CLIMATE RESILIENT RAJASTHAN

Mukhya Mantri Jal Swavlamban Abhiyan as a climate change adaptation model for tropical dry regions of India

Forest Department
Government of Rajasthan
Jaipur

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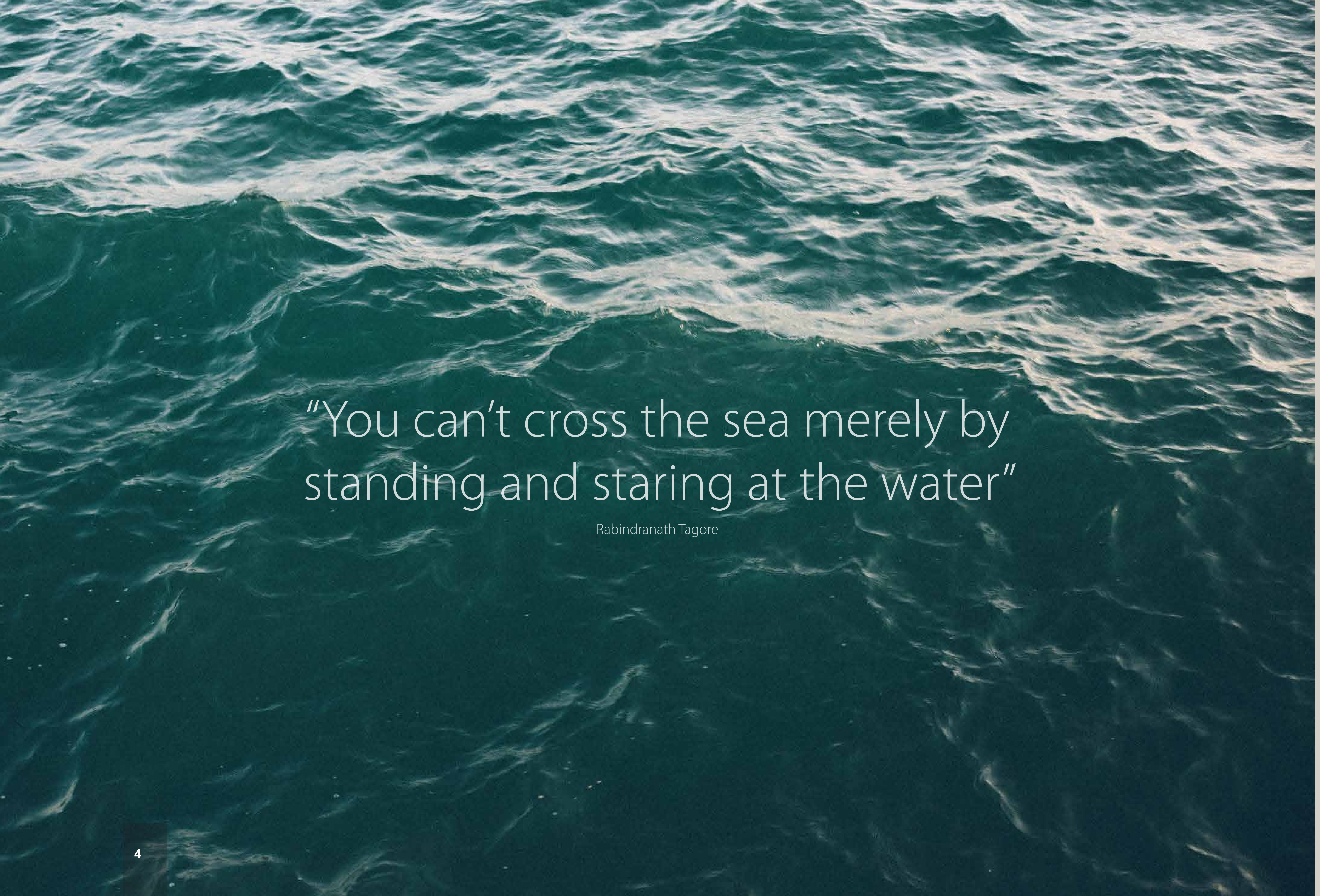


Smt. Vasundhara Raje
Hon'ble Chief Minister, Rajasthan

Climate change is the greatest challenge before the global society. Studies have shown that Rajasthan falls within the areas of greatest climate sensitivity, maximum vulnerability and lowest adaptive capacity. Rajasthan also has the maximum probability of occurrence of drought in India. If we fail to act timely and coherently, climate change is likely to negatively impact ecology, economy and society.

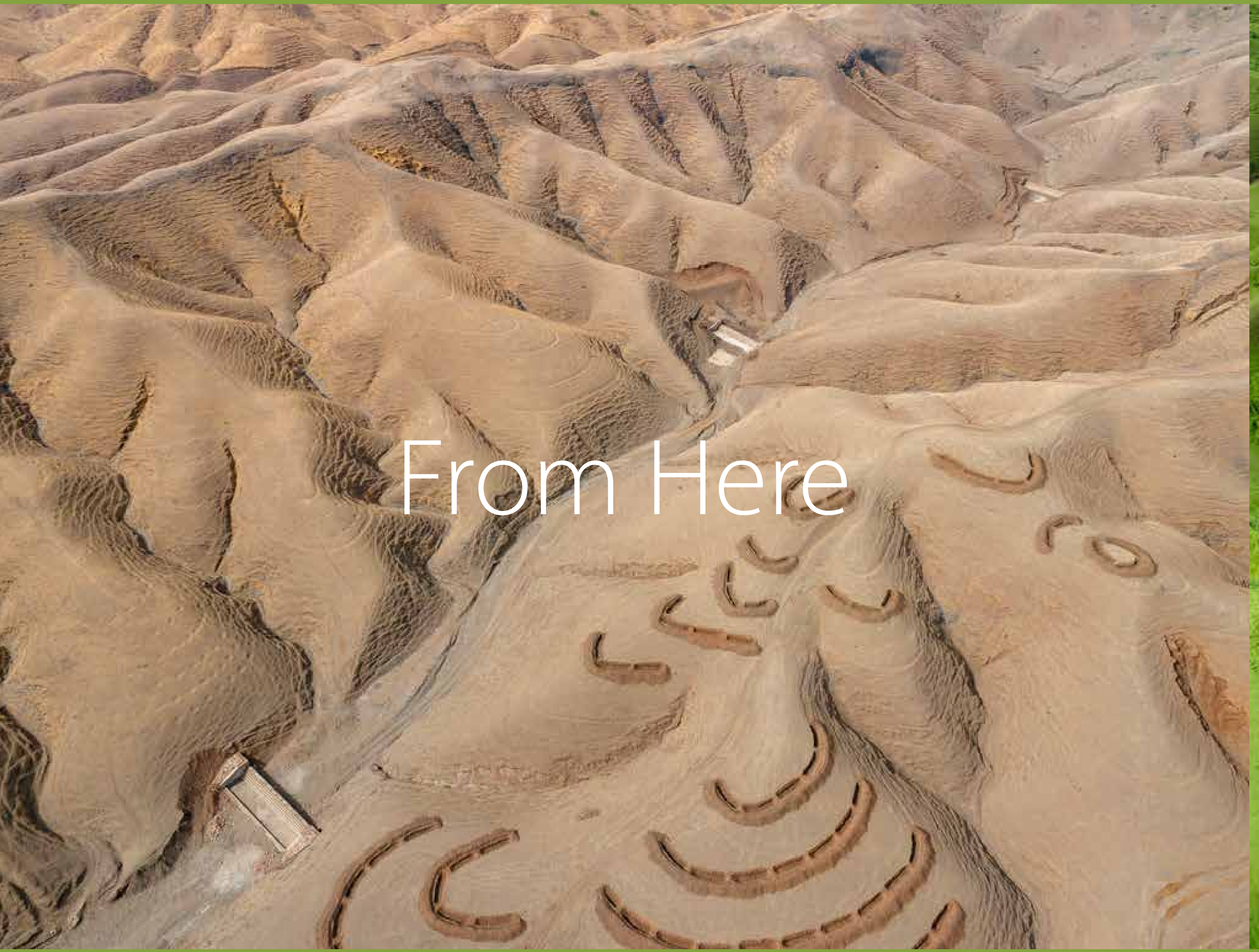
'Mukhya Mantri Jal Swavlamban Abhiyan' (MJSA) was launched in the state to achieve water self-reliance. This is an ambitious programme converging the activities of multiple line departments working for conservation and storage of water, both under and above the ground.

