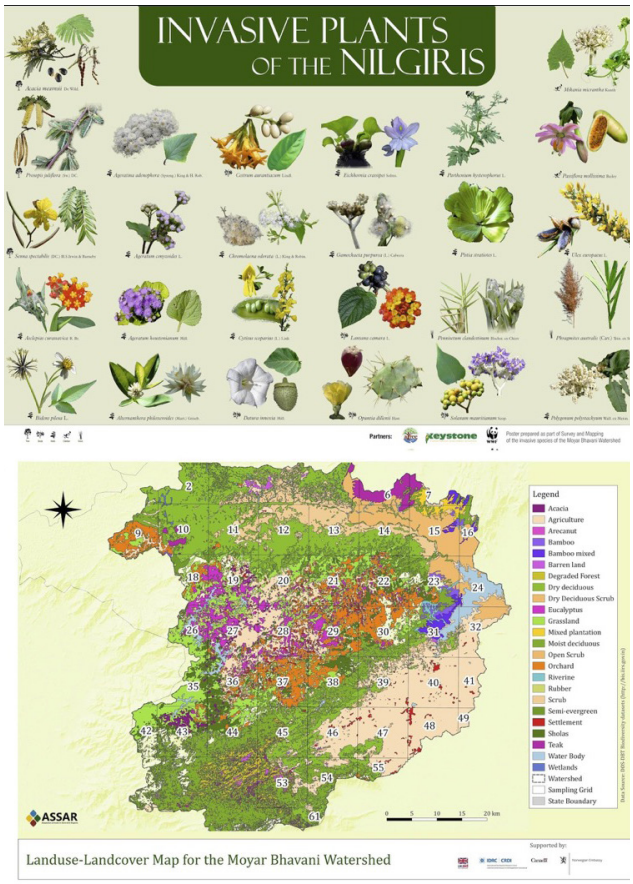
WORKING WITH STAKEHOLDERS TO IMPROVE ADAPTATION AT MULTIPLE SCALES

ATREE has contributed to discussions regarding the impacts of land-use-land-cover, and climate change and variability on ecosystems and communities at regional, national and international fora. Jagdish Krishnaswamy was appointed as a coordinating lead author for the IPCC Climate Change and Land special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems.

ATREE's association with regional stakeholders began early and continued throughout ASSAR's duration. Our target groups were: decision makers/policy circles; technical staff of various state agencies; and the wider public, including civil society organisations. The objective was to raise awareness around issues of environmental governance, including forests, agriculture, water and rural livelihoods. Advised by key informant interviews with researchers from Tamil Nadu Agricultural University, we have been working with researchers from the Foundation for Ecological Research Advocacy and Learning to assess changes in the NE monsoon, which provides significant amounts of rainfall to the region.

Although IAS have adversely impacted ecosystems and communities in the region for decades now, the issue has come to the forefront in the last few years through ongoing litigation in the regional (state) High Court. The Tamil Nadu Forest Department (TNFD) also invests significant effort in the control of IAS, yet little is known about (i) the extent of some of these invasive species (esp. *Prosopis juliflora*), and (ii) the success of TNFD's current removal strategies. Recognising the dearth of spatial information on the extent of *Prosopis*, and building on data on other IAS that WWF-India had provided, we set about collecting data to create a *Prosopis* map for TNFD. By working with the Forest College and Research Institute, Mettupalayam, we were able to improve our assessments of the impacts of IAS in the Moyar landscape.

Even as we set about to achieve the above, our conversations with WWF-India and Keystone Foundation suggested that there was no systematic baseline information on IAS occurrence, especially outside of the protected area network.



Landuse-Landcover Map for the Moyar Bhavani Watershed

Responding to this need, ATREE formed a collaborative network of researchers and practitioners called 'PARDESI' (Participatory Assessment of the Regional Distribution of Exotic Species in India) to collect data on IAS through researchers, practitioners, Forest Department officials, schoolchildren, college students and citizen volunteers, using a citizen science approach. For this, ATREE used the Open Data Kit platform available on Android devices to map invasive species, and conducted a series of skill-building workshops on the use of this digital platform. Our partners have taken this initiative forward, working with schools and higher-education institutions in the region to map IAS in the region. By using the camera and GPS that smartphones are equipped with, users can provide spatially explicit, verifiable information on the location of these invasive alien plants in the landscape.

At the state level, the past few years have seen a number of court cases before the Madurai Bench of the Hon'ble Madras High Court that have examined the critical state of grassland ecosystems and IAS across Tamil Nadu. Through PARDESI and other ASSAR work, Jagdish Krishnaswamy and Milind Bunyan, together with other colleagues at ATREE, are providing scientific support to legal teams petitioning for the removal of IAS and grassland conservation, and contributed to a workshop co-organised by ATREE and the Kalakkad-Mundanthurai Tiger Conservation Foundation (KMTCF) in Kalakkad-Mundanthurai Tiger Reserve (KMTR) on 30 April 2018.