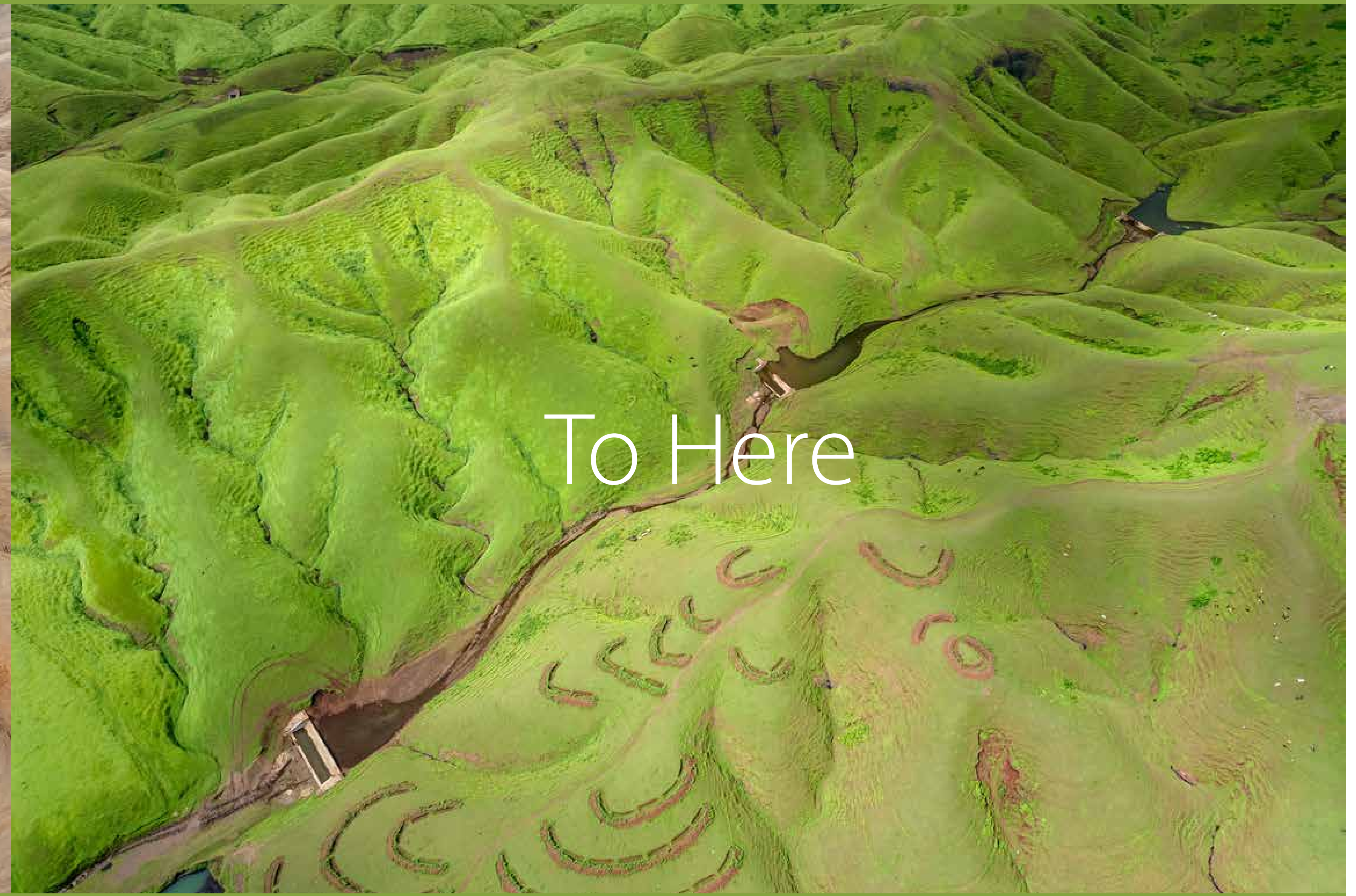
MJSA interventions are being welcomed by rural populations and their wholehearted participation is a key factor in the success. MJSA as an adaptation to climate change can be replicated in other parts of the country as well.

I am happy to note that a multi-disciplinary team of scientists and practitioners from Indian Institute of Science, Bengaluru, Indian Institute of Technolory, Kharagpur and Rajasthan State Pollution Control Board, Jaipur, Rajasthan River Basin and Water Resource Planning Authority and Forest Department have collaborated to study MJSA and propose a model for climate change adaptation for tropical dry regions of India.

I hope this document will serve as a valuable source of ideas for policy-makers, practitioners and scientists striving to address the challenge of climate change through evidence-based policy and action.

Embark on a journey with us





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Same place in different seasons! World's most threatened forests--tropical dry forests or seasonally dry forests--are also found in Rajasthan. See, how the same place changes within a season--from bone dry to lush green! Pratapgarh Forest Division, Rajasthan, India. See also the result of watershed treatment and assisted natural regeneration that resulted in restoration of these forests.

Rajasthan is famous for rich and deep history of rainwater harvesting. A dam in Sirohi, Rajasthan.

1. Introduction

Climate change has played a vital role in shaping the course of human history. Human societies have evolved through complex interactions of climate and environmental systems. There is an intimate relationship between climate variability and consequent human responses such as migration, adaptation and mitigation. Extreme climate events such as aridity, droughts, floods, cyclones, cloud bursts and stormy rainfall are expected to leave an impact on human society. They are also expected to generate widespread response to adapt and mitigate the sufferings associated with these extreme events[1]. Adaptation to anthropogenic climate change as envisioned in policies and programmes are often incremental adaptations aimed at avoiding disruptions of current economic, ecological and social systems. However, in several places, for many systems, vulnerabilities and risks may be so large that they require transformational rather than incremental adaptations[2].

Rajasthan is precisely such a system that can provide a role model in India[3]. Indeed, the State falls within the areas of greatest climate sensitivity, maximum vulnerability and lowest adaptive capacity[4]. The environmental degradation and environmental stress is further accentuating the adverse impacts of current climate variability and long term climate change. Rajasthan also has the maximum probability of occurrence of droughts in India. Districts with the highest probability of drought consists of both those that have normally distributed seasonal rainfall (e.g., many districts from western Rajasthan) and those which do not have (e.g., many districts from eastern Rajasthan)[5]. Consequently, the implementation of large scale statewide Mukhya Mantri Jal Swavlamban Abhiyan (MJSA) programme of rainwater harvesting and ecological restoration across landscape in every village of Rajasthan, for making these villages water self-reliant, is a transformational adaptation to climate change.

Above: A newly constructed anicut photographed in the dry month of June in Sikar, Rajasthan under the MJSA programme. The district receives amongst the lowest rainfall in the state and water collected in such structures is sometimes the only source of water in a large area.

These denuded lands cannot be restored without intensive rainwater harvesting with the help of contour trenches and protection wall against the detrimental biotic factors such as grazing. Before-After photograph from Baran Forest division, Rajasthan shows trenches and MPTs laden with water in the month of August.

“Rajasthan falls within the areas of greatest climate sensitivity, maximum vulnerability and lowest adaptive capacity”

Below: Rainwater harvesting in landscape continuum is an important input to enhance the quality, productivity and resilience of the grazing lands for the livestock based economy of Rajasthan. Another photograph from Jaisalmer taken in summer.

Below: The inseparable connection between large trees, which are keystone structures for a large amount of biodiversity, and water structures. This traditional pond in Jaisalmer holds water even in the scorching summer.

An aerial view of a member of the documenting team traversing the landscape of Jaisalmer. Life in such landscapes is very tough and water is considered more valuable than any other resource.

Rainwater harvesting in landscape continuum is an important input to enhance the quality, productivity and resilience of the grazing lands for the livestock based economy of Rajasthan.

“Incremental adaptations in water management have only a limited role under the circumstances that prevail in Rajasthan.”

Incremental adaptations in water management have only a limited role under the circumstances that prevail in Rajasthan. Therefore, implementation of the transformational adaptation is the need of the day. It is worthwhile to note that transformational adaptations are those that are either implemented at a much larger scale, that are really new to a specific region or resource system, or that transform places or locations. Ordinary, common or incremental adaptation interventions can become transformational when they are implemented at a greater scale or magnitudes and in integrated combinations with much larger societal, economic or ecological effects than before[2, 6, 7]. The Intergovernmental Panel on Climate Change (IPCC) defines transformational adaptation as adaptation that changes the fundamental attributes of a system in response to climate and its effects. IPCC further clarifies that, "transformational adaptation can include introduction of new technologies or practices, formation of new financial structures or systems of governance, adaptation at greater scales or magnitudes and shifts in the location of activities" (IPCC, 2014: pp 80)[8].

Examined in the light of the above position taken by IPCC[8], as well as the relevant studies that appeared since the publication of the IPCC report[6, 7, 9-13]—Mukhya Mantri Jal Swavlamban Abhiyan (MJSA) is a transformational adaptation to climate change. As we will discuss in subsequent chapters, MJSA not only encompasses the adaptation actions at greater scales and magnitudes (e.g., activities of all the relevant departments in all 44,795 villages of Rajasthan), it used new technologies and practices including use of fully automated geographical information system (e.g., geotagging of each structure and plantation, web and mobile application based real-time monitoring system) and even new models of tropical dry forest restoration. Nine government departments converged their activities from planning to implementation including formation of new financial structures (e.g., convergence of budget and activities, livelihoods improvement through introduction of new agricultural and horticultural practices,) and systems of governance (e.g., Governing council and Directional committee at the apex level, independent monitoring and so on).

Above: With unpredictable monsoons and no rainwater harvesting structures, some areas can be flooded while others are left bone dry. Both of these scenarios cause nuisance and demand mitigation measures. This photograph from Banswara, Rajasthan shows one of the many flooded culverts in August.

Photograph from Naal Mehndiya Fala, Bagidora Range, Banswara, Rajasthan showing farms and houses in the villages adjacent to MJSA sites directly benefiting from such interventions. This treated watershed is home to numerous MPTs, trenches and anicuts accounting for a multi-faceted treatment.

"Mukhya Mantri Jal Swavlamban Abhiyan (MJSA) is a transformational adaptation to climate change."

Majority population relying heavily on farming for livelihoods means the gargantuan pressure on groundwater resources is only increasing. MJSA empowers the people to grow a variety of local crops which was earlier difficult to manage in an unfavourable weather.

A word of clarification shall be in order here. First, the distinctions between incremental and transformational adaptations may not always be straightforward, sharp or clear-cut. Those who wish to replicate the MJSA should adopt the comprehensive model and not just a few components selectively in an ad hoc manner. Second, not all programmes implemented at larger scale necessarily become transformational adaptations. They must conform to holistic and comprehensive criteria suggested by IPCC[8] and subsequent research as discussed earlier. For example, let us take the case of country-wide implementation of Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA), which is one of the contributing programme to MJSA among many others. Well-designed research has found that activities undertaken in MGNREGA have reduced the vulnerability of farm production, water and livelihoods to rainfall uncertainty, water scarcity and low soil fertility[14, 15]. Yet, MGNREGA, even though implemented throughout the nation, cannot be assumed to be transformational adaptation to climate change. There is unequivocal evidence to show that MGNREGA has made a major contribution towards resilience to climate change[14, 15], but since the fundamental objective of MNREGA is to give employment when and where demanded and not the holistic intervention for adaptation, it requires many improvements to maximize its contribution to long-term climate change adaptation[16].

In view of the observed and predicted changes described in subsequent chapters, the basic premise of any action on climate change adaptation should be to promote adaptive capacity and concurrent provisioning for sustainable livelihoods and sustainable development. A first step towards adaptation to future climate change is reducing vulnerability and exposure to present climate variability[8]. MJSA, to begin with, addresses current climate variability and risks. In addition, by creating robust infrastructure for periodic rainwater harvesting year after year, it also tackles the long-term climate change. In a nutshell, MJSA contributes to disaster reduction, natural resource management and climate change adaptation with a transformational approach to reduce vulnerability and enhance resilience[17].

Two conditions warranted transformational adaptation to climate change in Rajasthan: large vulnerability of people and their resource systems, and severe current and expected environmental as well as climatic challenges that overwhelm even the most robust indigenous resource use systems. In initiating MJSA as a transformational adaptation, focus has been on climate change, recurrent droughts and multiple stresses on village livelihoods systems which are likely to increase with increase in global warming. The role of state leadership in comprehending and responding to these multiple stressors and vulnerabilities has been extraordinary. Early steps included constructing several water impounding systems as part of the water conservation in strategic locations to manage the risks of severe water crisis. The programme has now expanded in terms of area as well as types of adaptation actions.

"MJSA addresses current climate variability and risks while also tackling the long-term climate change."

Not just useful for groundwater recharge, but anicuts can have backwaters running into kilometres and therefore adjoining farms benefit from improved soil moisture regimes, and there, better production. The water available in these rainwater harvesting structures, also provides supplementary irrigation, particularly during terminal drought. Photograph showing Before-After from Naal Mehndiya Fala, Bagidora Range, Banswara, Rajasthan.

Right: Investment in urban green spaces is a multifunctional investment in city's ecological health as well as the health of urban population that confronts perpetually growing air and water pollution. A view of the city of Jaipur, from Smriti Van, an urban green space developed by the govt. of Rajasthan. This area of lush green forest is located in the heart of the city.

Our purpose in writing this book is to propose a model for climate change adaptation project for the country, which is informed by both robust scientific and experiential knowledge generated through the implementation of the MJSA in Rajasthan. We trust that experience of MJSA is useful not just for Rajasthan but for the entire tropical dry and arid regions of India.

With this brief introduction, in Chapter 2, we present a brief insight on the prevailing and projected climatic challenges, vulnerabilities and necessity for adaptation in Rajasthan. In doing so, we have drawn on specifically prepared database of scientific research. Our database includes, to the best of our knowledge, all research papers published on the subject relevant to our analysis in peer-reviewed and leading journals from around the world.

In Chapter 3, we present MJSA as an adaptation to climate change, in more detail. The chapter provides full process of implementation including "hard adaptation" (infrastructural components) and "soft adaptation" (societal interventions). In addition, from the perspective of three pillars of sustainability—ecological, economic and societal—we discuss how MJSA contributes to livelihoods improvement of local communities.

Finally, in the concluding Chapter 4, we propose the components of a model for nation-wide implementation and provide a way forward.

This book combines the elegance of visual art with the objectivity of science to bring alive a profound story of MJSA. We hope that the vivid images and the scientific description in this book are likely to engage stakeholders, practitioners and policymakers alike. This book is unique in two distinct perspectives. To begin with, it narrates the story of a commitment of the Government of Rajasthan towards climate change adaptation and sustainability for the benefit of the societies. It is a story of evidence-based policy intervention for protecting and replenishing the water resources for the benefit of nature and society. It is also a story of extraordinary success in investing and achieving water self-reliance. We hope that analysis and magnificent photographic evidence will provide useful and usable knowledge and expertise to inform actions which can be followed by other regions and States desiring to develop, restore and manage their water, soils and forests. The book not only provides a fascinating place-based photographic story of the largest climate change adaptation effort of our times, it also gives a synthesis of robust generalizations through a review that has drawn both on experiential knowledge as well as the best available science. For that reason, this book is a call to action for other State Governments to plan and implement appropriate response to climate change.

Right: Protection given to planted saplings in urban green spaces also promotes natural regeneration of local species, mainly because of the enhanced soil moisture regime and seed addition to otherwise heavily grazed and seed-limited soils. Photograph from Urban MJSA site in Ajmer, Rajasthan.

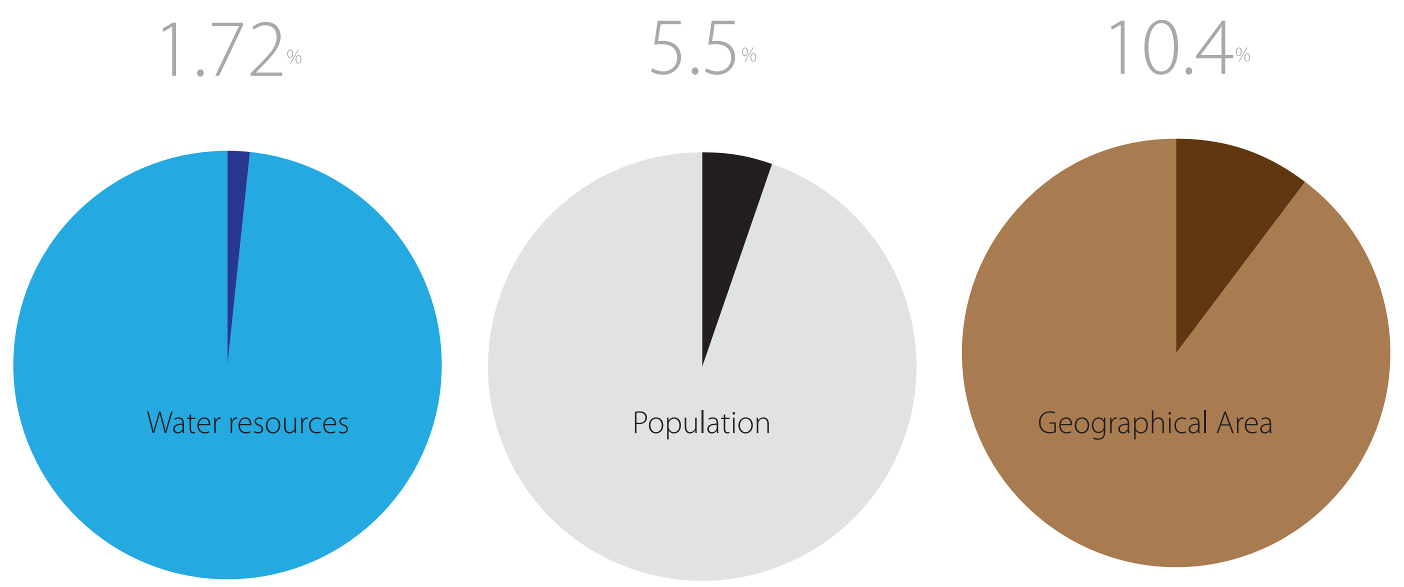
2. Climate Challenges and Need for Adaptation

Before we discuss the details of implementation of MJSA, it would be useful to understand the prevailing and projected climatic challenges, vulnerabilities and necessity for adaptation in Rajasthan.