Our engagement with state agencies has also been informed by larger environmental and livelihood threats in semi-arid regions outside of Tamil Nadu. In Karnataka, ATREE has long been engaged in the water reform process, and Shrinivas Badiger and other experts were invited to be on the state task force instituted to advise the Karnataka Knowledge Commission in November 2017. The Knowledge Commission was established by the state government to reformulate guidelines and policies in the agriculture and water sector. A final report was submitted by the task force, which was informed by the sub-committees with active involvement of ATREE researchers.

In October 2018, ATREE researchers working in the agriculture and water sector, led by Shrinivas Badiger, organised a 10-day training workshop titled "Management Development Programme on Integrated Water Resources Management for Karnataka State Water Resource Engineers and Managers", with support from the Karnataka State Government's Advanced Centre for Integrated Water Resources Management (ACIWRM) and the Asian Development Bank (ADB). The goal of the training workshop was to enhance the capacities of engineers and managers in water-related departments of government to understand, analyse and address water-resource management in an integrated and holistic manner. ATREE will be organising a series of such capacity assessments and training programmes for the Karnataka State Water Resources Department officials in the coming years, and continues to support the state's effort in reforming the agricultural and water sectors.

NEXT STEPS FOR RESEARCH, POLICY AND PRACTICE

Our research in the Bhavani has highlighted the need for policy to take into consideration the how and why of risk management, recognising the role of individual and household aspirations and perceptions of risk. For policy to comprehensively promote sustainable rural livelihoods it is important to integrate agricultural and non-agricultural interventions. Our study on groundwater use in the region has emphasised the importance of policy to consider long-term impacts, particularly in climate-vulnerable semi-arid regions that face multiple stressors. Furthermore our study underscored the insidious role of policy in reinforcing gender inequality in the region.

Considering the regional variability of climate risks (e.g., shifting monsoons, erratic rainfall), differential resource availability and socioeconomic capacities, generic welfare and development programs alone are insufficient to address specific adaptation needs of communities in the region. This is especially pertinent for semi-arid regions that have unique and diverse socio-ecological characteristics which make them more vulnerable to the impacts of climate change; explicit and regionally-specific policy focusing on adaptation is required. Research programmes targeting climate resilience and improving adaptive capacity should link to – or be embedded in – rural development processes that address water scarcity, food insecurity, social welfare, and poverty alleviation. Climate advisories, including crop advisories, should be customised to assist rainfed farming practices since these are most vulnerable to climate change.

Patterns of historical marginalisation manifesting as asymmetrical capabilities have severely impeded the adaptive capacities of scheduled castes and tribes in the region. Programs are needed that focus on building their adaptive capacities through access to capital, skill building, and the strengthening of institutions to ensure equitable access to natural resources. Research that leads to impact and benefits for people should be undertaken in a collaborative manner between government, non-governmental organisations (NGOs), communities (including those most marginalised and disempowered), the private sector and academia, and integrate these diverse sources of knowledge. Long-term, targeted responses are needed, and government needs to support people's livelihoods by building adaptive capacity, making governance inclusive, providing jobs and creating markets.

With temperatures expected to rise and rainfall regimes expected to change (e.g., delayed monsoon onset, declining contributions from the NE monsoon), scientists and researchers need to direct more effort at understanding the dynamics and trends of climate variables. Special attention is required for understanding the expected changes to the NE monsoon which tends to be understudied compared to the better understood (and researched) southwest monsoon.

Insufficient IAS management and monitoring strategies, and changes in forest management regimes, have impacted the livelihoods of forest communities, increasing their vulnerability to the impacts of climate change. Although the Forest Department currently invests significant effort in managing IAS, the department and researchers need to work collaboratively in assessing the efficacy of current removal strategies, and – where needed – test new ones. IAS management by the Forest Department should focus on developing forest management plans that are sensitive to the needs of these communities, and could provide a source of income to communities by involving them in IAS removal and use.

In our engagement with the state and civil society organisations in peninsular India, we will continue to work with the Karnataka State Government on providing scientific evidence and training programmes for capacity building of the state water resources department officials. Expanding our ongoing engagement with the Forest Department in Tamil Nadu, we are initiating a series of such discussions with organisations in Tamil Nadu working on sustainable water management, and we expect similar progress with the state water resources departments and planning commissions.

AUTHORS

Jagdish Krishnaswamy* (jagdish@atree.org), ATREE
Milind Bunyan (milind.bunyan@atree.org) , ATREE
Shrinivas Badiger (sbadiger@atree.org), ATREE
Divya Solomon (divya.susan.solomon@gmail.com), ATREE
Brendon Bosworth (brendon.bosworth@mailbox.org), University of Cape Town
Tali Hoffman (tali.s.hoffman@gmail.com), University of Cape Town
Lucia Scodanibbio (scolucia@gmail.com), University of Cape Town

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: Moyar Bhavani sub-region, Tamil Nadu*. [Information brief]. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link.