Rajasthan (23°4′–30°11′ N, 69°29′–78°17′ E) is the largest state in India with a geographical area of 34.22 million ha. The regional climate varies from semi-arid to arid with average annual rainfall ranging from about 480 mm to 750 mm. On the lower side it is as low as 150 mm in the western arid region and on higher side it is about 1000 mm in the southeastern plateau. Pre-monsoon (April–June) is the hottest season of the year with temperature varying from 32°C to 45°C. In western Rajasthan the air temperature rises up to 48 °C and the prevailing westerly winds cause dust storms. The region often suffers from frequent droughts due to scanty rainfall, very high summer-temperature and insufficient water resources. The major part of the state is arid comprising of 12 districts in western and north-western parts, accounting for 61% of the total hot Indian arid zone [17, 18].

Rajasthan has just 1.16 percent of surface water and 1.72 percent ground water for a 5.5 percent population and 10.4 percent geographical area of the country. Water for people and their livestock remains a top priority. Currently, about 70 percent drinking and domestic supplies depend on groundwater. Consequently, groundwater scenario has reached an alarming state of depletion. The annual draft of dynamic groundwater is much more than the quantum of annual recharge and replenishment. This is also now depleting the static reserves. Majority of blocks are in vulnerable and over exploited category, and merely 10 percent are in safe category. The primary groundwater aquifers are nearing depletion.

> "In western Rajasthan the air temperature rises up to 48 °C and the prevailing westerly winds cause dust storms"



Rajasthan's Share of India

Thar Desert region in western Rajasthan, globally the most densely inhabited desert, has the maximum probability of occurrence of drought in India [19]. In the Northwest region of India including Rajasthan, the probability of moderate drought (i.e., rainfall deficiency between 26 and 50 per cent of long-term average) varies from 12 to 30% and that for severe drought (i.e., rainfall deficiency more than 50 per cent of long-term average) varies from 1 to 20% in most of the parts and about 20-30% in the extreme northwestern parts [20]. State also falls within the category of the greatest climate sensitivity with exposure to multiple stressors[4]. In addition, monsoon fluctuations have also resulted in severe floods in western Rajasthan. For instance, in 2006 several stations registered very heavy downpour of about 125 mm in 24 hours [21]. Overall, Rajasthan shows a significant warming of 0.5 °C, comparable to the global mean trend of 0.3 °C and all India mean of 0.4 °C per 100 years[22].

> "Rajasthan shows a significant warming of 0.5 °C, comparable to the global mean trend of 0.3 °C and all India mean of 0.4 °C per 100 years."

The model projections for mean annual surface air temperature in Rajasthan indicate an increase by 2-4 °C for the 2071-2100 period. Mean annual rainfall is predicted to decrease slightly, whereas the extreme rainfall is expected to increase in frequency and intensity. Maximum 1-day rainfall is expected to increase by 20 mm, and maximum 5-day rainfall by 30 mm in the period 2071-2100 [23]. A recent modeling study[24] suggests that average annual temperatures are expected to increase by 1.8 to 2.2 °C by 2035. Minimum temperature is expected to increase more than the maximum temperature, and average monthly temperatures may increase by 2.5 to 3.5 °C, in the same period. Over the last 100 years, the average minimum temperature has already increased by 1.0 °C. Rainfall may remain constant, or only slightly increase, although predictions for monsoon are not as robust as for temperature[24]. Studies have documented a rising trend in temperature at Barmer, Jodhpur, Ajmer and Pali in Luni river basin of arid western Rajasthan. In the same region, annual rainfall has shown increasing tendency at 19 stations (around Ajmer in upper part of the Luni Basin). Decreasing temperature trends have been observed at Udaipur and Jwaibandh, and decreasing rainfall trend at the remaining nine stations in lower Luni Basin, i.e., Barmer [25].

Predictions for rainfall are less certain. Some studies note that there may be a 20% rise in all-India summer monsoon rainfall during the 21st century[26], other more robust studies note that all-India precipitation under the business-as-usual scenario is projected to increase from 4% to 5% by 2030s and from 6% to 14% towards the end of the century (2080s) compared to the 1961–1990 baseline[27]. In Rajasthan overall rainfall is projected to slightly decrease, and evapotranspiration to increase, due to global warming[24]. Whatever the scenario, even 1% increase in temperature from base data could result in an increase in evapotranspiration by 15 millimeter (mm), resulting into additional water requirement of 34.275 million cubic meter (mcm) for Jodhpur district alone and 313.12 mcm for entire arid zone of Rajasthan [28]. Although analysis of 100-year rainfall data for the arid region of Rajasthan indicates an increasing trend of 0.5 mm/year, but increased evapotranspiration due to global warming can put tremendous pressure on existing overstressed water resources of this region[28]. In an era of climate change, Rajasthan is likely to suffer further water shortage due to overall reduction in rainfall, increased evapotranspiration and increased exploitation[17].

Change in the landscape of a Vriksha Kunj in Chittaurgarh district, Rajasthan in a span of 2 months. Planting was done in sync with the arrival of monsoons to ensure the highest survival rate.

Tropical dry forest restoration in combination with rainwater harvesting (anicuts, mini-percolation tanks, trenches, microcatchments) is likely to result in better biodiversity tomorrow. Before-After photograph from Bhanwar Kara, Banswara, Rajasthan.

In addition to climate change, there are challenges from multiple stressors such as land use/land cover change in agriculture land[29]. Recent studies have predicted significant increase in the desertification over India in next 100 years due to climate change[30]. Land degradation remains a persistent challenge in Rajasthan which has the largest area (21.77% of the total geographical area) under land degradation[31]. Model studies on the wind erosion potentials in the Thar region for AD 1951 to 2100 suggest that significantly larger efforts in land conservation practices would be needed to stabilize the aeolian bedforms in the Thar desert[32].

Impacts of projected climate change in Rajasthan are not comprehensively studied. Even in cases that are comparatively well studied, such as exemplified by impact on food crops, the yield change projection uncertainties are large due to the uncertainties associated with the yield models.

These complex set of findings are difficult to reconcile. They may either be the result of regional heterogeneity linked to orography or scientific uncertainty, or perhaps both. In a new study, the average mean temperature for base period and three future periods over four regions of Rajasthan was observed highest in region 3 which shows an incessant increase in mean temperature about 2.6 °C i.e. north-east and north-west parts of Rajasthan. Surface air temperatures may increase in the future and future maximum temperature in all the seasons varies from 2.43 °C to 4.27 °C in the direction from south to north of Rajasthan during 2071–2100. On the minimum temperature side, the range of temperature changes varies from 0.23 °C to 1.42 °C from south-east to north-west of Rajasthan during 2011–2040. In the temperature indices, the number of tropical nights, warmest day, warmest night and summer days is expected to increase during all three future periods. The maximum change was found in region 2 (39.4 days) and region 1 (38.8 days) during the 2071–2100 periods, followed by 2041–2070 and 2011–2040. In all the four regions, the annual occurrence of Cold Spells Duration Indicator (CSDI) decreased and Warm Spells Duration Indicator (WSDI) increased for all three future periods[33].

A recent study that analysed the changes in rainfall, extreme indices and their future projections over Rajasthan found that there is a possible decrease in monsoon precipitation at many grid points for all the three future periods. The maximum decrease in rainfall (–142 mm) is observed in Banswara for the period 2041–2070, while the maximum increase (37 mm) is found in Alwar along with Churu and Ganganagar during the period 2071–2100. Consecutive dry days (CDD) are predicted to increase in the west and south-west direction[34]. There is likely to be an overall reduction in the quantity of the available runoff under the climate change scenario. The river Luni of Rajasthan shall face acute water shortage conditions. Similarly the river basins of Mahi and Sabarmati shall also face water shortage conditions[35].

There is unequivocal scientific evidence to show that rainwater harvesting is an adaptation to climate change, which has been practiced globally for millennia[1, 36-40]. Interestingly, success of MJSA has also brought home an understanding that even as adaptation practices may draw on scientific, experiential and local knowledge, the programme and projects on adaptation essentially are of political nature[7]. This becomes discernible both by examining how MJSA has been implemented as well as the vulnerability, adaptation, political ecology and social theory literature on Rajasthan. Indeed, success of MJSA explains how power is reproduced or contested in adaptation practice through the three core concepts of subjectivity, knowledge and authority.

In Rajasthan, although most of the precipitation is already being used, it still falls short of the demand for consumption. Groundwater being the primary source of fresh water in Rajasthan, consumption is faster than it is naturally replenished. Thus, groundwater depletion is inevitable. Overall stage of groundwater development in India is 58%, Rajasthan has already reached 125 to 135%[41]. This is causing serious decline in groundwater tables such that robust long-term studies suggest that groundwater is being depleted at a mean rate of 4.0 cm per year equivalent height of water, or 17.7 cubic kilometers per year in the region[3].

Indeed, measures such as robust regulation of groundwater extraction and use, artificial recharge of groundwater, efficient management of on-farm irrigation and water conservation practices including recycling and reuse of domestic and industrial wastewater are absolutely mandatory. Otherwise, a considerable portion of the productive upper alluvium aquifer will go dry within the next 10 years if groundwater extraction continues at the present rate[42].

Left: To the hands of the people-- water, trees and agriculture in cultural landscapes and agroecosystems. Banswara, Rajasthan.

Left: Small structure for rainwater harvesting can yield big results, if appropriately placed. Use of geographical Information System is very helpful in such endeavours.

“Rajasthan is likely to suffer further water shortage due to overall reduction in rainfall, increased evapotranspiration and increased exploitation.”

3. MJSA as a Transformational Adaptation

About 3900 years ago, one of the biggest cradles of Bronze Age civilization collapsed. People fled the Indus Valley to settle in smaller villages and farms farther towards the eastern regions. The reason was change in strength of summer monsoon. Yes, Indus-Saraswati Civilization (ca. 3000–1300 BC) collapsed because of climate change[43]. This dry region situated at the northern edge of Rajasthan, was relatively wet from about 5.1 ± 0.2 ka BP (thousand years before present). That was the time of beginning of the agriculture-based Early Harappan phase of the Indus Civilization. Indeed, monsoon became strong between 5.0 and 4.4 ka BP. This was the period when Indus urban centres developed in the western Thar Desert margin and on the plains of Haryana to its north. Suddenly drier conditions set in after 4.3 ka BP. By about 3.9 ka BP an eastward migration of populations occurred and the civilization collapsed[44]. If we are not to face another civilizational collapse, transformational adaptation, such as MJSA, remain fundamental to build societal and economic resilience[45]. Accordingly, this chapter provides elements of implementation of MJSA.

Below: Result of watershed treatment and assisted natural regeneration that lead to restoration of these forests in Aarampura, Pratapgarh Forest Division.

Aerial photograph of Nakki lake in Mount Abu, Rajasthan, beautifully shows the intricate connection that societies have had with sources of water. The importance of abundance of water is clearly known to a state that has the least abundance of it.

Transformational? Indeed!

Some of the MPTs around Ghodi Tejpur in Banswara, Rajasthan.

Effect of watershed restoration interventions in Begun range, Chittaurgarh, Rajasthan. The stream is now carrying cleaner water, devoid of silt, post intervention.

MJSA

	Phase I	Phase II	Phase III
Villages Involved	3529	4213	4314
Works Completed	95,192	1,30,384	1,53,022
Saplings Planted	2.8 million	6 million	6 million

Phasewise Achievements

MJSA is a transformational adaptation effort of the Government of Rajasthan, and not a conventional development programme. This unique and historic venture aims to radically and pragmatically transform the water scenario of the State, particularly the rural Rajasthan, in a phased manner. The key aim is to make every village water self-reliant. The uniqueness of the programme is evident in its core conceptualization, science-based interventions, appropriate use of technology, convergence with synergistic programmes,

> "MJSA has a planning process with multiple layers of examinations, reviews and monitoring."

and participation of all stakeholders for common societal good, all assembled under one umbrella programme. The MJSA has a planning process with multiple layers of examinations, reviews and monitoring. All concerned departments coming under one roof is indeed a welcome departure from conventional work culture that often prevails in government departments.

As we have already noted earlier, Rajasthan is water-deficit state and faces the vagaries of nature because of the geographical, geological, hydrogeological, meteorological and demographical factors prevailing in the region. Therefore, extensive and innovative intervention for rainwater harvesting as an adaptation to climate change was the answer for the long-term sustainability. While water self-reliance, particularly provisioning of the potable water at a basic minimum, in collaboration of all stakeholders is the main aim of the programme, the MJSA has also resulted in a host of consequential benefits. These include protection and restoration of the biodiversity and ecosystem services of the threatened tropical dry forests, livelihoods improvement of local people and creation of green infrastructure for climate change adaptation.

MJSA was launched on 27th January, 2016. The first phase was implemented in 3,529 villages, with representation of each administrative block of the State. During the phase one, 95,192 rainwater harvesting, water conservation and groundwater recharge works were implemented. In addition, 28 lakh saplings have also been planted along with the provision of watch and ward, survival-watering, upkeep and maintenance for five years. The second phase was launched on 9th December, 2016, encompassing 4213 villages. During the MJSA-II, 1,30,384 rainwater harvesting, water conservation and groundwater recharge works as well as planting of 60 lakh saplings were accomplished. The third phase of MJSA commenced on 12th December, 2017. It further accommodated 4314 villages in which about 1,53,022 works and plantation of 60 lakh saplings are nearing completion. Further, currently the planning process for the fourth phase of MJSA, involving about 4000 villages, is underway. This involves use of satellite maps and data as well as conducting UAV (unmanned aerial vehicle, i.e., an aircraft piloted by remote control or onboard computers) surveys. Survey of specific project areas (blocks) has been completed and preparation of detailed project report has started. The target finally is to cover all the 44,795 villages of Rajasthan.

In addition to the interventions in rural areas, MJSA has also been extended to urban areas albeit with specific components. Under urban campaign, three core interventions are being implemented. These are rehabilitation of traditional drinking water sources, known as Bawaries, Rooftop rainwater harvesting (RTWHS), and urban afforestation. During the first phase, rehabilitation of 259 Bawaries, construction of 1452 RTWHS across 66 towns was launched on 31st December, 2016. These works have been accomplished successfully. Learning from the phase-I of urban MJSA, the second phase involving 162 towns (including 37 towns of phase-I) with additional innovative components such as action plan for treatment and reclamation of urban waterlogged areas, was launched on 20th January, 2018. The second phase of MJSA (Urban) has taken up the rehabilitation of 214 Bawaries, 1482 RTWHS and planting 3.0 lakh saplings in the form of urban green spaces. In both phases, Forest Department has created 192 urban green spaces, covering a total area of 1959 ha and 4.41 lakhs saplings.

An anicut filled with fresh and clean water has the capacity to fuel the growth of biodiversity around it while providing multi-faceted benefits to surrounding residents and cattle. Before-After photograph from Rohaniya Laxmansingh, Range Dungra, Banswara, Rajasthan.

Cascading rainwater harvesting structures enhance the soil moisture regime as well as promote natural regeneration of tropical dry forests. All these contribute to improvement in local livelihoods.

Series of MPTs in Sarwan, Banswara, Rajasthan.

"Transparency throughout is equally important feature of MJSA. Every information, data and status of each work is available in public domain readily accessible to citizens through a State portal"

It is interesting to note here that geo-tagging of each structure and activity including plantations, and transfer of assets created under MJSA to custodian department are important features. In order to monitor the programme, in addition to regular central and departmental monitoring teams, an exercise was conducted with subject-matter specialists of respective fields on board, to carry out a rapid impact assessment of MJSA (Rural) Phase-I. The results suggest that, on the supply side indicators, there has been an average increase in groundwater level in 22 non-desert Districts by 4.66 feet and surface water enrichment by 628.6 million cubic feet (Mcft). On the demand side indicators, the findings are that there has been a reduction in water supply through tankers, rejuvenation of defunct hand-pumps, revival of tube wells, revival of open wells, increase in cropping area of 44,409 ha, and increase in green cover by 3678 ha. Other benefits include, improvement in status of flora and fauna, enhancement in soil moisture contents, reduction in turbidity level which is an indicator of reduction in soil erosion.