ASSAR. 2018. *Dreaming of a better life: Let's recognise and value people's changing aspirations.* [Infographic]. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link.

ASSAR. 2018. *Household relationships help determine whether and how we can – or can't – respond to pressures.* [Infographic]. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link.

ASSAR. 2018. *Sometimes our interventions can lead to unintended consequences: A well does not always lead to wellbeing*. [Infographic]. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link.

Ashwathi, V. K. and Badiger, S. 2018. *Impact of Climate Change on Hydrology of Moyar-Bhavani Basin*. [Poster]. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link.

Ashwathi, V. K., Badiger, S., Krishnaswamy, J. and Bunyan, M. In prep. Implications of future climate and land use/ land cover change on catchment water budgets in Moyar-Bhavani sub-basin. Link to poster.

ATREE. 2019. *Wells and a lack of wellbeing*. [Video]. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link.

ATREE. 2019. *Is an increase in green cover good?* [Video]. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link.

Bridges, K. 2017. *The role of climate information and advisory services in drought resiliency: A comparative case study in Tamil Nadu, India.* Master's thesis. Oxford University. Link.

Bunyan, M. 2018. *Vegetation response to climate (over a 33-year period) in the semi-arid regions of India*. [Presentation]. *Adaptation* at Scale in Semi-Arid Regions (ASSAR). Link.

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.

Duraisamy, V., Mugari, E., Segnon, A. C., Togarepi, C., Tesfaye, M., Alare, R. and Misra, G. In prep. Landsat based LULC mapping and cross-site analysis at South Asia and Africa.

Krishnaswamy, J., Bunyan, M., New, M., Bazaz, A., Wolski, P. and Daron, J. In prep. Are semi-arid regions in Africa and Asia climate-change hotspots?

Krishnaswamy, J., Bunyan, M., Duraisamy, V., Segnon, A. C., Mugari, E., Togarepi, C., Molefe, C. and Degefu, M. In prep. Consistent vegetation response to global change drivers in semi-arid ecosystems.

Misra, G. and Shrinivas Badiger, S. 2018. *Mapping Prosopis Invasion in Moyar- Bhavani Catchment: Implications for Invasive Management*. [Poster]. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link.

Rao, N., Lawson, E. T., Raditloaneng, W. N., Solomon, D., and Angula, M. N. 2017. Gendered vulnerabilities to climate change: Insights from the semi-arid regions of Africa and Asia. *Climate and Development*. DOI: 10.1080/17565529.2017.1372266. Link to information brief.

Rao, N., Lawson, E. T., Raditloaneng, W. N., Solomon, D. and Angula, M. N. 2016. *Gendered vulnerabilities to climate change: Insights from the semi-arid regions of Africa and Asia.* [Information brief]. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link to ASSAR brief. Link to GSDR brief.

Rao, N., Singh, C., Solomon, D., Camfield, L., Alare, R., Angula, M., Poonacha P., Sidibe, A. and Lawson, E. In prep. Managing risk, changing aspirations and household dynamics: Implications for wellbeing and adaptation in semi-arid Africa and India. Link to summary. Link to presentation.

Rathore, D. 2017. *Blackbuck occupancy in Moyar Valley, Tamil Nadu*. Master's thesis. TERI School of Advanced Studies. Link.

Rathore, D., Krishnaswamy, J., Bunyan M., Venkitachalam, R., Kumaran, K., Devcharan, J. In prep. Blackbuck occupancy in Moyar Valley, Tamil Nadu, India. Link.

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.

Sajith, S. 2017. *Changing cropping patterns and its implications on household food security and nutrition*. Master's thesis. TERI School of Advanced Studies. Link.

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.

Solomon, D., Bunyan, M., Badiger, S. and Krishnaswamy, 2018. *The Impacts of change in land use on ecosystem services for adaptation in forested landscapes in semi-arid India.* [Poster]. Adaptation at Scale in Semi-Arid Regions (ASSAR). Link.

Solomon, D. S. and Rao, N. 2018. Wells and wellbeing in South India. *Economic & Political Weekly,* 53(17). Available at: https://tinyurl.com/yawfjgu7. Link to infographic. Link to information brief.

Solomon, D. and Badiger, S. In prep. Agrarian transformations: Impacts on wellbeing and adaptation outcomes in Western Tamil Nadu.

Solomon, D. and Badiger, S. In prep. The evolution of vulnerability: Rethinking the scope of indicator-based assessments in agrarian socio-ecological systems.

Solomon, D., Bunyan, M., Badiger, S. and Krishnaswamy, J. In prep. The vulnerability of ecosystem services and implications on the adaptive capacity of communities in semi-arid regions of Tamil Nadu. Link to poster.

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