Rapid impact pathway analysis among the stakeholders about the pre-MJSA and post-MJSA indicates the improvement in many other parameters. These include coping and mitigation of drought disaster, conservation of water owing to renovation and strengthening the distribution system, conservation of water attributed to switch over to pressure irrigation, improvement in livestock status, particularly in the most vulnerable desert districts due to availability of stored water in ***tankas*** (excavated, cemented and closed tanks in which runoff is harvested and stored) for extended periods in summers. All these direct and indirect benefits have led to gradual transformation in the socio-economic status and livelihoods improvement of people living in villages where MJSA has been implemented.

It must also be noted here that the green infrastructures created through the MJSA across State is bound to help support the three pillars of sustainability—societal, economic and ecological—in the State of Rajasthan.

Indeed, owing to scientific, systematic and evidence-based planning, convergence of the related activities of all the participating departments and stakeholders under one umbrella, from planning to implementation and completion stage, intensive and meaningful monitoring, reviewing, checking and consequent improvement on the ground, MJSA has yielded outstanding results compared to isolated and sporadic programme implementation culture that often prevailed prior to MJSA. Transparency throughout is equally important feature of MJSA. Every information, data and status of each work is available in public domain readily accessible to citizens through State portal called ***Rajdhara***.

Interestingly, MJSA is not only a transformational adaptation to climate change, it also clearly addressed the issue that activities should never turn out to be ***maladaptation***. MJSA has the components that avoid degradation that causes negative effects in situ. It also avoids the shifting of pressures to other environments (neighboring areas or areas that are connected ecologically or socioeconomically). It ensures the conservation and restoration of the protective role of ecosystems against current and future climate-related hazards. MJSA also integrates uncertainties of climate change impacts and the response of ecosystems. The programme has also set the primary purpose as being to promote adaptation to climate-related changes by making villages water self-reliant. By starting from local social characteristics and cultural values that could have an influence on risks and environmental dynamics, and by deploying new skills that the community is capable of acquiring, MJSA effectively addressed the sustainability issues. Further, by adopting, developing and using local skills and knowledge related to climate-related hazards and the environmental system, MJSA ensures equity of knowledge. It has also facilitated the reduction of socioeconomic inequalities. And, MJSA contributes to livelihoods improvement by supporting the diversification of economic and livelihoods enhancement activities, and integrates changes in economic and subsistence activities potentially resulting from climate change.

Households in Rajasthan rely on agriculture, agroforestry, horticulture and livestock for their livelihoods. Thus, livelihoods in Rajasthan are inherently dependent on the climatic circumstances. Many of these households have limited access to assets and infrastructure that could protect them against climate change. Many districts are ill-adapted to extreme range of temperature. Thus, situation today and in future underscore the need for adaptive development: development policies that emphasize risk mitigation and explicitly account for climate-change-related risks, while continuing to promote growth, equity, and sustainability. MJSA clearly fits into this criteria[46]. MJSA as sustainable landscape management in Rajasthan—integrating water, soil, forests, agriculture and agroforestry—is vital to achieving resilient socio-economic systems and landscapes in an era of climate change. In a nutshell, the programme has reduced the vulnerability and enhanced the climate resilience.

4. A Functional Model for Climate Change Adaptation

Our proposed model takes into consideration the fact that climate change adaptation will require strategies for the landscape continuum starting with human settlements, agroecosystems, cultural landscape, forests and protected areas. The model aims to contribute to improved livelihoods and adaptive capacities of vulnerable rural communities in India. MJSA model is well aligned to Government of India's National Action Plan on Climate Change (NAPCC) which clearly outlines its first principle as "protecting the poor and vulnerable sections of the society through inclusive and sustainable development strategy, sensitive to climate change"[47]. The MJSA is also in coherence with Rajasthan State Action Plan on Climate Change that clearly outlines a vision "to achieve sustainable development by reducing vulnerability to climate change impacts and enhancing resilience of ecological, economic and social systems in Rajasthan"[48]. The MJSA is also in consonance with other state level policy instruments such as Rajasthan State Environment Policy 2010, and Climate Change Agenda for Rajasthan (2010-2014)[49]. At the global level, MJSA demonstrates coherence with key United Nations conventions that have a bearing on the sustainability of the planet Earth. These include The United Nations Framework Convention on Climate Change (UNFCCC), The Kyoto Protocol, The United Nations Convention to Combat Desertification (UNCCD), The United Nations Convention on Biological Diversity (UNCBD), and The United Nations Convention Concerning the Protection of the World Cultural and Natural Heritage. Activities such as urban afforestation, vriksha-kunj, and assisted natural regeneration of forests being converged with the MJSA are also contributing to the Bonn Challenge, established in 2011 that aims to restore 150 million hectares of forests globally by 2020, and another 200 million in the subsequent decade. Finally, catchment treatment also contributes to the UN Sustainable Development Goals, 2015, particularly the goals related to clean water and sanitation.

MJSA model can be implemented in areas that have similar environmental and climate challenges. While the core philosophy remains the treatment of the watershed from ridge to valley, it is not yet another watershed development programme. While we have already described the details of implementation earlier, for the benefit of those who wish to implement, a brief recapitulation is necessary.

Chief construction activities under MJSA in rural areas include

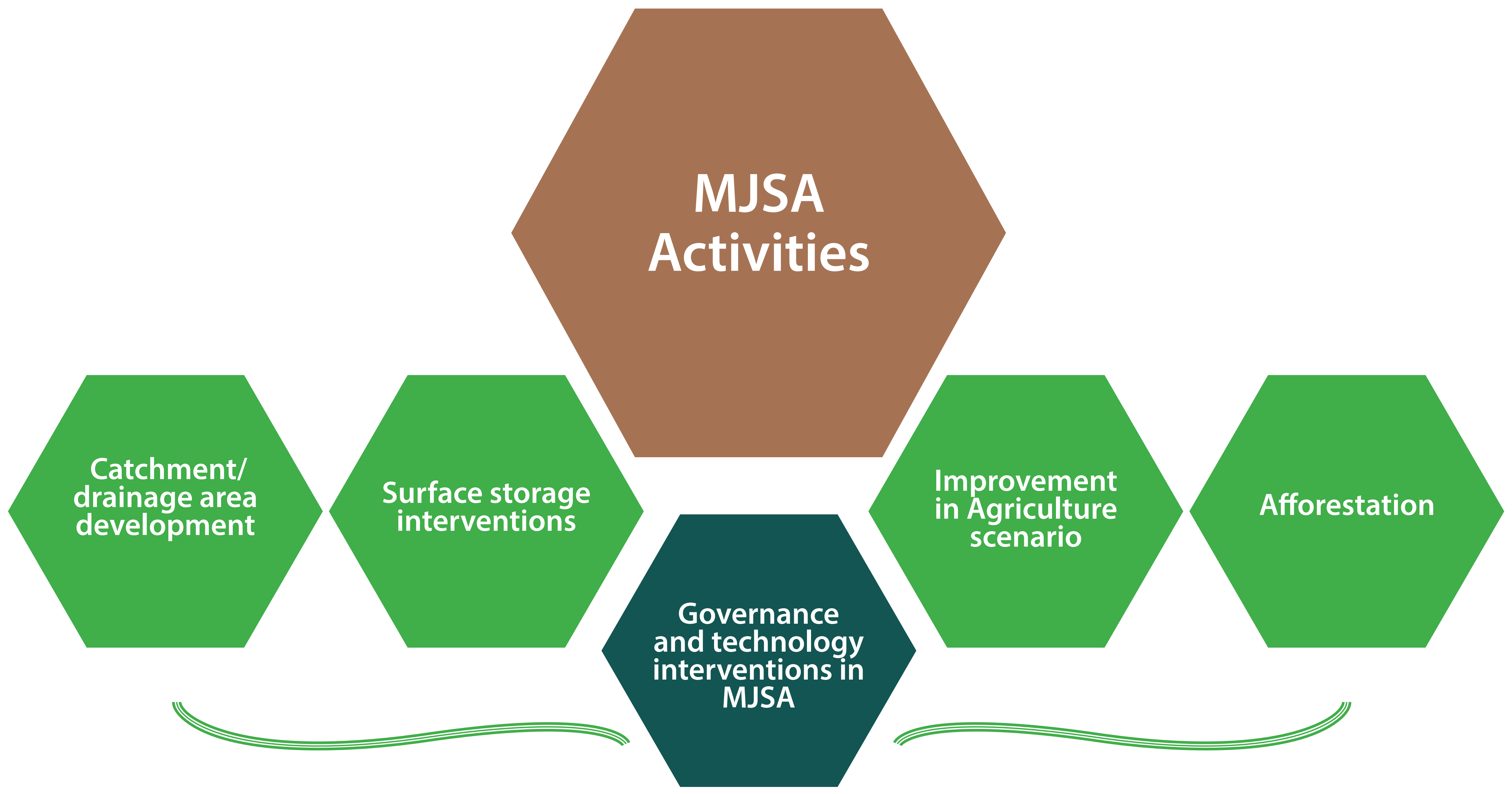
1. **Catchment/drainage area development** adhering ridge to valley approach vis-à-vis prevention of catchment area degradation. For groundwater recharge, soil moisture conservation, and enabling spring flow, and preventing soil erosion, and protecting the trees, following activities are taken up: Contour trenches, Continuous Contour Trenches, Deep Continuous Contour Trenches, Mini Percolation Tanks, Percolation Tanks, Loose Stone Check Dams, Micro Check Dams, Sunken Gully Pits, Field Bundings, Farm Ponds, and Artificial Recharge Shafts over the landscape continuum.

2. **Surface storage interventions** for enhancing local storage of surface water: Check Dams/Anicuts, Khadins, Johad, and Sub-surface barriers, Micro-storage tanks, Repair/restoration/rehabilitation/remodelling of existing mini and micro-storage structures and transmission systems, improving or redefining water ways to existing storage structures, Construction of open wells, Construction of Tankas (Micro underground storage tanks) in desert areas. In addition, restoration and rejuvenation of traditional village tanks (*talabs* and *talais*) were also undertaken.

3. **Improvement in Agriculture scenario** includes the following activities: Transforming flow irrigation command over to Sprinkler Irrigation, Nurturing Orchards through drip irrigation, and use of soil health card as well as motivating farmers to practice soil friendly cropping pattern.

4. **Afforestation** activities are aimed at enhancing the green cover as well as density of local species. The most vital aspect of plantation was, assured protection, survival-watering, upkeep and maintenance for five years.

Governance and technology interventions in MJSA are already discussed in the text in greater detail.



Activities under MJSA in rural areas

An appropriately located anicut can have backwaters running into kilometres. The farmlands located nearby benefit from improved soil moisture regimes, and there, better production.

Vegetation-clad watersheds arrest soil erosion and therefore silting of water impounding structures. Before-After photograph from Hathni Aodi, Chittaurgarh, Rajasthan.

Above: This is an ideal site for Vriksha Kunja. The school compound as well as the land in the proximity where the saplings have been planted, has the benefit of rainwater harvesting structure constructed across a dry stream. This now supplies water for survival-watering to plantation.

Below: Ethnoforestry practices of tree-growing in agroecosystems as well as protected ridge vegetation promotes both rainwater harvesting and protection to soils. In addition, this also promotes landscape heterogeneity necessary for the biological control of insect pests in farmlands.

Sacred groves and cultural landscapes have long been famous for protecting local biodiversity.However, these are now degraded. Planting in the form of vriksha kunja, in combination with micro catchments for rainwater harvesting, is a robust adaptation to climate change that contributes to ecology economy and society. Photograph of Kachnariya Vriksha Kunj in Baran, Rajasthan.

Plantation at Mangarh Dham in Banswara Forest Division, Rajasthan. This site is of sacred importance to the community and various MJSA activities have been taken up at a large scale.

Left: Water water everywhere. Yes, this is Rajasthan. Photograph from Sarwan, Banswara Forest Division.

Right: Writing on the walls! Onsite permanent display boards with data and information about the work promotes transparency.

Same place in different seasons! World's most threatened forests--tropical dry forests or seasonally dry forests--are found in Rajasthan. This is also the result of watershed treatment and assisted natural regeneration that resulted in restoration of these forests. An anicut downstream holds on to the precious rainwater in Aarampura, Pratapgarh Forest Division, Rajasthan, India.

Protected watersheds with conserved forests provide clean water. This is one of the most important ecosystem services of tropical dry forests of Rajasthan. Before-After photograph of watershed restoration interventions in Begun, Chittaurgarh.

Protecting and, where possible, restoring the integrity of degrading and dwindling natural forests is an urgent priority for current efforts to halt the ongoing biodiversity crisis, slow rapid climate change and achieve sustainability goals. Retaining the integrity of natural tropical dry forest ecosystems should be a central component of proactive global, national and local environmental strategies, together with halting deforestation and promoting reforestation. MJSA has been fully cognizant to this fact[50].

Seasonally dry tropical forests of Rajasthan, which are counted among the most threatened ecosystems globally, are highly sensitive to climate change and altered rainfall regimes. Increasing or decreasing frequency and intensity of droughts in these forests will likely alter species distributions and ecosystem processes[51]. Forests are required to play a multifunctional role that includes, but is not limited to, biodiversity conservation and maintenance of ecosystem functions, yield of goods and services to the society, enhancing the carbon storage in trees, woody vegetation and soils, and providing social and economic well-being of people. The management of multifunctional forests over landscape continuum, employing tools of conservation biology and restoration ecology, shall be the vital option for climate change adaptation and mitigation in future[52]. For example, restoring the vegetation in watershed has many benefits including yield of clean water. As the forest cover increases, turbidity of water decreases. Indeed, conversion of 1% of a watershed from forested to developed land is associated with an increase in turbidity by about four percent[53].

Plantation activities across the landscape continuum specifically include vriksha-kunj in villages and green spaces in cities and towns. Forest Department has converged all its plantations in villages and towns with MJSA. Among many, some innovations can be noted here as examples.

Interestingly, if a plantation area or a forest restoration area of 50 ha has a small water impounding structure for each 4 to 5 ha of portion, the soil-moisture regimes become much more favourable for restoration. Interspersed rainwater harvesting structures including trenches and water impounding structures promote forest restoration over the landscape. This is a new model for restoration of tropical dry forests. Further, combining rainwater harvesting with direct seeding yields outstanding results. It is a well-known fact that seedling performance across tropical rainfall gradients is determined primarily by variation in soil water availability across space and time, while variation in nutrient and light availability plays a lesser role[54].

Below: Intricately made contour trenches serve as a robust network for rainwater harvesting. Photograph from Pipalkhunt, Pratapgarh Forest Division, Rajasthan.

Right: Long flat valley in between two parallel running hillocks. Note the relatively better fertility and soil moisture regime, and therefore, better growth of vegetation.

Left: The system of cascading rainwater harvesting structures conserves every drop of water for people and nature. And of course, it provides groundwater recharge as well.

Overall, there have been numerous innovations in technical interventions in MJSA planting, particularly from the perspectives of livelihoods as well as climate change adaptation, with a view that that forests are required to play multifunctional role. While a full description is beyond the scope of this book, it is worthwhile to keep in mind the interventions briefly that are useful in fulfilling the economic, ecological and societal objectives. The interventions helpful in realizing the full potential include:

• Convergence of forestry activities throughout the landscape continuum representing forest areas available in the MJSA villages including provisioning of water for wildlife in protected areas.

• Protection of natural forests against wild-fires, grazing, and unmanaged removals by provisioning of watch and ward for five years.

• Priority protection to threatened ecosystems such as tropical dry forests of Rajasthan. This also includes water provisioning in micro-storage tanks (similar to traditional talabs) to support local flora and fauna.

• Preventing fragmentation and providing connectivity to conserve biodiversity in landscape continuum by implementing a mix of forest plantations, agroforestry, village tree-groves, urban green spaces and farm-horticulture. Fragmentation of natural forests has a sequential path that starts with killing of big trees followed by degeneration of habitat specialists, paucity of regeneration due to impoverished seed germination in fragments, and ends in denuded areas. These issues have been kept in mind in implementation.






Large saplings for plantations are necessary to achieve better survival in water deficit regions such as Rajasthan. Forest Nursery is the backbone of any successful plantation. Photos above, show nurseries in Sikar Forest Division (Reengas, Range Shri Madhopur) and Pratapgarh Forest division, with large saplings of a diversity of species suitable for tropical dry forest restoration and plantation under MJSA. Trained and dedicated staff, has all the facilities to grow good saplings including vermi-compost unit, seed-store, watertank, green-house, and sprinkler system (no flooding).

Rainwater harvesting can quickly help replenish shallow groundwater that influences 22 to 32% of global land area, including about 15% as groundwater-fed surface water features such as springs and streams. Aerial long exposure of a stream in Kota, Rajasthan.

1.48 cr.	30 lit.	100%	50%	90%
Number of microcatchments constructed to harvest rainwater for individual saplings	Apporximate amount of water which a microcatchment can capture in just 11 mm rainfall	2 Yr. Percentage increase in height and collar girth of saplings when planted in a microcatchment	Percentage increase in soil water storage in the upper 75 cm layer in a microcatchment	Percentage of survival of planted saplings when in a microcatchment

Microcatchments: Small interventions, big results

"Forest Department has carried out total 32,417 works of various types including plantations and rainwater harvesting structures."

• Maintenance of gene pool diversity in natural and cultural landscapes. For example, some of the species that had become locally extinct in wilderness, such as Kalmegh and Tulsi, have been reintroduced through direct seeding in tree-groves and urban green spaces.

• Restoration of degraded forests with multiple use species of trees, shrubs and herbs along with regeneration regimes that necessarily combine rainwater harvesting, direct seeding, resprouting, stake-planting, and plantations.

• Protection and management of natural regrowth that may be able to supply a variety of goods and services depending on the age and condition of the forest. All the activities implemented through assisted natural regeneration contribute to this strategy.

• In some of the most degraded and difficult areas, restoration plantings and direct seeding using small number of short-lived nurse trees and shrubs, such as Jatropha, has been carried out. This is capable of enhancing diversity depending on the colonization from nearby forest remnants. This strategy is likely to supply ecological services as well as some goods depending on species.

• Protection and management of natural regrowth both in forests as well as near water harvesting structures, and enrichment with socially and ecologically useful species are enhancing the value of forests to local communities.

• Restoration plantings using large number of local species from later successional stages results into higher initial diversity in restoration areas. In addition, this also promotes colonization from nearby forest remnants.

• In addition to planting, direct seeding of a combination of both leguminous and non-leguminous species is being used to initiate reforestation in barren areas. It is also very useful to enhance diversity and productivity in depleted forests.

• Active maintenance of woody vegetation in ethnoforestry regimes in landscape continuum (households, cultural landscapes, agroecosystems, and wilderness) by simultaneously planting by various departments and stakeholders in their respective lands is another interesting innovation. Protection to a variety of woody vegetation management regimes in agroecosystems is expected to maximize social and economic benefits to the people as well maintenance of ecosystems functions such as natural pest control, pollination, carbon storage, and regulation of hydrological cycle across landscape.

• Mixed species tree plantation of native species are expected to facilitate the subsequent establishment of more species-rich restoration site (e.g., via nitrogen fixation and microclimate alterations) that supply a wider range of goods and services. Leguminous species of tropical dry forests are known to enhance soil microbial biomass and N mineralization and promote growth of other saplings growing in their vicinity.

• Protection and restoration of the functional groups of biodiversity is another important input in MJSA. Several ecological keystone species are also socio-culturally valued, their inclusion in ecological restoration programme is helpful. For examples, all the tree-groves and urban afforestation sites are being planted with some saplings of *Ficus religiosa*, *Ficus bengalensis* and *Ficus glomerata* among other species. These species have a disproportionately large role in supporting an ecosystem. The *Ficus* species in tropical forests around the world have been found to produce regular fruit crops that birds, bats and primates rely on during dry pinch periods. Their foliage is an important food source for other animals. All of that helps with pollination and seed dispersal, which encourages regeneration of the forest and trees in landscape continuum[55-57]. Fruit-eating animals and birds prefer to eat figs even when other food is abundant, because high calcium levels contribute to the desirability of figs as food for many animal species[58].

• Large old trees are among the biggest organisms. They are keystone structures in forests, agricultural landscapes, villages and urban areas. They play unique ecological roles not provided by younger, smaller trees. But, populations of large old trees are rapidly declining[59]. It has serious implications for ecosystem integrity and biodiversity[60]. Attempt is being made to protect these large trees where ever they are found near MJSA works in natural, cultural and human modified landscapes.

• Watershed treatment from ridge to valley also contributes to soil conservation and enhancement of soil fertility through many ways including protecting soils from being washed away with runoff and conservation/restoration of woody leguminous species across landscape continuum.

One example needs to be discussed in a little more detail here. As of now, Forest Department has carried out total 32,417 works

“Efforts for climate change adaptation and sustainability, climate-smart agriculture, and climate-smart landscapes in dry regions of India must manage water, forests and soils first, all else later.”

of various types including plantations and rainwater harvesting structures. During the last three years, 1.48 crore (14.8 million) microcatchments have been constructed to harvest rainwater for individual saplings. It consists of two elements: the surrounding runoff area and the focal infiltration basin or half-moon shaped saucer (thaonla) around the planted sapling[61]. It is a very effective restoration technique. This small intervention yields big results in terms of climate change adaptation as well as mitigation. These saucer-shaped micro-ponds around saplings can capture 30 to 40 litres of water, in just 11 mm rainfall. Imagine, we have 29 rainy days in Rajasthan. Even if we assume that it gets filled only twice every day during these 29 rainy days, that actually means that half a tanker of water in each season is harvested by just one micro-pond! A microcatchment provides double dividend: rainwater harvesting as an adaptation to climate change as well as carbon sequestration through enhanced biomass growth of sapling. These microponds actually supply water to green multifunctional factory—the sapling. These microcatchments can significantly increase the height and collar girth of saplings. For example, studies in Rajasthan have found that in less than two years after planting, trees can attain double height in saucers compared to the ones without saucers. In addition, microcatchments result in 50 percent higher soil water storage in the upper 75 cm layer, as compared to areas without microcatchment treatment. Likewise, survival of planted saplings improves from 50 percent in the untreated areas to more than 90 percent in microcatchments[62]. Even in the arid region plant survival has been found to improve from 30 percent in areas without microcatchment to 86-97 percent, and soil moisture storage has been found to be 39-51% higher in trenches and saucers[63].

Indeed, there are numerous studies that have demonstrated unequivocally that rainwater harvesting enhances habitat heterogeneity, nutrient build-up, soil water, nutrients, vegetation covers, plant growth and biomass during the tropical dry forest restoration in degraded Aravalli hills of Rajasthan. Rainwater harvesting invariably helps conserve soil and water, promotes the growth of plantation and herbaceous biomass and facilitates restoration[64]. On top of all these benefits, the excavated soil also supports the seedlings through direct seeding. Direct sowing provides very encouraging results in tropical dry forest restoration provided it is done in combination with rainwater harvesting[51].

Rainwater harvesting can quickly help replenish shallow groundwater, that influences 22 to 32 percent of global land area, including about 15 percent as groundwater-fed surface water features such as springs and streams[65]. Green infrastructure for rainwater harvesting has been instrumental in reviving some of the dead rivers in Rajasthan[66]. This understanding has helped in reviving the springs in mountainous regions[67]. Indeed, with the help of accurately located rainwater structures, discharge rate of existing springs almost doubled and a few new springs appeared. Recently, we observed that trenches, ponds, mini-percolation tanks, and other such water harvesting structures in landscape continuum in Rajasthan, created through MJSA, are helping to sustain the surface water flow in ephemeral streams for much longer period, after the rainfall spell has ended. It is a very interesting case of constructing small anicuts across the ephemeral stream which never held water for more than a day after the rainfall. Impounding water across such long stretches of otherwise dry streams not only retains surface water for a much longer period, it also recharges dry wells downstream. Indeed, wells and hand-pumps that have gone dry over all these years are now instantaneously rejuvenated because of such impoundments. The water so available in hand pumps, tubewells and openwells in agroecosystems provides additional survival irrigation. This makes agriculture in dry regions climate-smart.

MJSA in Rajasthan has created the green-infrastructure at an unprecedented scale. We must also remember that the water impounding in these rainwater harvesting systems is going to be a periodic phenomenon, harvesting runoff in every fresh spell of rainfall. That makes MJSA infrastructures a long-term survival and livelihoods asset.

In conclusion, those who wish to replicate the MJSA in their areas would benefit by learning from the infrastructural adaptations as well as societal adaptation implemented in MJSA. To them we wish to say that remember, whenever water flows out of forests, farms and landscape—carrying with it the fertile soil, silt and nutrients—know that it is not just water and soils that are going waste. It is an opportunity squandered. It is a hope wasted, of a water-sufficient, agriculturally-resilient, and climate-smart landscape. A clear, evidence-based conclusion emanating from the vivid depiction and description of MJSA in this book is that efforts for climate change adaptation and sustainability, climate-smart agriculture, and climate-smart landscapes in dry regions of India must manage water, forests and soils first, all else later.

Protecting both sites of watershed and creating structures across the valley for rainwater harvesting system in a series is boon to local farmlands and livelihoods. Photograph of a valley treated in Beda Ismilepur, Alwar, Rajasthan.

Only well protected forests can yield clean water. Anicut in Sitamata wildlife sanctuary, Pratapgarh Forest Division, Rajasthan.

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Yes, this is Rajasthan! Panorama of Daultapura, MJSA work site in Alwar, Rajasthan

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